THE RIGHT PLACE
An integrated model for the evaluation of suitability and estimation of potential on alpine pastures for sheep and goats

edited by

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To our colleague and friend

Chiara

The „Alpinet GHEEP“ project

In the past, the use of pasture in Alpine areas during the summer has been an economical resource for farmers, but, in the last 50th years it dramatically decreased, due to the industrial production processes application. However, the utilisation of Alpine pasture is becoming important again both for its economical impact linked to the typical production and for the environment protection. The extensive characteristic of pasture and its contribution to biodiversity and landscape variability represent management systems that fit the requests of the society on agriculture. In this framework the sheep and goat breeding has a new role in several Alpine areas because the decrease of cow heads affects the increase in sheep and goat number. Furthermore, sheep and goats are suitable for extensive use of marginal pasture and take part in farm multi-functionality.

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, was developed in order to give sustain to the operators. The aim of the project was to promote sheep and goat productions e.g. wool, meat, milk and dairy products, as well as the connected activities through a permanent network set up among the breeder associations, local administrations and research institutes. In the three years project period, the productive sectors of Austria, Germany, Slovenia and North-East Italy were involved in order to enhance the economical aspects of breeding, to increase their role in the social context and to emphasize the positive effect on environment and on sustainable development of territory.

The project partners were:

- Autonomous Province of Trento - PAT - Lead Partner (I)
- Sheep and Goat Breeders’ Association of Trento - APOC (I)
- Agricultural Institute of S. Michele all’Adige, Research Centre - IASMA (I)
- Breeders’ Federation of Southern Tyrol - VSK (I)
- Regional Agency for Rural Development Friuli Venezia Giulia - ERSA (I)
- Department of Animal Science University of Udine - DIAN (I)
- Breeders’ Association of Bergamo - APABG (I)
- Breeders’ Association of Belluno - APABL (I)
- Bavarian State Research Centre for Agriculture Institute for Animal Breeding - LfL (D)
- Bavarian Herdbook Society for Sheep Breeding e. V. - GHG (D)
- Enterprise of Wool Processing and Handicraft Products Commercialisation - WLW (D)
- Society for the Conservation of Old and Endangered Livestock Breeds - GEH (A)
- Federal Research and Education Centre Raumberg-Gumpenstein - HBLFA (A)
- Austrian Federal Association for Sheep and Goats - OEBSZ (A)
- Biotechnical Faculty University of Ljubliana - INUBFLJ (SLO)
- Sheep and Goats Breeders’ Association of Slovenia - ZDRDS (SLO)

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THE RIGHT PLACE - AN INTEGRATED MODEL FOR THE EVALUATION OF SUITABILITY AND ESTIMATION OF POTENTIAL ON ALPINE PASTURES FOR SHEEP AND GOATS

1. Introduction

In the Alps, summer grazing of livestock on mountain pastures has been used for centuries to augment the limited hay resources of the lowlands. Additionally, it contributed to farm and family income by saving manpower during the summer months. This system of resource organisation was challenged by modernisation processes (increase in productivity, concentration and increase in size of farms, etc.), which affected the breeding sector not only in the low zones, but also in mountain areas. The difficulties of adapting traditional agricultural practices to changing conditions translated into risks of abandonment for many Alpine grazing areas.

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).

While mountain pastures still have a zootechnic function, some research has highlighted that the economic value of their non commodity outputs is significantly higher than their commodity (milk and meat) ones (Raffaelli et al. 2004). In any case, almost everywhere in the Alps the recognition of the public value of mountain pastures justified forms of financial support to foster their multifunctional use.

Among these trends, sheep and goats have acquired a new role for at least two reasons. First, because in many areas the cattle farming declined, which lead to an upward trend of small ruminant breeding. However, this requires new solutions for management of mountain pastures. 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.

Given the relevance of public interest concerning mountain pastures, public administrators, above all at the local level, need adequate operational tools to plan optimal use of these resources. The development of objective methods for evaluating the suitability and estimating the potential of mountain pastures for sheep and goats is the main purpose of the present study. The results of this study come 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).

The transnational character of the partnership was very useful since, as it is well known, the situation of mountain pastures is extremely diversified in Alpine areas. In some areas

Table 1: Numbers and trends for cattle, sheep and goats in the Alpine Space

	total number (2005)			Δ 2000 (%)		
	cattle	sheep	goats	cattle	sheep	goats
French A.S.A.	1,814,069	1,427,377	195,200	- 5.5	- 1.9	- 0.2
German A.S.A.	2,579,179	319,860	17,068	- 6.3	- 0.6	10.4
Switzerland	1,554,696	446,350	73,970	- 2.1	6.1	18.4
Liechtenstein	5,473	3,149	286	8.3	-5.1	19.7
Italian A. S. A.	3,525,400	257,448	134,906	- 4.8	- 13.5	- 8.9
Austria	2,010,680	325,728	55,100	- 6.5	- 4.2	7.8
Slovenia	452,517	129,352	25,480	- 8.3	34.4	15.6
Total Alpine Space	11,942,014	2,909,064	502,010	- 5.3	- 0.7	1.4

Sources: Ministère de l'agriculture et de la pêche (AGRESTE), Ministerium für Ernährung und Ländlichen Raum Baden Württemberg, Bayerische Landesanstalt für Landwirtschaft, Swiss Federal Statistical Office, ISTAT, Landesverwaltung Liechtenstein, Statistik Austria, Statisticni Urad Republike Slovenije

N.B.: data referring to 2005 are derived from sample surveys made by statistical offices, data referring to 2000 come from Census surveys. For Austria the difference with 2005 was calculated on the basis of Agrarstruktur Vollerhebung 1999 data.

the risk of abandonment is very low, while in others it has already gone beyond risk, becoming a reality. On the other hand, in some areas complete information on existing pastures is available, while in other areas there is still a gap of information. Within this framework, the exchange and discussions between the four participating teams allowed to take a variety of situations into account.

The two methodological approaches developed through an interdisciplinary work are presented in the first part of this manual. Some examples for implementation are shown, based on study areas in the Austrian and Italian Alps. Both the model-orientated and the field-orientated approach are shown in the second part. The software program called ENEALP, which analyses the energy flow on alpine pastures (ENE = energy, ALP = alpine) and which gives an estimation on the number of animals that can be pastured, is presented in the third part of the manual. The installation package of ENEALP is available, together with the complete cartography of all study areas, in the specific CD-ROM.

2. Material and methods

2.1 Interdisciplinary concept of system development

The central aim of the project is to develop an assessment of suitability and potential for the development of future grazing strategies. To achieve this aim, the fields of vegetation ecology and plant production, animal nutrition and geo-information sciences must be linked to their model parts. This link is given through a qualitative and a quantitative approach.

Several scientific disciplines are necessary to clarify the question of suitability of alpine grassland for grazing with domestic animals. The first aspect is connected to questions on ecological and plant production of a site. Local characteristics of the soil and the (micro-) climatic conditions like precipitation and temperature create a great diversity of species. These differ in respect of their biomass yield and energy density. The second aspect is connected with their usability as forage for ruminants like cattle, sheep and goats. But together with these aspects, the practical suitability of the species of animal used (slope inclination and accessibility) and the availability of water are also of great significance. The third aspect, geo-information science, deals with plant production and animal nutrition according to their spatial manifestation. Biotope types can be deduced from satellite images in the specialised field of remote sensing. The integration of management data, such as pasture borders and data on animals allow a local estimation of the quality and quantity of alpine pastures. The ENEALP

Figure 1: Interdisciplinary approach

software, which unites all three aspects in an interdisciplinary approach, is introduced in chapter 4. The information and formulas necessary for the calculation are taken from the individual specialised areas. Data from the study area can be combined with expert systems (scientists, farmers, shepherds) as wished. The technical implementation of geo-informatics are encapsulated from the system, and thus bring the attention to the data entered into the calculation.

2.2 Basic principles

2.2.1 Field studies and basic parameters

As introduced in the previous chapter, a suitability study of grazing areas should take into account the analysis of the environmental and management factors, which affect the area itself. The starting point for a qualitative and quantitative assessment of alpine pastures for sheep and goats is the study of land cover. Only good knowledge of the available vegetation enables further conclusions concerning the yield capacity and forage quality of a pasture. Additionally, vegetation data contain in some way also information on microclimatic and geo-morphologic parameters. Therefore, the area studied must completely be mapped and classified. This means, so-called biotope types are recorded in the field. The mapping of land cover is possible through field work or with the aid of remote sensing methods. For this process as a first step, the locally available vegetation has to be studied and classified. The assessments of vegetation in the study area were made after the tried-and-tested Braun-Blanquet (1928) method. The relevees were, following a detailed multivariate analysis, aggregated to biotope types. These biotope types served for the validation of the classification of land cover by means of aerial- and satellite-image evaluation. The validity and precision of classification depend on the number of classes, where the appropriate energy content must be calculated for every class. In the present study vegetation was classified by all partners according to the categories (called structural types) defined in the „Pasture Evaluation Model“ (PEM) model set up at the Research and Education Centre Raumberg-Gumpenstein, the Austrian partner in the Project (Egger et al. 2004). The result of field mapping and remote-sensing classification is a comprehensive map of land cover. 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’ knowhow was very important to calibrate the model.

Experts generally agree that goats and sheep are suited for areas that are less favourable for the development of other zootechnical activities (Bertaglia et al. 2007). Goats have a higher suitability than other livestock, for the rough, nutrient-poor and rich in trees and shrubs natural pastures (Bonanno et al. 2005), like for example the open areas recently abandoned or the so called marginal zones. Moreover, goats seem to prefer alternating their diet among different vegetation types in environments with a great structural diversity to grazing solely on open pastures. With regard to this, it became important to consider among the suitability criteria for goats the „fragmentation“ level of the vegetation, i.e. the differentiation in different patches (Farina 2001).

After vegetation, a second essential constraint for livestock management on pastures is water availability. In some parts of the alpine space, where for instance karstic phenomena occur, the lack of this resource can be a severe limiting factor. The water availability can play a role in the choice of grazing circuits as well. This resource was evaluated in terms of distance of every point of the pasture from the available watering sites. The third considered criterion is the landform and, particularly, the slope development in the pasture. The capability of small ruminants to reach even the most impervious areas permits them to use resources that otherwise would remain inaccessible, but different slope assigns different suitability to different parts of the pasture in question. From this point of view goats and sheep are in general complementary to dairy cows. The three above mentioned factors, vegetation, water availability and landform, are the basic parameters to assess the suitability of a pasture. However, the structure of the models developed in this study can take additional site specific parameters into consideration, if, for example, data by more detailed field surveys are made available. In the chapter dedicated to the qualitative model some additional parameters used in the analysis of the Italian study areas will be presented.

2.2.2 A tool called GIS: Advantages in using Geographic Information Systems

Imagine a simplified landscape: plain geometrical entities, as points, lines and areas, scattered across your study area and transferred them into a map. In Geographic Information Systems (GIS), every entity comes with its attributes, which describe the properties of this entity in a data base: for example a point could be recorded with elevation data, text data as a name, or an identifying code. In a landscape analysis, like the one presented in this work, you may individually need to examine these objects across their own attributes. Maybe the task is not so easy: This is the case of research crossing many individual entities. These could be queried crosswise based on their interconnected data bases only, or their spatial relationships, or both.

Some examples of queries achievable with GIS tools are: The calculation of the distance from/to different items, the detection of presence/absence of an attribute, statistical relations throughout a certain catchment area, the building of buffer polygons, algebraic operations between different layers of information, heading towards more complex items as the Multi-Criteria Analysis or the Principal Component Analysis.

The GIS tools, born to perform such analysis, are traditionally classified into „vector“or „raster“ (or a mix of both) systems. The basic architecture of GIS software could be split into four sub-systems:

- the data input,
- the data management
- the analysis
- the output

The first sub-system makes it possible to import cartographic data from different formats, or to create new maps, drawing and georeferencing geometrical elements.

The data management options work with relational data bases, in table format with records and fields, linked with the geometrical entities in the maps. The analysis sub-system is the core of GIS software, the collection of modules apt to solve geographical and spatial problems like the ones listed above. The output tools stand at the end of the job with the production of a printed thematic map, or with tabular statistic results.

The strength of GIS is the power of processing enormous amounts of data and to guarantee an output precision impossible to reach with other methods. Moreover, the ability to link geometrical entities with large databases permits combined spatial/relational data queries and computations not possible with tools as CAD-Systems (Computer Aided Design) or merely graphic software.

2.3 Two different approaches for one goal

2.3.1 Introduction

The data on pastures, particularly for sheep and goat sector, are really various in the alpine areas due to the different research development. For this reason, the interdisciplinary character of the project permits differing methods to reach a solution. Two methods are presented, with either the use of models (model-oriented approach) or to give preference to implementation by experts (field-oriented approach).

Both approaches offer advantages and disadvantages, which are discussed here. The great difference lies in the practical depth of realisation. The field-oriented approach 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.

Field-oriented approach:

This is undertaken according to an assessment of the real world by persons with knowledge in the field of (vegetation) ecology or agriculture. The locally available plant communities and their biotopes are evaluated and their suitability for grazing assessed in the field. Above all, the capacity for inductive awareness enables experts to evaluate the overall situation of a pasture. Only rarely persons can be found ,who have many years of experience as a shepherd on a specific alpine pastures. This could enormously increase the quality of alpine-pasture assessment. The field-oriented approach brings sound, but locally restricted results and has the disadvantage that only small areas can be covered. It can also be very difficult to carry out systematic standardisation, which means that two groups of experts often achieve different results. Field-oriented approaches exclusively enable a qualitative field assessment of alpine pastures.

Model-oriented approach:

This is undertaken according to the scientific analysis of model trials in spatially small regions. The results of these trials are subsequently applied to larger areas. This approach is supported by geographical information systems and offers the possibility to study of larger areas. The results of this approach are comparable and easily reproducible and can be used as a base for planning to a larger degree. The disadvantage is seen in the lack of local focus.

Fine details of ground cover or characteristics with a negative influence on grazing by sheep and goats cannot be recognised. The model-oriented approach is divided into qualitative and quantitative models.

The following criteria are decisive for the choice of approach:

- Availability of experts
- Availability of local scientific knowledge
- Capacity for the realisation of GIS projects
- Availability of the necessary primary data

2.3.2 Qualitative model

The aim of the qualitative model is to obtain sheep and goat pasture suitability maps on the basis of qualitative data. In the following sections the procedure of maps' setting up is presented.

Study area definition

Study areas were defined on the basis of land legally declared as pasture. Given the diversity of the available documentation about the Alpine territory, even in the same country, the identification of the areas has not even been

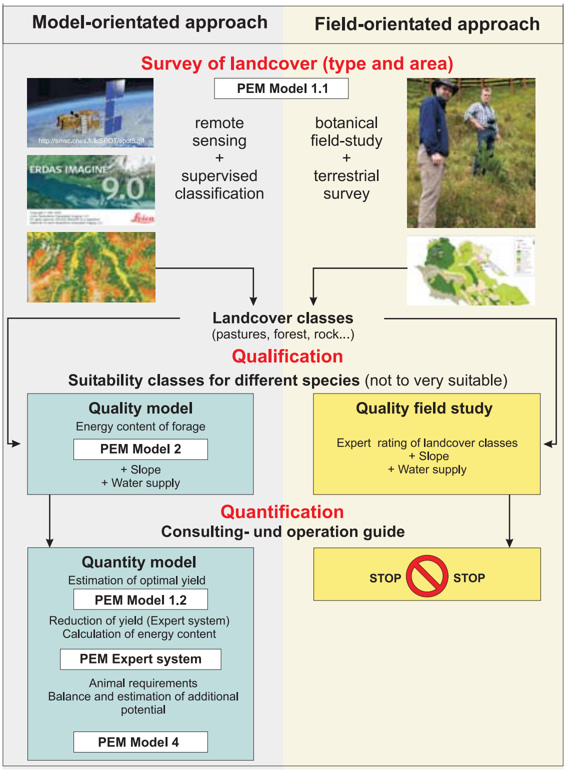

Figure 2: Rough methodical concept

based on uniform rules for all the three Italian provinces used in these studies for example; in fact not every administration has cadastral inventories, regional or provincial technical maps or forest management plans in a digital version. Concerning the Province of Trento, where the above mentioned maps are available, the survey area was defined by using both the cadastre and the forest plan, which are included in the pastures´ lease contract.

They were kindly supplied for the study by the managing bodies or by the responsible persons of the forest management plans.

Suitability scores

Sheep and goat pasture suitability was attributed on the basis of a classification using a scale of decreasing scores from 5 to 1 (suitability scores) according to Land Suitability Classes (FAO, 1976) as reported in table 2.

The suitability scores are the result of a mathematical formulation applied to basic criteria (land cover, water availability and slope, following described) used by Italian partners. Some of them utilized also three additional criteria: productivity, structural fragmentation of pasture and pasture accessibility.

For each criteria a map was obtained by means of a mathematical formulation process, in which the criteria were represented in classes. For each class a score was assigned

Table 2: Suitability scores assigned to the indicators (FAO, 1976, modified)

Land Suitability Classes	Suitability score	Description
S1 Highly suitable	5	Land without significant limitations. Include the best 20-30% of suitable land as S1. This land is not perfect but is the best that can be hoped for.
S2 Moderately suitable	4	Land that is clearly suitable but which has limitations that either reduce productivity or increase the inputs needed to sustain productivity compared with those needed on S1 land.
S3 Marginally suitable	3	Land with limitations so severe that benefits are reduced and/or the inputs needed to sustain production are increased so that this cost is only marginally justified.
N1 Currently not suitable	2	Land with limitations to sustained use that cannot be overcome at a currently acceptable cost.
N2 Permanently not suitable	1	Land with limitations to sustained use that cannot be overcome.

as following described in detail. For example „land cover“ criteria was divided into different typologies (classes: rich pasture, rough pasture, etc.) depending on sheep and goats preference. The pasture surfaces are then represented on the map with different colours on the basis of the class.

The maps of each criteria were integrated through a geographical elaboration in one map. It was then normalised, using the Land Suitability Classes (FAO, 1976), to obtain the suitability map. The suitability map, using five different colours (table 3), simplifies the identification of the pasture suitability for sheep and goats grazing.

Table 3: Suitability classes and related colours

Classes	Suitability	Colour
I	Permanently not suitable	Red
II	Currently not suitable	Orange
III	Marginally suitable	Yellow
IV	Moderately suitable	Dark green
V	Highly suitable	Light green

Basic criteria

Land cover

As previously said, land cover of study areas has been classified in the categories (called structural types) used in the PEM („Austrian model“) which are based on the vegetation structure and are rapidly recognizable and identifiable on field. For every study area, these types have been identified and mapped through the interpretation of available orthophotos and field observations. For every typology three phyto-sociological relevees were carried out on every pasture in order to characterize the vegetation with higher detail. The map of the structural types has been classified according to suitability values agreed upon by experts and presented in table 4.

Table 4: Suitability scores agreed upon by experts

	Suitability score	
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 sp. formations	2	4
Tall conifer shrubs	1	1
Wood	1	1
Unproductive	0	0

Water availability

The watering points have been found with the help of the technical regional or provincial maps („Carta Tecnica Regionale“ or „Carta Tecnica Provinciale“) made available in every region by local authorities. These maps show both flowing (creeks, sources, sinks, tubs) and standing water (swamps, lakes, ponds). In the Province of Trento, the vectorial data of the main hydrographic reticules was also available. From the watering points the real distance in metres towards the border of the study area following the maximum slope direction was calculated. The software used for that was GRASS 6.2. The derived distance maps were then reclassified according to the scores reported in table 5.

Table 5: Suitability score 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

Slope

The map of slope inclination has been produced on the basis of the digital terrain model (D.T.M), with a square cell matrix structure and a sampling distance of 10 metres. The obtained map has been reclassified according to the suitability values reported in table 6.

Table 6: Suitability scores for slope

Slope (°)		Suitability score	
sheep	goat	sheep	goat
0-20	21-40	5	5
21-45	0-20	3	4
> 45	41-50	1	3
	50-60		2
	> 60		1

Additional criteria

With the model it is possible to introduce additional criteria to be integrated with information obtained through field surveys. The description of the three additional criteria analysed (productivity, structural fragmentation of a pasture, accessibility) is reported as follows.

Productivity analysis

In the study areas of Trentino, it was possible to analyse the productivity of different pastures, i.e. the production of biomass during the vegetation period. These values have been used as an additional parameter for the implementation of the model in Trentino. The analysis was done during summer 2006 and 2007. A total of 21 exclusion cages with an area of 1 m² each have been positioned on the four surveyed pastures in order to avoid grazing by animals. Then 108 cuts (localised by GPS) of an area of 1 m² each have been carried out between the end of July and the beginning of August. Vegetation was cut in the cages, while in June samples were taken out of the different vegetation structural types available: Pasture before its use, shrubs, bush and wood. The measurement of the biomass production in the cages is the maximal one, since the samples were cut in the phenological phase of maximum productivity. For the samples taken outside the cages, the maximum production values were calculated through a model based on the relief of phenological stages of each species found in the cut (Orlandi et al. 1997).

Furthermore in the areas occupied by Alnus viridis the biomass production on the ground has been summed up with leaf production of the bushes. This second value has been estimated through 5 cuts of the leaf mass: For every cut the corresponding volume of an area of 1 m² meter at a height of 1,5 m was taken. Finally, the average value of maximum production of each structural type was calculated for each area.

Structural fragmentation of pastures

In order to take into account the environmental heterogeneity of vegetation, its Interdispersion Juxtaposition Index (IJI) was calculated for each pasture with the FRAGSTAT 3.3 software. This index analyses the spatial configuration of landscape patches, which in our case are the different vegetation types, expressing their interdispersion level, i.e. highlighting how much the different vegetation types are dispersed or how wide they are spread in the total area (Eiden et al. 2000, Camuffo 2004).

For the area fragmentation analysis some structural types have been aggregated into the following classes:

- Open areas (rich pasture, rough pasture and tall herbs)
- Tall bushes
- Dwarf shrubs
- Tree pasture
- Coniferous wood (together with *Pinus mugo* bush)

The bigger the heterogeneity of the vegetation, the higher the index: It is at the maximum when the classes are equally adjacent between each other and when the border length is equal. Low values characterize landscapes

Figure 3: Exclusion cage used in Trentino trial

Table 7: Evaluation of the accessibility quality

Access modality	Qualitative evaluation
Asphalt covered or forest road accessible with a normal car	Good
Forest road accessible only by off road car (4x4)	Average
Path that can only be utilized by foot	Poor

in which classes are bordering only a few other classes.

Pasture accessibility

The possibility to reach the pastures by transport means has been considered an useful indicator in the suitability analysis, above all for dairy livestock. It has been evaluated as shown in table 7. Differently from the previous criteria, accessibility characterizes the pasture as a whole.

Sheep stocking rate estimation

The Provincial Breeders Association of Belluno, responsible for the implementation of the model in the Province of Belluno, used as additional parameter the estimation of sheep rate on pastures. The optimal livestock rate should make use of the biomass produced by a pasture in the most complete and homogeneous way, avoiding at the same time the deterioration of the landcover and contributing to an adequate nutrient balance. The process to determine the values of these indicators is based on an expert evaluation of forage production in the ecologically differentiated conditions. It benefited from the results of a detailed typological analysis and detailed field surveys according to a methodology set up by Ziliotto et al. (2004).

This typological analysis specified 160 different types and sub-types; for each of them an average production rate has been estimated, expressed in dry matter (DM) per hectare. This estimation has been compared with the number of sheep that can use the relative amount of dry matter without compromising the floristic and vegetation cover. After some calibrations on the site specific conditions, average values of this indicator have been calculated for each suitability class.

Table 8: Sheep rate values (Andrich 2007)

Suitability classes	Sheep stocking rate (heads x ha^{-1}) indicators
5	8.4
4	6.6
3	5.1
2	3.4
1	1.4

Indications for GIS model application

The procedure adopted in the qualitative model to obtain sheep and goat pasture suitability map is reported as follows. According to this procedure it is possible to apply the model in other study areas.

The workflow of data and methods may change by using different software products or GI-Systems. Sometimes the name of the methods differs from the figure, but in each system a comparable method is included, otherwise it is not a GI-System. Basically each process starts with a reading or importing step on basic data like a digital elevation model, vector patches of vegetation or a hydrological network. Specialised methods calculate intermediate steps like slope, distance from water, productivity in one or more steps. On the CD included to this book a standard way for Arc Map and GRASS is shown in the document „gismodel.pdf“. Finally, the important parameters are merged to have one result (different weights for the input parameters are possible).

Note: The estimation of the distance to water, using cost distance modulus, requires a „friction surface“ calculation. This is a raster image that contains with every pixel the information of a quantification of the effort spent for going on, that can be a very high value in the maximum slope points or a unitary value in the flat areas. In the Trentino study cases the raster image of slope has been used as

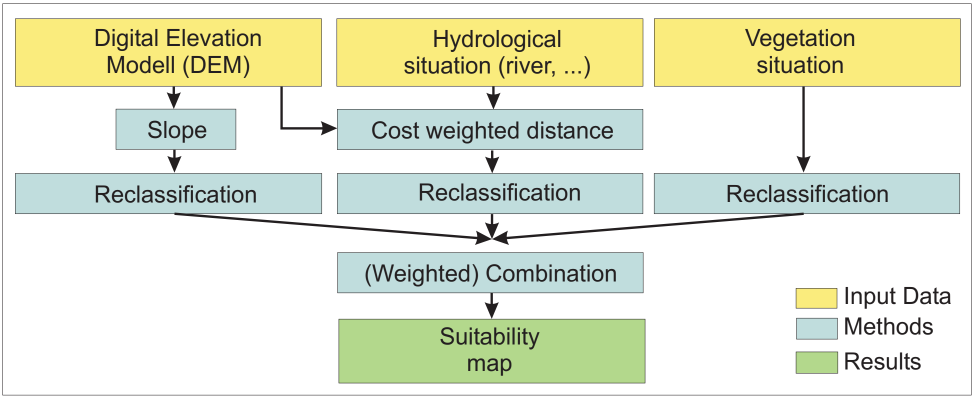

Figure 4: General workflow of data and methods

„friction surface“, while in Friuli Venezia Giulia study cases a different method was applied. Considering that the direction of the maximum slope can toughen or facilitate the walking, the difference between the direction of the maximum slope and the direction of the walking has been calculated. Then the slope value has been proportioned to that difference and the resulting image has been used as „friction surface“.

Model validation

The aim of the model validation is to verify the reliability of the adopted method and the criteria chosen. For the set up of a model to evaluate the suitability as sheep and goat pasture, useful for different situations as in the Alpine area, a careful selection of study areas and adopted criteria is needed. Furthermore, the high fragmentation and difficulties to reach pastures were determining factors of study area reduction.

The suitability of the areas was verified by three different field assessment modalities:

- Model application in other malghe different from those studied
- Interviews to sheep and goat farmers
- Observations of grazing circuits of animals

The model application was carried out in one malga (Colalto) in Friuli Venezia Giulia and in another one in Trentino. The first one is traditionally grazed by sheep and goats and is located in an area with environmental characteristics similar to those observed for previous studied cases (prealpine area, calcareous lithology, karst morphology, water scarcity). The second is grazed by sheep, cows, heifers, donkey, horses and, starting from 2006, by goats too. Also in this case the environmental characteristics are similar to those observed for previous studied cases.

The aim of the interviews with farmers was to verify the representativeness of the adopted criteria for the model set up and to confirm on-site the suitability as sheep and goats pasture. Finally, the observation of grazing circuits of animals, recorded by GPS, were useful to evaluate the selection of different vegetation types.

In order to verify the reliability of the model for the estimation of suitability for sheep and goat pastures, the model has been applied to some other pasture areas different from those analysed before. The main collected information is summarised in the following tables. Table 9 shows the results of the procedure for the model validation concerning the suitability map. The validation allows the verification of the correlation between the outlined areas in the maps and the areas preferred by animals with the level of preference taken into account.

In table 10 the results of the procedure for the model validation concerning the criteria used to set up the suitability map are shown.

Table 9: Results of the procedure for the model validation concerning the suitability map

Subject	Remark
Suitability map	The correlation between the most suitable areas and the areas preferred by animals is remarkable. To improve the map reliability the assignment of a weight to each criteria, taking into consideration the breeding system, is needed. For example the use of summer pastures with dairy animals requires a careful evaluation of „water distance“ criteria due to the high water need of milk animals. For this reason pastures with good vegetation and morphological characteristics but with insufficient water resources are not well suitable. Otherwise the use of summer pastures with animals for meat production and in particular with autochthonous breeds requires good value for „vegetation“ criteria.

Table 10: Results of the procedure for the model validation concerning the criteria used to set up the suitability map

Subject	Remark
„Vegetation“ Criterion	The criteria values reflect the information collected through field surveys and farmers interview. The scores assigned to some structural types i.e. „grazed wood“ and “short shrubs” should be improved by means of specific evaluation on animal preference. Some observations on structural types: Mainly preferred are the deciduous broad-leaved areas, in particular the Alnus viridis wood, or wood borders characterised by Corylus avellana, Sorbus aucuparia, Salix caprea, etc.; Fat and poor pastures are suitable pasture areas. Tender leaves, grass ears, legume (mainly clovers) and other species inflorescences are grazed. This kind of vegetation is preferred if shrub and young trees are present; The sparse spruce wood in the subalpine belt with underbrush rich in tall herbs (Adenostyles sp.), wet areas are particularly favoured.
„Slope“ Criterion	For goats the slope is not a limiting criterion because they also can graze steep slopes. Sheep avoid both steep and rocky areas while easily graze areas which are „only“ steep. Additionally, the criterion value depends on breeding type, in fact dairy breeds prefer pastures with a moderate slope because the amount of energy required to move is restrained and vegetation quality is high. The grazing methods are also an important issue because animals not controlled (free grazing) prefer to take place on the top. This behaviour is due to the need of the animals to defend against predators.
„Water distance“ Criterion	This criterion is affected by breed and production phase of animals, dairy animals need higher amount of water.
„Fragmentation“ of Criterion in particular	The criterion is useful because itdefines the feed variability available for animals, vegetation this aspect is important for goats. Furthermore the change between herbaceous and wood can be important for animal protection from sun and bad weather.

As a conclusion, a high correlation between real suitability and theoretical suitability proposed by the model has been pointed out. Interviews with farmers suggest to investigate more on the influence of breeding types and grazing methods as well as the knowledge of vegetation preference on the pasture suitability evaluation.

2.3.3 Quantitative model

Scientific base

The establishment of parameters and class values in a qualitative model is undertaken by experts in animal husbandry and plant production. Transition between classes rapidly takes place; constant concentrations and numbers of nutritional amounts are not taken into account.

This approach is not in accordance with natural conditions, which almost always provides a smooth, continuous transition over a broad spectrum of possibilities. The illustration of natural contexts thus takes place in various functions. These constantly take into account the dimensions of the environment and thus lead to better results. One example is the estimation of the vegetation period of a site according to altitude. The coefficients of the functions must be laid down in systematic trials and subsequently adapted to local areas. Two current studies, as follows, are available for modelling the quantitative estimation of pastures or mountainous regions.

- The GIS-supported Pasture-evaluation Model (PEM): Egger, Angermann, Aigner, Buchgraber, 2003
- „Höhenprofil Johnsbach“: Gruber, Guggenberger, Chytil, Eder, Krimberger, Sobotik, 1997

(for a detailed reference see chapter 7)

The authors have drawn up a conceptual model in the PEM for the estimation of energy quantum and used also several Alpine pastures as examples. 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 so-called biotope types. These types are 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.

Both the field-oriented as well as the model-oriented approach can be chosen for the practical differentiation of the biotope types. In the field-oriented approach, experts (vegetation scientists, grassland experts...) define the biotope types. In the model-oriented approach, the additional techniques of remote sensing and supervised classification are used (Schowengerdt 1997).

The nine biotope types are separated 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. Biotope 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, Knees 1999). A similar model for the assessment of the energy content of the forage is used.

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, 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“. 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.

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 a systematic trial undertaken over several years. This trial, the „Höhenprofil Johnsbach“ covers all of the key factors of typical sites in the smallest possible area in an almost ideal North-South line. The trial takes two types of bedrock (limestone, silicates) into account, two different areas of exposition (Southeast to Southwest, Northeast to Northwest) and the local available altitudinal zones (1,100 m, 1,300 m, 1,500 m, 1,700 m). On the larger

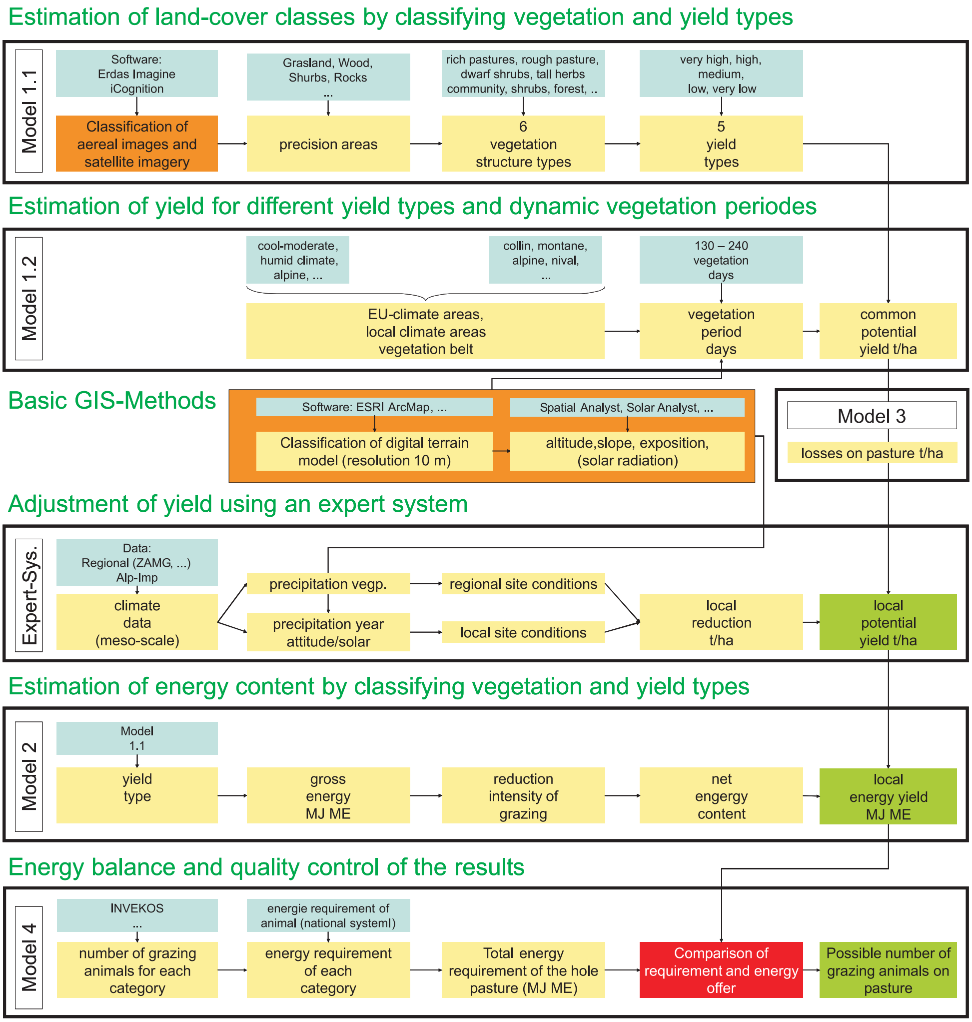

Figure 5: Procedure of the pasture evaluation model

trial sites, alpine forage was manually harvested on site and conserved into hay without loss of residue at the Research and Education

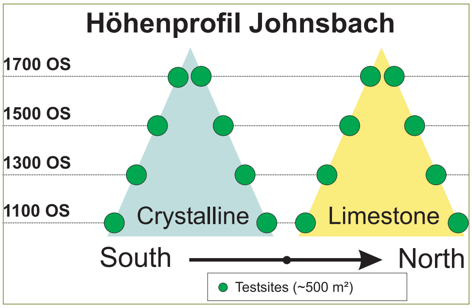

Figure 6: „Höhenprofil Johnsbach" trial plan

Centre Raumberg-Gumpenstein. This was fed to male sheep in a digestion trial to define the exact usable energy content (in vitro digestibility) (GFE 1991, GFE 1998). The trial was repeated between 1994 and 1997. The systematic findings of the „Höhenprofil Johnsbach" are embodied in easily understadable and high-quality formulas.

Overview

The basis of the quantitative model is the abstract design of the PEM. It can be applied worldwide to every alpine-pasture-like area. Adaptation to local biotope 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). In the case of the Raumberg-Gumpenstein project partner, the „Höhenprofil Johnsbach“ is used for the local definition of yield functions. The following results are calculated as a summary from chapter 2.3.3.

- Optimum forage- and energy yield (maximum theoretical volume)
- Local forage- and energy yield (realistic volume)
- Potential (balance from local need and yield)

Data

The following data sources must be made available in current GIS formats (vector/grids) for the realisation of the quantitative model.

Biotope types

From the point of view of exact plant production, the characteristics of biotope types are given as mesoscaled nominal values. These characteristics make the use of remote sensing methods possible and thus offer the provision of reasonably priced data. If the plant communities are classified by exact field work, the observed species have to be registered in their biotope types. It has to be assumed, that the records of the biotope types (species and site) are generally unavailable and must first be drawn up. With the technical availability of an appropriate satellite image (e.g. Spot 5), within a period of two months, a so called scene (region) of 3,600 km² can be processed with the necessary accuracy at an estimated cost of about 13,000 Euro (including image and image processing).

In the same period field work with accompanying geodata recording will cover an area of 8-10 km² at a cost of about 6,000 Euro. The resulting, additionally collected findings cannot be of real use for this kind of project. In regard to costs, there is a factor of 160 between these methods in favour of a remote-sensing project (e.g. Corine land cover) and offers neither the necessary spatial resolution nor the individual classes (Corine 2000).

Digital terrain model

The altitude of any site can be taken from a digital elevation model (DEM). These models are contained in the standard records of every national GIS in several stages of precision and are available to research institutes. If this kind of data is unavailable, the results of the NASA „Shuttle Radar Topography Mission“ (SRTM) are used. This dataset is available free of charge (http://www2.jpl.nasa.gov/srtm/).

Hydrological information

These data are required in the qualitative model and describe the course of streams and rivers, as well as the location of lakes

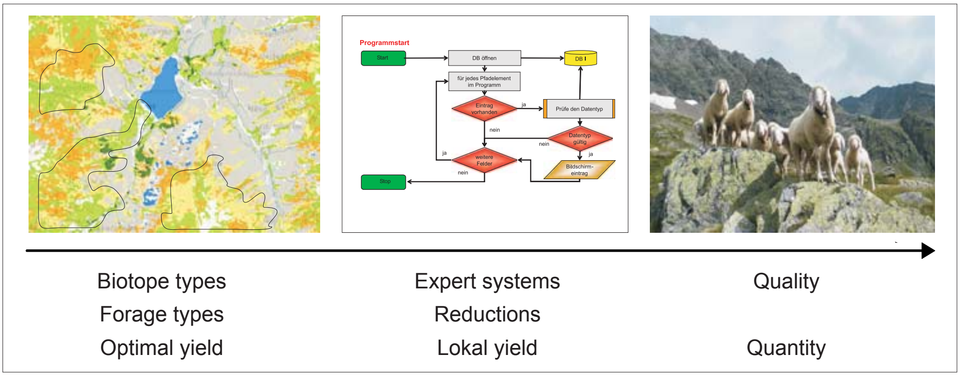

Figure 7: Work phases

and springs. These data must be taken from a national GIS. An alternative is automatic calculation from the terrain model.

Annual precipitation and precipitation during the vegetation period

For the Alpine Space, both records can be taken from the ALP-IMP project of the „Österreichische Zentralanstalt für Meteorologie and Geodynamik“ (http://www.zamg.ac.at/ALP-IMP/). An interpolation of the discrete data of the alpine region is available free of charge from the authors.

Pasture borders

These describe the allocation between alpine-pasture-owner relationships and the lists of the animals driven up onto the alpine pastures (including species and age). The individual alpine pastures must in a second record be summarised to larger units (valleys). There is a total of three types of descriptive areas. The core pastures, the land-register borders and the regional borders. The availability of this kind of data can be checked at the regional or local agricultural administration offices.

Comparative equations

The estimation of forage- and energy yield is actually calculated for three biotope types. In figure 8 the optimum forage yield as a function of the individual biotope types on the vegetation period is presented. For a vegetation period of 120-200 days (altitudes of 1,100 to 2,000 meters), a yield for rich pastures is calculated as 2,600 - 3,300 kg DM/ha, and for rough pastures as 1,900 - 2,400 kg DM/ha. The biotope types of dwarf-shrub heathland and bushes are described with a yield capacity of 600 to 1,200 kg DM/ha. The equations of energy concentration of rich and rough pastures are the result of a combined evaluation from botanical statistics and energy contents. (Buchgraber 2000, Cernusca and Seeber 1998, Gruber et al. 1998, Pötsch et al. 1998) The energy difference between rich and rough pastures is constant with 0.9 MJ ME/kg DM. The equations for yield estimation can be taken from the ENEALP software.

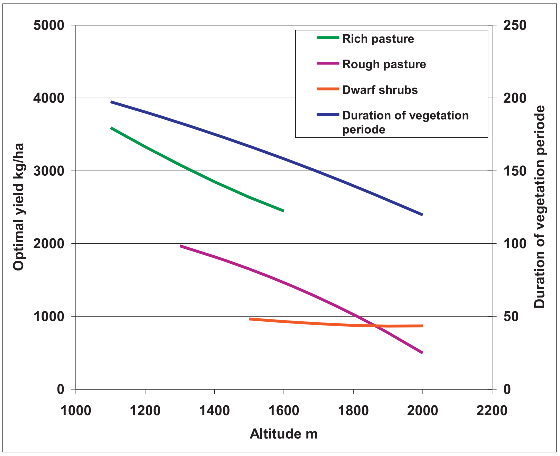

Figure 8: Yield and vegetation period

GIS implementation

Most quantitative-model parameters constantly form an interface in the form of grid data. The technical implementation in GIS thus requires a system that implements elementary methods. The possibility to convert back - and forth between vector - and grid data has to be provided. The individual algorithms are based on the basic mathematical operations, which must be applicable on grid datasets. The complexity of the model arises through the necessity for an ordered procedure. Several hundred formulas are to be set for a complete evaluation of all biotope types to give a net-energy- and forage yield.

The balancing of the potential of an alpine meadow and the distribution to individual grazing animals is technically the most difficult part within the project. Thus a logical link between the grid dataset and the related data has to be created.

In the case of ENEALP in chapter 4, the individual pixels are given in a relational tupple with clear X/Y coordinates and linked with all necessary information, above all with the alpine-meadow ID. The result is a relational database that permits all calculations of animal feeding (energy requirements of the animals per pasture…). A practical, combined indexing of the database can be helpful for local differentiation of different species of animals and their competitiveness to each other. In this way the competitive relationship between sheep and cattle, initially the cattle, can be allocated with pixels that show high energy yields and low altitudes. In the final phase these data are again transformed into a geo-dataset.

Validation of the quantitative model in the Schladminger Tauern

Validation of the classified plant communities in their respective biotopes will be of great importance, if the quantitative model is created on the basis of remote sensing data. In this case, 13 plant communities recorded in the field had to be aggregated to four biotope types. These are rich pastures, rough pastures, dwarf-shrubs and bushes. A comparison of the two systems quickly shows that the class of rich pastures is systematically shifted by half a class in the direction of alpine pastures. Additionally, this explains the low share of 2.3% of rich pastures in the area of examination. For all other classes this means that about two-thirds will fully and correctly be classified. In the remaining third, 80% of the examination points are shifted by one class at most (typically from rough pasture to dwarf-shrub heathland, and in reverse), 20% were falsely allocated. The falsely interpreted share of the entire material amounts to 8%. The erroneous interpretations are partly to be traced back to the fact that only one image (taken in July) was used. Completely grazed rich pastures, high herbal plants and concentrated deposits of animal dung as well as dry rough pastures then clearly change their spectral signature. The validation result emphasises the necessity for close cooperation between field workers and remote sensing (best in the same team or even in personal union).

3 Study areas and results

3.1 Friuli Venezia Giulia

3.1.1 Study area

The study area includes two contiguous valleys: Val Cellina and Val Tramontina, which are located in the Northern part of the Province of Pordenone and in the Eastern part of the Friuli Venezia Giulia Region (figure 10). The two valleys cover a surface of 752 km^2 that represents 54% of the mountainous and hilly area of the whole Province of Pordenone (spread out on 2,273 km^2).

Three Sites of Community Importance (SIC, listed in the 1st Annex to the European Community decision of 22 December 2003) are included in the study area: Regional Natural Park of Friuli Dolomites (European code: IT 3310001), which covers a surface of 36,698 hectares, part of Cellina River canyon (European code: IT 3310004, 286 hectares) and part of Colvera of Jof Valley (European code: IT 3310002, 393 hectares).

Val Cellina

This area includes the municipalities of Andreis, Barcis, Cimolais, Claut, Erto and Casso, all located in socially and economically highly disadvantaged areas (DGR 3303 of October 10th, 2000).

It belongs to the orographic unit of Dolomiti Friulane (Del Favero et al. 1998) and develops along the drainage-basin of Cellina River and its main tributaries: Settimana, Cimoliana, Ferron, Chialedina, Provagna, Prescudin, Pentina and Caltea on the right side of the basin and Varma and Alba on the left one. The higher area of the valley is characterised by karstic phenomena.

From the orographic point of view, Val Cellina is a landscape classified as geologically relatively young (Mesozoic). The area is typical for the Dolomites with many mountainous massifs (over 2,000 m a.s.l.) with steep slopes that go down to cliffy and narrow valleys

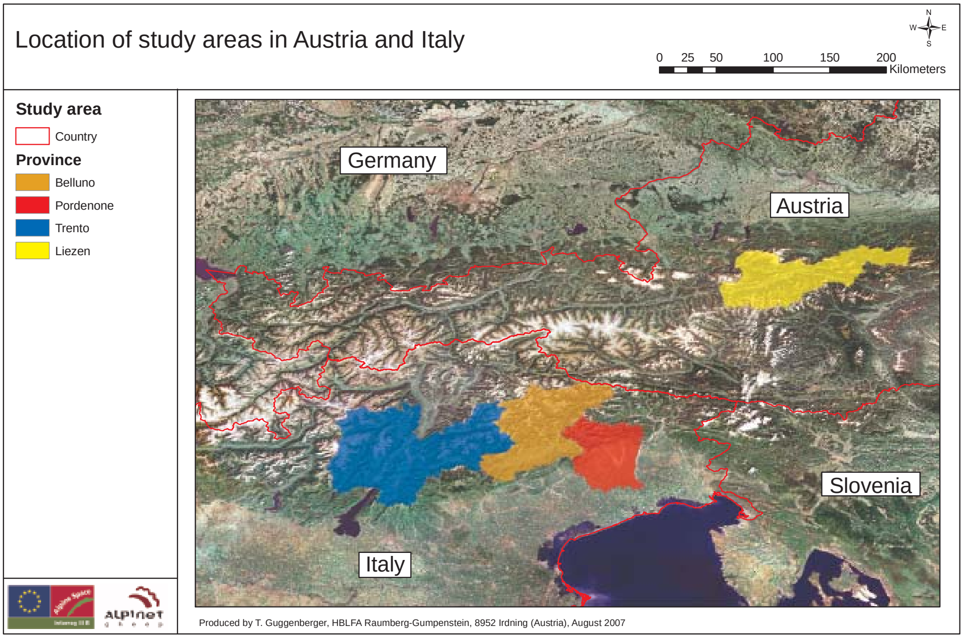

Figure 9: Location of study areas in Austria and Italy

(600 m a.s.l.). The valleys had been modelled during the quaternary glaciation when great quantities of pebble and gravel were stored up. The main pedogenic substrate is of dolomite and limestone, more or less stratified with marl intercalation often located in the lower territories of the valley.

The climate is mainly cold and temperate. Precipitation is homogeneously distributed between spring, summer and autumn, with lightly higher levels in spring and autumn. The precipitation amounts to more than 1,500 mm per year and the average temperature is between 10° and 11°C in most parts. The tormented development of the massifs and the narrowness of the valleys cause thermic reversals that greatly influence the vegetation of the area.

The amount of precipitation, which is characteristic for this area, is favourable to beech (*Fagus sylvatica*), which is dominant in the mountainous belt. Among the coniferous trees the white spruce is mixed with beech and spruce, whereas spruce wood is located in continental places on acid soil. Austrian pine (*Pinus nigra*) woods grow on steep slope with low water supply and they are often found together with Scots pine (*Pinus sylvestris*). In the sub-mountainous belt, the forest with flowering ash and European hop hornbeam is common, together with other broad-leaved woody and thermophil species.

During the last fifty years, the population of the valley gradually lowered from 10% to 2%, compared to the total number of inhabitants of the Province of Pordenone (ISTAT, 2001) and this decrease occurred after the construction of new connecting roads at the bottom of the valley. Additionally, the absence of enough plain areas to allow establishment of industrial activities and mechanisation of agricultural production in the valley boosted depopulation.

At the beginning of the last century, the main activities in the valley were forestry and pasture farming, while today the general trend is to use natural sources for recreational and tourist purposes. In Val Cellina, 99% of the Usable Agricultural Area (UAA) are managed as grassland. The poor (rough) pasture

Figure 10: The study area (red) in Friuli Venezia Giulia region

that usually develops on lime substrate is generally poor of nutrients and therefore suitable for grazing animals with low demands. In fact, before the end of eighteenth century, in all the villages of Val Cellina, sheep and goat livestock was much higher than cattle. At present, the breeding of sheep and goats is lowering both in regard to the number of farms and to the number of animals. The main typology of sheep and goat breeding is on a familiar level with an average of 17 animals per farm.

Val Tramontina

This area includes the pastures of the municipalities of Frisanco, Meduno, Tramonti di Sopra and Tramonti di Sotto. All the above mentioned municipalities are located in socially and economically highly disadvantaged areas (DGR 3303 of October 10th, 2000), except Meduno, which, starting recently, is recovering and shows a good economic development.

It belongs to the orographic unit of Prealpi Carniche (Del Favero et al. 1998) and stretches along the drainage-basin of Meduna river and its main tributaries: Silisia e Muiè on the right side of the basin and Velia, Chiarchia, Tarceno and Chiarzò on the left one.

From the orographic point of view, even Val Tramontina is a territory geologically relatively young with, bare and horrid valleys formed by the alluvial cone of the main streams at the bottom of the mountainous massifs.

The lithologic substrate is limestone and dolomite stratified in groups from the higher Triassic and Cretacean ages. This kind of substrate is not very permeable and not easily eroded. Because of the steep slopes, the surface water flows at high speed with consequently high effects of erosion. Also the karst characteristics of the area have to be pointed out, together with cracking of the hydrographic grid.

The climate is mainly cold and temperate. Precipitation reaches more than 2,000 mm per year and is concentrated during the summer. This water regime is favourable for beech (*Fagus sylvatica*). The average annual temperature is 8°C. The vegetative period, at an altitude of 1,000 m a.s.l., starts in the second half of May and ends in the first half of September.

Forest vegetation is similar to Val Cellina. At Tramonti di Sopra and Tramonti di Sotto, two typologies of forests are dominant: beech wood and Austrian pine wood. Both contain other tree species, which appear in particular micro-climate conditions of aspect, humidity and soil. Vegetation belts are often overlapping in this region.

From the historical point of view, Val Tramontina had not been isolated as Val Cellina. At the beginning of the nineteenth century, a road that connected the valley with the plains already existed. In the past, the mountainous economy of the valley was based on activities related to forestry and pasture farming, while at present, the inhabitants of the valley are working to promote the valorisation of the naturalistic and environmental sources of the area for tourist purposes.

In Val Tramontina, the breeding of sheep and goats is not only at a familiar level, some of

Figure 11: Val Tramontina

Table 11: List of the main data referred to the municipalities included in the study area, divided between Val Cellina and Val Tramontina (data fonts: Istat, 2001, Research report on the fifth survey on agriculture in Province of Pordenone, Report of the Direzione centrale risorse agricole, montagna e foreste of Friuli Venezia Giulia Region, 2006).

Municipality	Number of inhabitants	Surface in in km²	Hectares of UAA - Usable Agricultural Area Total	Grassland	No. of animal husbandry	No. of sheep and goat farms
Val Cellina						
Andreis	308	26	1,281	1,281	9	9
Barcis	293	103	97	96	9	2
Cimolais	462	101	422	145	14	2
Claut	1,135	165	742	728	37	16
Erto e Casso	419	52	125	120	29	8
Total	2,617	447	2,667	2,370	98	37
Val Tramontina						
Frisanco	693	61	216	216	2	1
Meduno	1,734	31	654	271	80	11
Tramonti di Sopra	406	125	318	311	14	6
Tramonti di Sotto	444	85	1,221	1,220	13	5
Total	3,277	302	2,409	2,018	109	23
Total study area	5,894	749	5,076	4,388	207	60

the breeders seem to have good perspectives to continue and improve their production even in the future.

3.1.2 Description of the study cases

Mountain agriculture is historically depending on the geographical characteristics of the territory, as well as on the availability of the basic resources for living population.

In the Cellina and Tramontina valleys the pasture areas were originally located at the bottom of the valley, near the villages or on the alluvial terraces. The demographic increase between the 18th and the 19th centuries lead the population to exploit new areas for pastures, only available in the valley bottom or near the mountain tops, where the glaciers shaped the land in form of wide corries.

The exploitation of high pastures, originating from primary grassland or by cutting forests, implied a shorter pasture period because of the shorter vegetation growth season.

The method of Alpine transhumance was then applied, in which the valley bottom pastures were used at first at the beginning of the season, secondly the high mountain pastures, and finally the valley bottom ones again, such as to provide enough forage for the whole season.

The harsh living conditions in the pre-alpine pastures (malghe), often worsened by the scarcity of water in the karstic environment, lead to their progressive abandonment during the last century.

Based on the above considerations, some study cases were chosen, in which the alpine transhumance is still practised, and some other ones, in which pastures were abandoned. Seven districts were selected, defined as malga units (table 12), including one or more malga, still under grazing or suitable to grazing from the same herd, thus having the same type of management.

In the analysed study cases, there are access roads and facility conditions in order to allow their utilisation by means of occasional goat

Table 12: Study cases of Cellina and Tramontin valleys

Val Cellina	Malga Unit	Pastures	Total area (ha)	Use
	01 Fara	Monte Fara	13.36	Abandoned
	02 Cimoliana	La fontana, Pian Pagnon, Meluzzo	9.89	Grazed
	03 Settimana	Settefontane, Pussa, Senons	15.45	Grazed
	04 Alta Val Cellina	Casavento, Pradut, Ressetum	16.18	Abandoned
	Total		54.88	
Val Tramontina	**Malga Unit**	**Pastures**	**Total area (ha)**	**Use**
	05 Valine	Chiavalot, Valine alte, Salinchieit	40.63	Abandoned
	06 Rest	Somp la Mont, Monte Rest	39.54	Abandoned
	07 Teglara	Teglara	145.45	Abandoned
	Total		225.57	

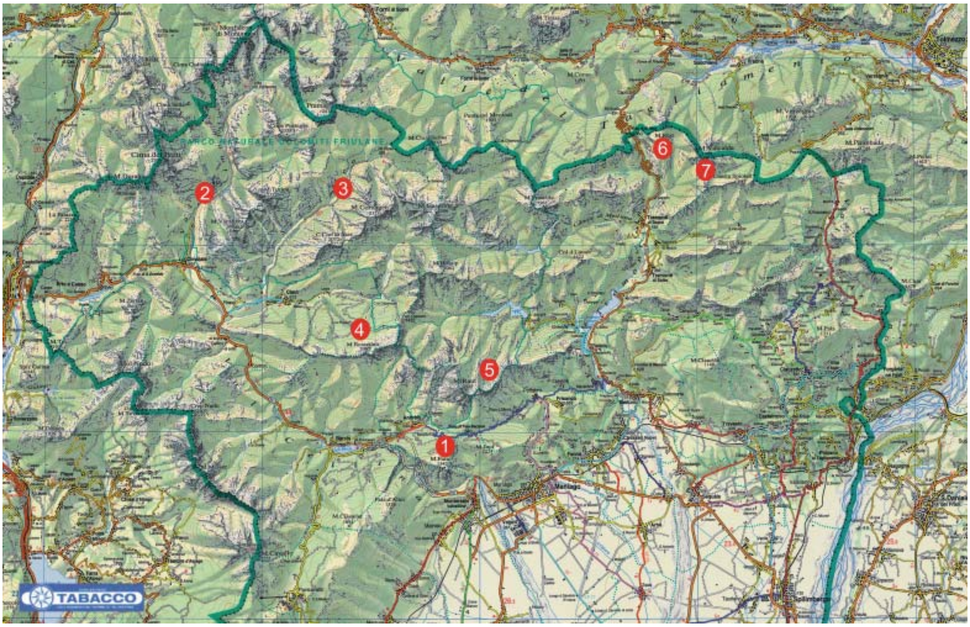

Figure 12: Geographical distribution of the malga units analysed: 1 Fara, 2 Cimoliana, 3 Settimana, 4 Alta Val Cellina, 5 Valine, 6 Rest, 7 Teglara.

and sheep grazing (aiming at habitat conservation), or permanent goat and sheep grazing (also with productivity objectives).

The study cases were also selected with the aim to represent all the existing pasture types in the most comprehensive way, as:

- Valley bottom pastures on shallow soils in plains
- Mountain pastures limited in range
- Sub-alpine pastures on mountain slopes
- Sub-alpine pastures with variable micro-morphology based on karstic phenomena

Figure 12 shows the geographical distribution of the case studies.

The variation of pasture vegetation caused by abandonment or discontinuous grazing made it difficult to detect the used areas; the increase of woodland in many cases made the old boundaries completely undetectable. Based on the objective of the study, carried out on both grazed and abandoned areas, an unambiguous criterion was chosen to select the study areas, defined by the forest boundaries as reported in the regional technical map (CTRN 1:5000). The term „analysed area“ indicates the detected area according to this criterion, for which the suitability for sheep and goats grazing is estimated.

The seven Friuli Venezia Giulia study cases are fully described on the CD-ROM, which contains the model application software together with the entire text. Here the description and results achieved from the model application for the malga unit Fara are reported as an example.

Malga unit Fara study case

Malga Monte Fara is located in the municipality of Andreis, on the Northern slope of Mount Fara, accessible by the provincial road connecting Andreis (Val Alba) to Poffabro (Val Colvera) on a paved track stopping at the entry to the shepherd's house.

The pasture area is continuously, stretching towards the mount from the elevation of the facilities. Pasture vegetation is secondary, originating from a removal of a beech forest. Recently, two forest tracks had been built, which from the shepherd's house flank the lower boundary of pastures both on the East- and West-side.

Water resources

The lack of water springs made it necessary to find different solutions for water supply. Water for buildings is collected from the stable cover and conveyed into two tanks serving the shepherd's house and a drinker. Another drinker is available for animals in the Western zone of the pasture, fed by a nearby tank collecting the rain water.

Table 13: Characteristics of malga unit Fara

Malga Unit: Fara	
Pasture	Monte Fara
Owner	Municipality of Andreis
Analysed area	13.36 ha
Elevation	954 m a.s.l. (shepherd's house)
Aspect	N, N-E
Lithology	Cretaceous limestone
Use	Not grazed. Last grazing with productive animals: 1992
Facilities	Mixed type house, used as personnel residence at the floor and milk processing at the ground floor. Restructured in the 1980ies. Electric power is provided by a medium-voltage line. The stable, located towards the mountain and inaccessible with machinery, is a traditional building with double lying-stand. The dung tanks are located in the downstream zone.

Table 14: Distribution of pasture areas of malga unit Fara in slope classes. Classes covering less than 100 m² are neglected

	Class	1	2	3	4	5
Sheep	Slope	>45°	21°-45°	0-20°		
	Area (ha)	0.02	9.96	3.39		
Goats	Slope	>60°	51°-60°	41°-50°	0-20°	21°-40°
	Area (ha)	-	-	0.08	3.39	9.89

Morphological characteristics

Malga Monte Fara is located on the Northern slope of Monte Fara, at an elevation ranging from 920 to 1,050 m a.s.l. Most of the area has a slope between 20 and 45 degrees. In table 14, the area is divided in slope classes used for the estimation of suitability. The slope is carved by some catchment lines slightly modifying the aspect. The soil is shallow and characterised by erratic blocks (boulders).

Vegetation characteristics

Pastures extend on a shallow, stony soil with low fertility. The vegetation can be classified as rough pasture types consisting of Meso-Bromion-Communities. The spatial micro-morphological variation allows the growth of higher forage quality species in catchment points, but this is rarely significant. The dominant vegetation type is rough pasture (51%), followed by leave shrubs (18%).

3.1.3 Suitability map of goats and sheep grazing

The model application allowed estimating the suitability of the seven study cases analysed in the Friuli Venezia Giulia region for the goats and sheep breeding. The suitability

Figure 13: Pastures of malga unit Fara. The stable is on the right, the roof of theshepherd's house is partially visible on the lower left side

Table 15: Vegetation types of malga unit Fara

Vegetation type	Area (ha)	Characteristics of vegetation type
Rough pasture	6.78	Characterized by *Bromus* communities, has a remarkable amount of *Brachypodium rupestre* in the higher zones, not much grazed and indicator of abandonment. The increase of shrub and tree species is observed in the marginal zones, as white beam, rowan, hazel tree and juniper.
Rich pasture	1.81	Frequent in the catchment points or in the downstream zones of the stable, it is characterised by *Festuca pratensis*, *Geum rivale*, *Veronica chamaedrys* and *Dactylis glomerata*.
Tall Herbs	0.04	Located downstream of the shepherd's house, it is characterised by an abundant coverage of *Rubus idaeus*.
Dwarf shrubs	0.36	Located higher of the stable, it is characterised by heather and rhododendron.
Shrubs leaves	2.35	Lying on the marginal belt of the pasture, mainly characterised by hazel tree.
Forest	1.89	Located in the marginal zones, especially in the South-Western zones of the pastures, dominated by beech.
Not grazed areas	0.13	Characterised by buildings and access road.

maps are made to spatially detect areas with different degrees of suitability, distinguishing those more suitable for sheep grazing from the ones more suitable for goats grazing.

The criteria composing suitability are: (i) vegetation, (ii) slope, and (iii) water availability. To each of them a score was assigned, based on their influence with respect to the availability of pasture exploitation by sheep or goats.

The suitability scores were converted into spatial data for mapping. In the following paragraphs some remarks are reported, derived from the model application in each malga unit. As for table 16, the bigger part of the examined area is quite suitable for breeding of both species. The highest values are found in class 4 (42% for sheep and 45% for goats), followed by class 3 and class 4 for sheep, and by class 4 and class 3 for goats. This means that the vegetation types, the overall slope and water availability of pastures are in most cases suitable for sustaining both sheep and goats breeding.

Analysing data on a district scale (tables 17 and 18) it can be noticed that the case studies of Val Cellina have, on the whole, less available pasture areas than Val Tramontina

Table 16: Total areas of the 7 study cases analysed in Friuli Venezia Giulia Region distributed into suitability classes for each animal species (ha and % on total)

Class		I	II	III	IV	V	Total
Sheep	ha	2.82	21.95	74.19	115.85	61.76	276.57
	%	1.00	7.90	26.80	41.90	22.30	100.00
Goats	ha	0.04	12.64	43.42	124.02	96.45	276.57
	%	0.00	4.60	15.70	44.80	34.90	100.00

Table 17: Study case areas distributed into suitability classes for sheep (ha and % on total)

Class		I	II	III	IV	V	Total
Val Cellina	ha	0.00	0.01	5.35	20.07	27.29	52.72
	%	0.00	0.00	10.10	38.10	51.80	100.00
Val Tramontina	ha	2.82	21.94	68.84	95.77	34.48	223.85
	%	1.30	9.80	30.80	42.80	15.40	100.00

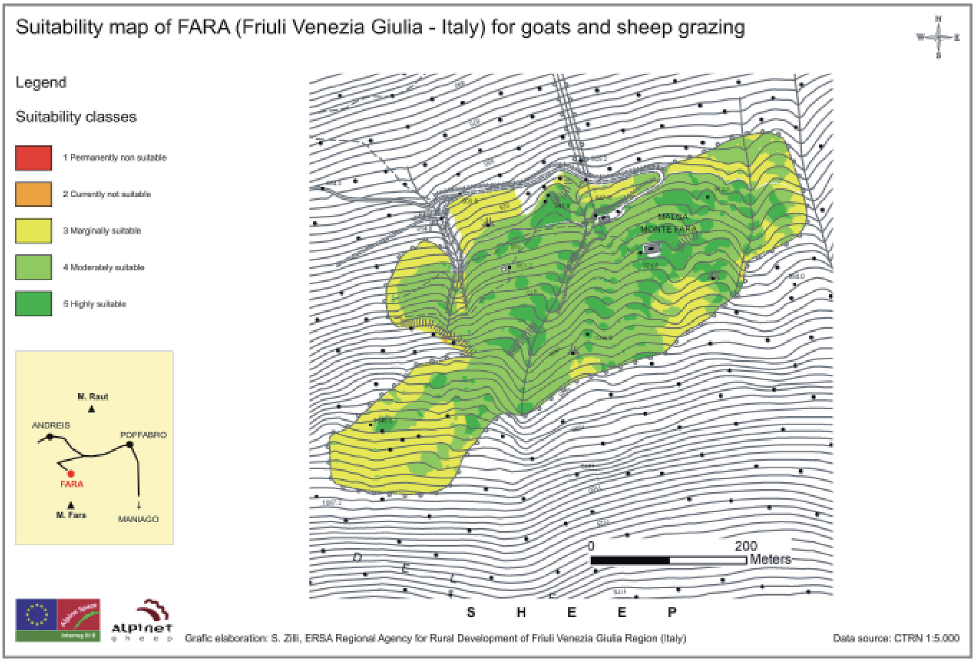

Figure 14: Suitability map of FARA (Friuli Venenzia Giulia - Italy) for sheep grazing

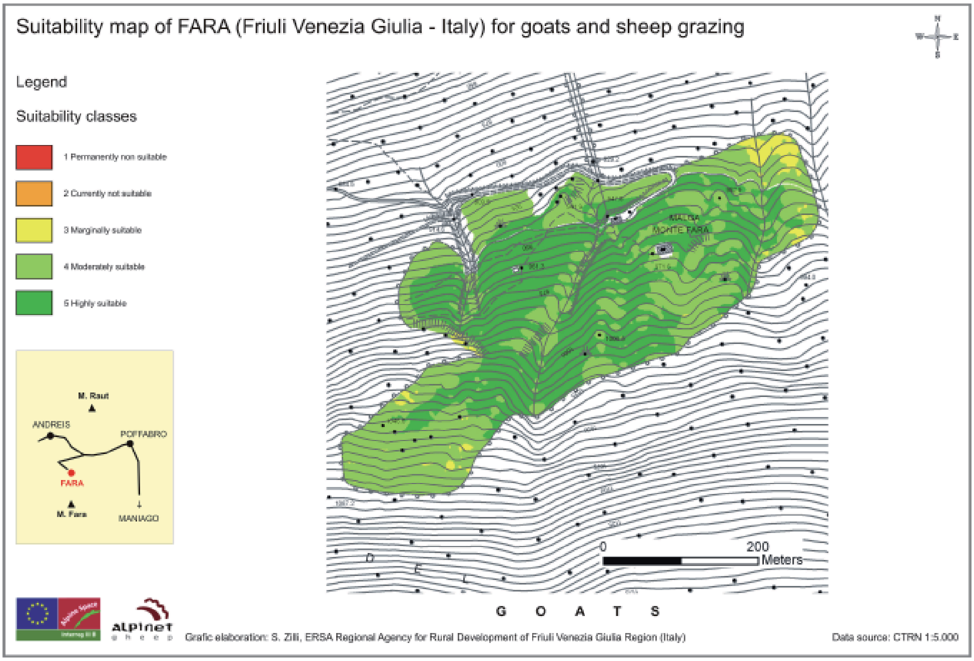

Figure 15: Suitability map of FARA (Friuli Venenzia Giulia - Italy) for goats grazing

Table 18: Case study areas distributed into suitability classes for goats (ha and % on total)

Class		I	II	III	IV	V	Total
Val Cellina	ha	0.00	0.00	3.16	19.58	29.99	52.72
	%	0.00	0.00	6.00	37.10	56.90	100.00
Val Tramontina	ha	0.04	12.64	40.26	104.44	66.46	223.85
	%	0.00	5.60	18.00	46.70	29.70	100.00

Table 19: Malga unit Fara. Total area distributed into suitability classes for the two considered animal species

Class		I	II	III	IV	V	Total
Sheep	ha	0.00	0.01	3.70	7.15	2.38	13.24
	%	0.00	0.10	27.90	54.10	18.00	100.00
Goats	ha	0.00	0.00	0.38	6.33	6.52	13.24
	%	0.00	0.00	2.90	47.80	49.30	100.00

(53 ha versus 224 ha), but with a good degree of suitability, meaning no area is in the lowest suitability classes.

In Val Tramontina, about 11% of the area is in the lowest suitability classes for sheep, whilst only 6% for goats. These values look quite limited with respect to the extension of the examined area. The amount of low suitability areas mainly depends on low water availability or bad water distribution in the grazed areas.

Considering the highest suitability class for both animal species, the highest percentages are found in Val Cellina (52% for sheep and 57% for goats), followed by Val Tramontina (15% for sheep and 30% for goats), highlighting the remarkable difference between the districts.

Furthermore, Val Cellina has more suitable pastures with smaller size, whereas Val Tramontina has larger available areas for grazing with remarkable vegetation diversity.

The results of the application of the model are reported as follows, considering both the mapped aspects and those concerning the areas classified into different suitability classes.

Results of the malga unit Fara

Malga Monte Fara has a good suitability for sheep and goat breeding, with a major extension of the area suitable for goats in comparison to sheep. In fact, the spread of shrub species in the South-Western part, makes this unit particularly suitable for goats. The small size of the malga allows grazing notwithstanding the availability of only one drinker, such that the model application does not detect areas belonging to low suitability classes. The pastures limited in extension are most suitable for breeding milk herds with few heads.

3.2 Trentino

3.2.1 General overview and study area

The Province of Trento, or Trentino as it is commonly known, is located in the North-East of Italy along the traditional communication paths between the German and Latin world. Livestock farming is fundamental to the upkeep of 90,000 ha mountain pastures and 30,000 ha of meadows, which represent about 80% of the total local agricultural area. Most of the livestock farms are cattle-dairying, although the number of sheep and goats, particularly of dairy goats, has been increasing during the last two decades. The dairy goat breeding developed particularly in Val di Fiemme, Val di Ledro and Val Giudicarie, and lately in Val di Pejo.

The qualitative model has been implemented in Trentino in four „malghe“ (summer grazing areas served by facility buildings): Three (malga Agnelezza, malga Sadole and malga

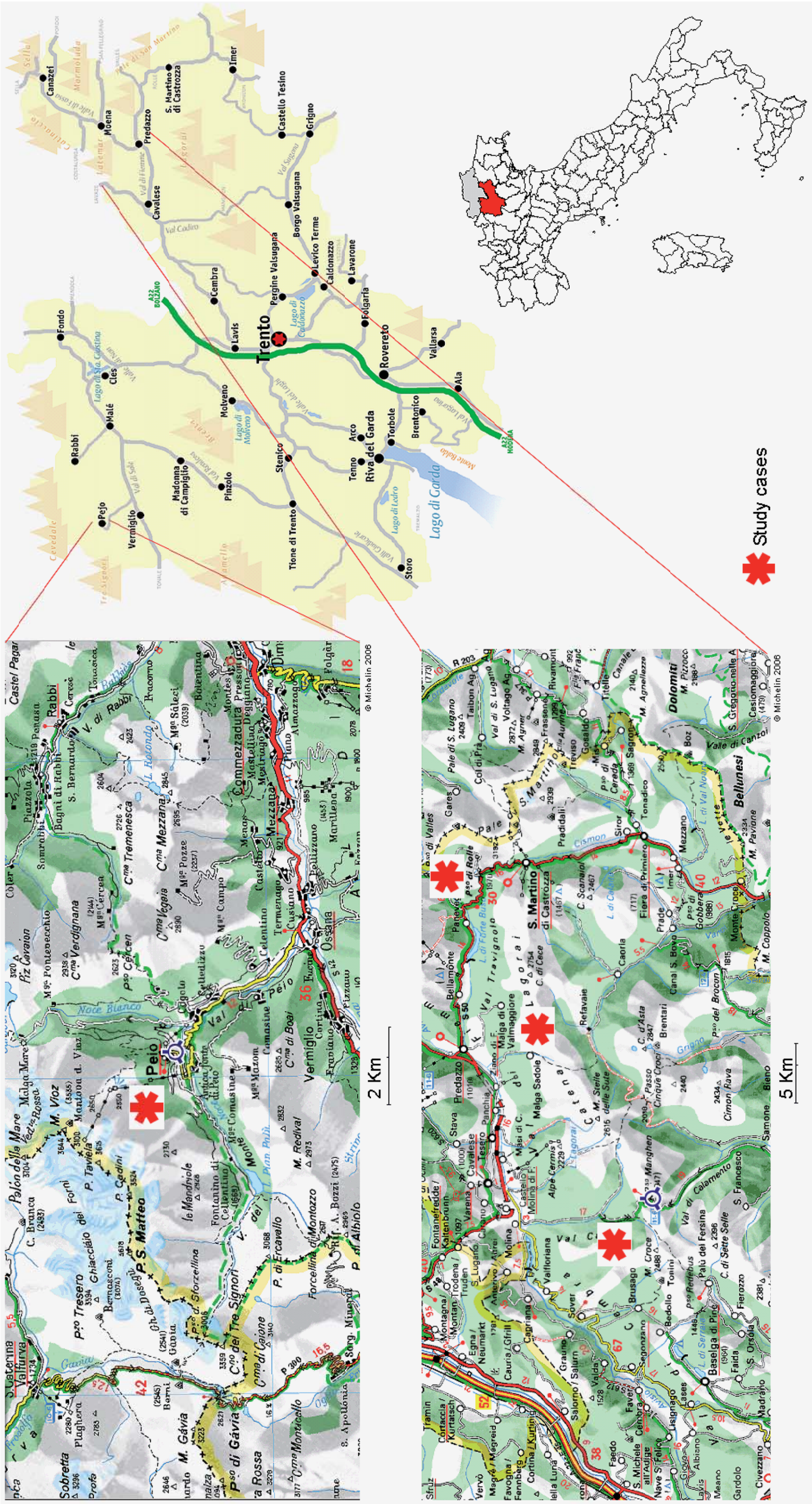

Figure 16: Study areas in Trentino

Juribello) in Val di Fiemme and one (malga Covel) in Val di Pejo. In this chapter, we illustrate the general geological, climatic and vegetation characteristics of Val di Fiemme and Val di Pejo.

Val di Fiemme

This part is mostly covered by wood (25,000 ha) and mountain pastures (7,766 ha), meadows and tillage account for 2,000 ha, while 12% of the total surface (50,000 ha) are covered by rocks and water courses and only a 2% by urban areas. The pastures lie in Val di Fiemme at altitudes between 1,500 and 2,300 metres. The valley has an East-West orientation, which favours a bigger radiation on the Southern exposed side of the valley, where agricultural activities are mostly located. The climate is continental pre-alpine with rainfall concentrated in spring and autumn. More details are illustrated in the climatic diagrams of Passo Rolle (2,004 m) and Cavalese (1,014 m).

In the study areas, acid rocks such as the porphyr of malga Sadole prevail, but there are also typical carbonate rocks, like in the area near malga Juribello. In this case, the geological substratum is made up of dolomite of the middle Triassicum, together with mudstone sediments of the lower Triassicum. Volcanic seams and lavic ducts can also be found, as well as areas that were probably covered by volcanic rocks in the past subsequently removed by erosion.

Val di Pejo

This area is located in North-Western Trentino as a side valley of Val di Sole. The morphology of the valley is typically glacial with every surrounding mountain peak higher than 3,000 m. The climate has continental characteristics with relatively scarce rainfalls.

The rock substrate shows a clear prevalence of metamorphic rocks of volcanic origin (schists, phyllites, paragneiss, quartzites, etc.), even if intrusive igneous rocks of the Adamello and the relative hypabyssal rocks even if there are also present. Moreover, moraines and alluvial deposits can be found in the valley.

Vegetation

The surveyed pastures generally lie in the area of the subalpine pine forest and, partially, in the area of natural high altitude grassland. Above the tree line, grassland communities with *Festuca varia* are observed (malga Covel) typical of steep, south-facing flanks and characterized by dense and circular tufts with stingy leafs; debris and detritus soils. Other plant communities found are: *Salix* communities typical of the small nival valleys and vegetation of the windy ridges. These plant

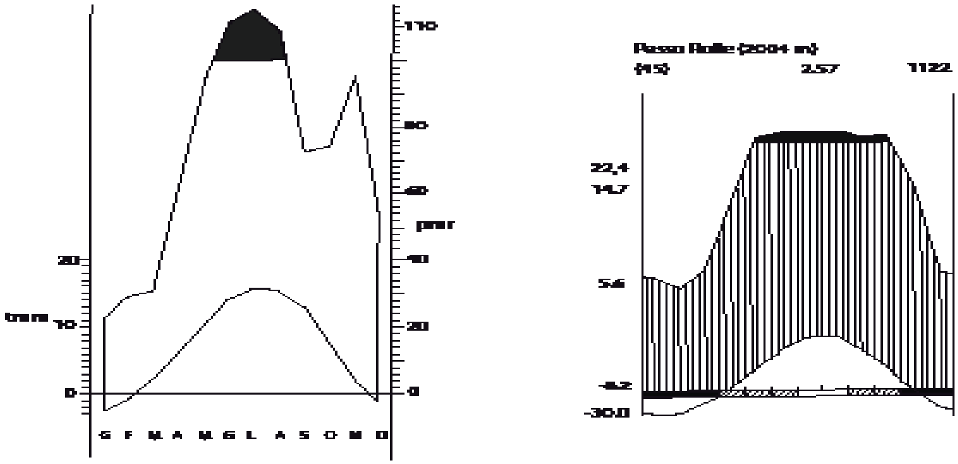

Figure 17: Walter and Lieth diagram of Passo Rolle and Cavalese

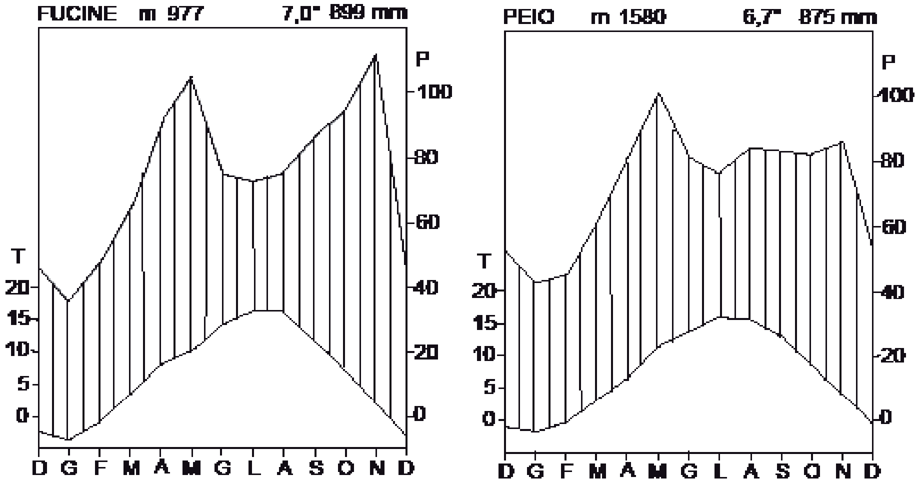

Figure 18: Walter and Lieth diagram of Fucine and Pejo

communities only offer, little pastoral value. Thus, they only allow a modest cattle load capacity, but have a high conservational value. At lower altitudes, among the rough pastures, *Nardion* communities cover the majority of the surface of the studied pastures. Here, also *Sesleria varia* communities are found. The vegetation of the open areas also comprises rich pastures and *Rumex* communities. The first ones occupy a relatively small part of the surveyed areas and are usually located in the flattest and lowest parts. The most characteristic species are *Poa alpina*, *Phleum alpinum* and *Festuca rubra*. The *Rumex* communities only cover small areas, usually near the malga's buildings or stable fences.

Among woodlands and shrubs, different plant communities were found: the *Rododendron-Vaccinum* communities quickly develop where pasture is under-used, while typical formations for the moraines and the impluviums are dominated by *Alnus viridis*. *Pinus mugo* is relatively common on gravel depots, especially calcareous ones. Finally, we have tree pastures dominated by *Larix decidua*, and pine or mixed pine and larch woods.

The complete analysis of all four malgas studied in Trentino, in particular concerning the floristic and vegetational aspects, is included on the CD-ROM attached to the book. For reasons of space, only results for malga Covel and malga Agnelezza are in full detail syntethic presented here, while just a table is reported for malga Sadole and malga Juribello.

3.2.2 Description of the study cases

Malga unit Covel study case

The pasture stretches over an area of 350 ha, completely within the Stelvio National Park.

During 2006, when botanical relevees have been making, 266 goats (partly in lactation) and 225 sheep were maintained on the pasture. Dairy goats received 800 g of concentrate

Figure 19: Malga Covel

per day as feed supplement. Sheep and goats stay on different portions of the pasture during the whole season. Two shepherds take care of the cattle, but controlled grazing is practised only for the dairy goats. Goats are milked twice per day at the malga's facilities and the milk is delivered for cheese making to the small dairy co-operative in Pejo. The malga is reached by a comfortable forest road, which can be used by motorcars only under authorisation and has a small retail shop. The area shows a diverse vegetation, partly due to its dimensions. Open pastures, of both primary and secondary origin, constitute almost half of the total surface. But almost half of them have low productivity, in particular those located on the highest parts. A fraction of the area is used for hay production and is accessed by animals only at the end of the season, after the cut of the meadows. The typical tree pasture of mountain areas with larch woods, cover a significant part of the area, while *Alnus viridis* and *Alnus incana* also have a remarkable proportion in the area.

Table 20: Descriptive characteristics of malga Covel

Ownership	Commons Administration Pejo
Managing body	Pejo sheep and goats breeders society
Total area	350 ha
Altitude	1,520-2,560 m a.s.l.
Exposition	Prevalently S-SW
Geology	Intrusive and hypabyssal igneous rocks, orthogneiss, amphiboles, metagabbros
Livestock management (2006)	266 goats (more than a half in lactation period) and 225 sheep. Controlled grazing for goats during the day, continuous grazing for sheep.
Buildings	Sleeping and living rooms for employees, stable used as waiting room to access the milking device, cheese storage room for the retail.

Table 21: Vegetation of malga Covel

Structural type	ha	Characterization
Rich pasture	9.9	Mostly *Poion alpinae* communities, which are located on the flattest area, lower than the buildings. They have a high pastoral value
Rough pasture	128.3	In malga Covel, this type mostly consists of *Festucetum variae*, that can be found at the highest altitudes. *Nardion*-communities are also well represented. Finally, the secondary vegetation that grows on the ski slopes. In this group we have also fen vegetation of Covel lake.
Tree pasture	75.6	The dominant species are *Picea abies* and *Larix decidua*.
Dwarf shrubs	31.7	Characterized by the abundant *Rododendron ferrugineum* and *Vaccinum* sp. cover, with a remarkable presence of *Juniperus communis*.
Alnus sp.	44.6	In general distributed along the Taviela torrent and next to the torrent valleys. *Alnus viridis* is dominant at higher altitude, *Alnus incana* at lower.
Wood	31.9	Typical pine vegetation on the silicate substrate, here the wood is mostly characterized by the co-presence of *Larix* and *Picea*
Unproductive	25.9	Rocks, buildings and internal roads cover a significant area of the pasture

Table 22: Water availability at malga Covel

Distance from water (Km)	Surface ha	Suitability score
0-0.5	304.5	5
0.5-1.0	44.9	3
1-1.5	0.0	1
>1.5	0.0	0

Table 23: Slopes of malga Covel

Slope (for sheep)	Surface (ha)	Slope (for goats)	Surface (ha)
0°-20°	99.6	21°-40°	216.7
21°-45°	238.5	0°-20°	99.6
>45°	11.4	41°-50°	30.1
		50°-60°	2.9
		>60°	0.2

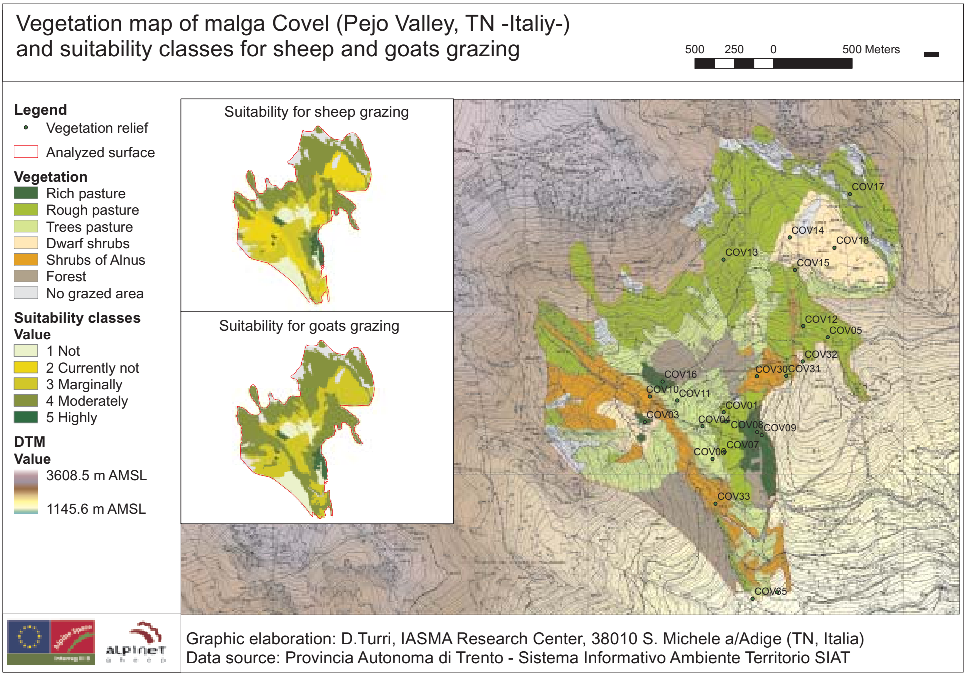

Figure 20: Map of vegetation of malga Covel (Trentino, Italy)

Water does not represent a limiting factor for this area: There are two springs and water courses. Moreover, the usual midday stop during the grazing circuits at the malga facilities guarantees that animals get the necessary supply of water. The malga covers the steep slopes towards the peaks of Dente del Vioz and Punta Cadini. Therefore the landform is a glaciated slope with a main South to Southwest exposition: the majority of the area shows slopes between 21° and 40°.

Malga unit Agnelezza study case

The area covers about 103 ha in the municipality of Molina di Fiemme. The animals are guarded by two shepherds; another worker helps with milking and facility maintenance. During the night the animals stay in a wide fenced area beside the malga's buildings. The animals receive 500 g of concentrated fodder per day as feed supplement.

Goats are milked twice per day and the milk is delivered to a dairy co-operative in Cavalese once a day. The pasture can be reached by a good forest road only with authorization.

The name of the malga suggests the word „lambs“ in Italian („agnelli“), showing that it was traditionally used for small ruminants.

The open pasture area is limited, while most of the area is covered by a larch tree pasture.

Rhododendron is also rather widespread, as well as wood and *Alnus viridis*. In recent years the increase in grazing goats seems to have remarkable consequences on the abundance of the second species.

Figure 21: Malga Agnelezza

Table 24: Descriptive characters of malga Agnelezza

Ownership	Magnifica Comunità di Fiemme
Managing body	Val di Fiemme goat breeding pastoral society
Total area	103 ha
Altitude	1,613-2,214 m a.s.l.
Exposition	NE-N-NW
Geology	Porphyric quartz of the Lagorai mountains
Livestock management (2006)	300 dairy goats, managed with controlled diurnal grazing, 2 donkeys, 1 horse.
Buildings	Sleeping and living rooms for employees, stable used as waiting room for the mobile milking facility.

Table 25: Vegetation of malga Agnelezza

Structural type	ha	Typology characterization
Rich pasture	2.60	It is present in the flattest areas and characterized by species like *Festuca rubra*, *Phleum alpinum* and leguminosae, but also with a high cover of *Descampsia caespitosa* (40%)
Rough pasture	3.76	Rough pastures in malga Agnelezza can be described as *Nardion* with forest re-colonization species (*Rhododendron* and *Vaccinum*)
Tree pasture	41.70	The dominant species are *Larix decidua* and *Picea abies* grown on ancient open pastures.
Tall herbs	0.90	Located in the parts close to the stable and the building, where *Rumex alpinus* and *Senecio alpinus* are dominant.
Dwarf shrubs	29.80	Characterized by the abundant *Rododendron ferrugineum* and *Vaccinum* sp. cover, with a remarkable presence of *Juniperus communis,* which is grazed by the goats.
Alnus	3.37	In the avalanche paths, the impluviums and the most humid flanks. It is characterized by the dominance of *Alnus viridis*.
Wood	6.73	High mountain pine wood of the silicate substratum, here *Larix* is mixed with *Picea abies*.
unproductive	9.30	Rocks, buildings and internal roads

Table 26: Water availability of malga Agnelezza

Distance from water m. Sadole (Km)	Surface ha	Suitability score
0-0.5	86.6	5
0.5-1.0	15.5	3
1-1.5	0.0	1
>1.5	0.0	0

Table 27: Slope of malga Agnelezza

Slope (sheep)	Surface (ha)	Slope (goats)	Surface (ha)
0°-20°	27.2	21°-40°	61.1
21°- 45°	71.6	0°-20°	27.2
>45°	4.4	41°-50°	13.8
		50°-60°	1.1
		>60°	0.0

A permanent torrent flows through the area; there are two sources, one near the river and another in the central, higher part near the malga's facility buildings. Considering also other seasonal rivers, water does not represent a limiting factor for this area.
The area has a typical glacial landform. The exposition is mainly from Northeast to Northwest and the slope varies from flat to about 56°.

3.2.3 Results of the qualitative model implementation

Malga Covel study case

The malga turns out to be well suitable for goat grazing: 87% of the total malga surface belong to the higher suitability classes 4 and 5 and 30% of the area turn out to be optimally suitable. Moreover, excluding the unproductive areas, there are no parts with

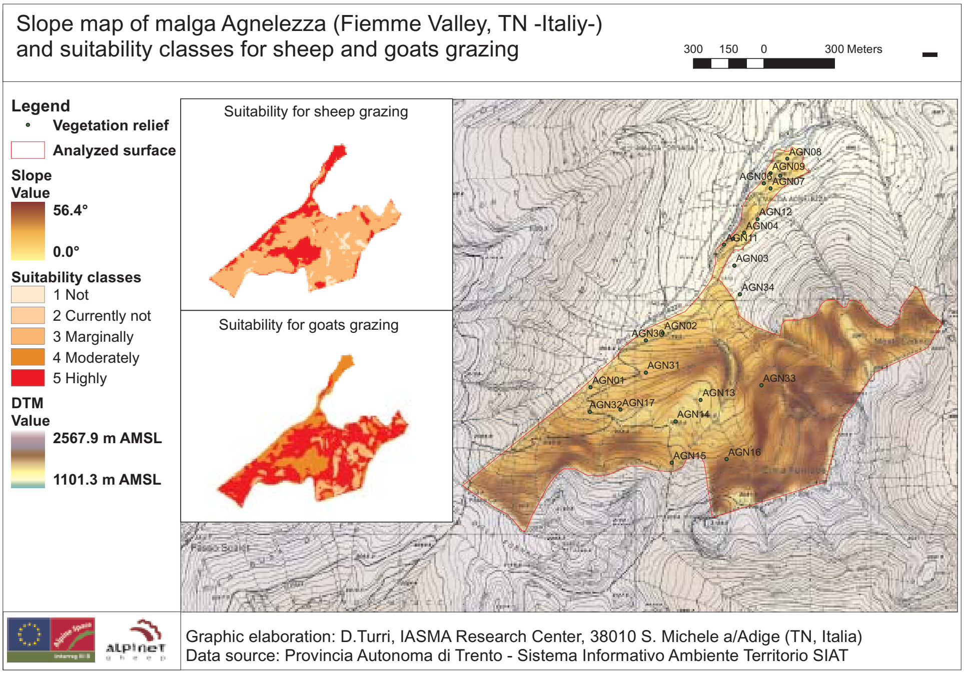

Figure 22: Slope map of malga Agnelezza (Fiemme Valley, Trentino, Italy) - suitability classes for sheep and goats

Table 28: Synthetic data of malga Sadole and malga Juribello

	Malga Sagole	Malga Juribello
Ownership	Municipality of Ziano	Autonomous Province of Trento
Managing body	Pastoral Society of Panchià-Ziano	Provincial Breeders' Federation of Trento
Total area	141 ha	226 ha
Altitude	1490-2215 m a.s.l.	1770 - 2295 m a.s.l.
Exposition	N-SW	West (NW-SW)
Geology	Porphyric quartz	Carbonate-dolomite rocks
Livestock management (2006)	43 dairy cows, 30 calves, 24 dairy goats and 7 horses. Goats are milked twice per day, uncontrolled grazing	150 dairy cows, with controlled diurnal and rotational night grazing, 2 asses, 2 horses, pigs.
Rich pasture (ha)	15.5	54.3
Rough pasture (ha)	15.1	89.8
Tree pasture (ha)	41.3	17.6
Tall herbs (ha)	2.2	1.9
Dwarf shrubs (ha)	0.9	29.0
Alnus sp. (ha)	28.1	1.5
Wood (ha)	28.4	18.9
Coniferous shrubs (ha)	0.0	2.1
Unproductive (ha)	9.3	10.2

an insufficient suitability. The best suitable areas are well distributed over the malga and this permits development of grazing circuits over the whole area.

Open pasture areas cover a large part of malga Covel, even though rich pastures are rare. Also the leaf bush areas are fundamental, because they offer the most desired nutriment

Table 29: Suitability values assigned to the surface of Malga Covel

Suitability value	Goat surface (ha)	Goat surface (%)	Sheep surface (ha)	Sheep surface (%)
0-unproductive	25.9	7%	25.9	7%
1-very poor suitability	0	0%	0	0%
2-poor suitability	0	0%	4.6	1%
3-sufficient suitability	19.2	6%	105.2	30%
4-good suitability	202.9	58%	168.5	48%
5-very good suitability	99.7	29%	43.6	13%

Table 30: Suitability values assigned to the surface of malga Agnelezza

	For goats		For sheep	
Surface	(ha)	(%)	(ha)	(%)
0-unproductive	5.2	5%	5.1	5%
1-very poor suitability	0	0%	0	0%
2-poor suitability	0.6	1%	4.6	5%
3-sufficient suitability	11.2	11%	41.3	41%
4-good suitability	80.2	79%	44.7	44%
5-very good suitability	4.0	4%	5.4	5%

for goats. In addition, the morphology seems to favour these animals which have a great ability in moving on flanks with a slope between 20° and 40°.

The model applied to the sheep pasture gives slightly different results, but anyway positive: 60% of the surface belongs to the highest suitability classes. The most suitable areas are next to the facilities (flat rich pastures) and flat parts at higher altitudes. In addition, there are no areas unsuitable for sheep.

Malga unit Agnelezza study case

The implementation of the model assigns good or very good suitability values for goats to 80% of the area (table 30). Nevertheless, parts with optimal suitability for goats are very limited:

There are only a few hectares of open pasture and leaf bush. The area assigned to the highest suitability classes is very low for both goat

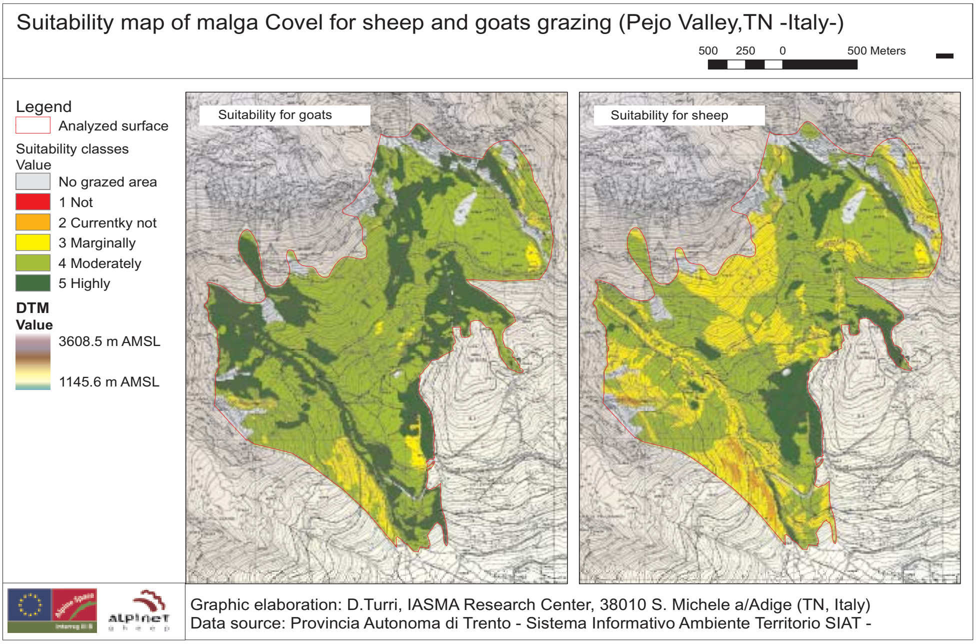

Figure 23: Suitability Map of malga Covel (Trentino, Italy)

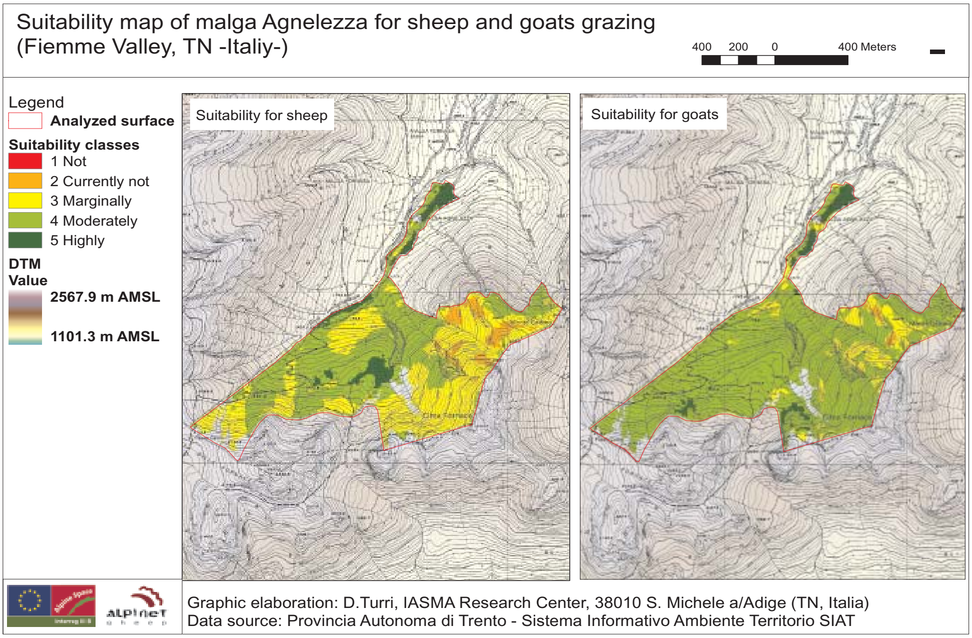

Figure 24: Suitability Map of malga Agnelezza (Trentino, Italy)

and sheep. As far as sheep are concerned, the model assigns 80% of the area scores of 3 and 4. Thus, the malga shows a sufficient suitability for sheep grazing as well, even though in general, this malga is more suitable for goats than sheep according to the model results.

3.2.4 Application of the Interdispersion Juxtoposition Index (IJI)

In order to compare the four study areas concerning suitability for goat grazing, a „structural fragmentation of pastures“ criterion (see chapter 2) was added to the model. Most of the zootechnic experts contacted

Table 31: Calculation of a synthetic indicator for water availability (malga Agnelezza)

Distance from water (m)	Pasture Agnelezza (ha)	Score (goat/sheep)	Weighed Values	Synthetic Indicator
0-500	85.64	5	428.20	
500-1000	15.53	3	46.59	
1000-1500	0.00	1	0.00	
>1500	0.00	0	0.00	
Total	101.17		474.79	4.69

Table 32: Synthetic index calculated for the studied malgas of Trentino

	Agnelezza	Covel	Juribello	Sadole	Agnelezza	Covel	Juribello	Sadole
indicator		goat				sheep		
Vegetation	2.67	3.15	3.56	3.93	2.31	2.80	3.41	2.50
Slope	4.44	4.52	4.21	3.93	3.44	3.50	4.52	3.52
Water	4.69	4.74	4.98	4.81	4.69	4.74	4.98	4.81
MEAN	3.94	4.14	4.25	4.23	3.48	3.68	4.30	3.61
IJI	0.81	0.85	0.67	0.83				
Total	3.19	3.51	2.85	3.51	3.48	3.68	4.30	3.61

agreed upon the preference of animals for non-homogeneous environments. To reach this aim, it is also necessary to find univocal and synthetic value of each parameter considered for every study area.
As synthetic value of each parameter (vegetation, slope and water availability), we used the weighed average of the suitability classes, using the area as weight. As fragmentation criterion we used the Interdispersion Juxtoposition Index (IJI) calculated on the entire surface of the pasture.

Table 31 shows an example calculation of the synthetic indicator for the distance from water of malga Agnelezza.

The synthetic indicator was then multiplied with the IJI (table 32). The final result is a unique coefficient for each study area that allows an indicative comparison of their suitability for grazing goats.

Although all the areas studied show good suitability values for sheep and goats, using the modality of comparison explained above, it turns out that the malgas Covel, Sadole and Agnelezza are more suited for goat grazing, while malga Juribello appears to be more suited for sheep grazing.

It should be noted that malga Agnelezza turns out to be less suitable for goats than malga Juribello, just considering the basic parameters, but after the application of the interdispersion index it turns out to be more suitable.

That reflects expert observation and the actual management of the studied areas. Thus it is clear that the use of this index is necessary for a more realistic analysis of pasture suitability for goats.

All these elements can supply administrators of the territory with useful information for pasture evaluation.

3.2.5 Implementation of the additional indicator „productivity“

Finally, for the Trentino study area an additional indicator was tested: Pasture productivity.

In table 33, the average forage production (DM) of the experimental areas is reported. Calculation of average values is not made for the structural type, but for more detailed vegetation types in order to have a lower data approximation error.

The production measured in field is the maximal one; it gives an important indication relative to the studied area. Unfortunately, the information about the biomass quantity used by the livestock is missing because the number of exclusion cages positioned tur-

Table 33: Average production in Trentino study areas

Structure	typology	Study area - Dry matter - q/ha Covel	Agnelezza	Sadole	Juribello
Rich pasture	*Nardion/Arrenatheretum* rich			24.49	
	Deschampsia rich pasture		18.37	20.58	
	Poietum	24.90			22.30
Rough pasture	*Carecetum* with *Carex nigra*				3.80
	Nardion	19.56			18.85
	Nardion/Arrenatheretum rough		14.26	14.38	
	Nardion/Vaccinietum		12.58	10.65	
	Seslerietum				10.36
	Festucaetum with *Festuca varia*	8.06			
Leaf bush (*Alnus* sp.)	*Alnetum*	21.00	14.61	25.50	
Tall herbs	*Rumexetum*		27.60	26.51	58.45
Tree pasture	Grazed wood	4.36	5.91	7.58	3.99
Dwarf shrubs	*Rhodoretum*	4.44	8.31	5.48	4.37
Wood	Conifer wood		4.19		

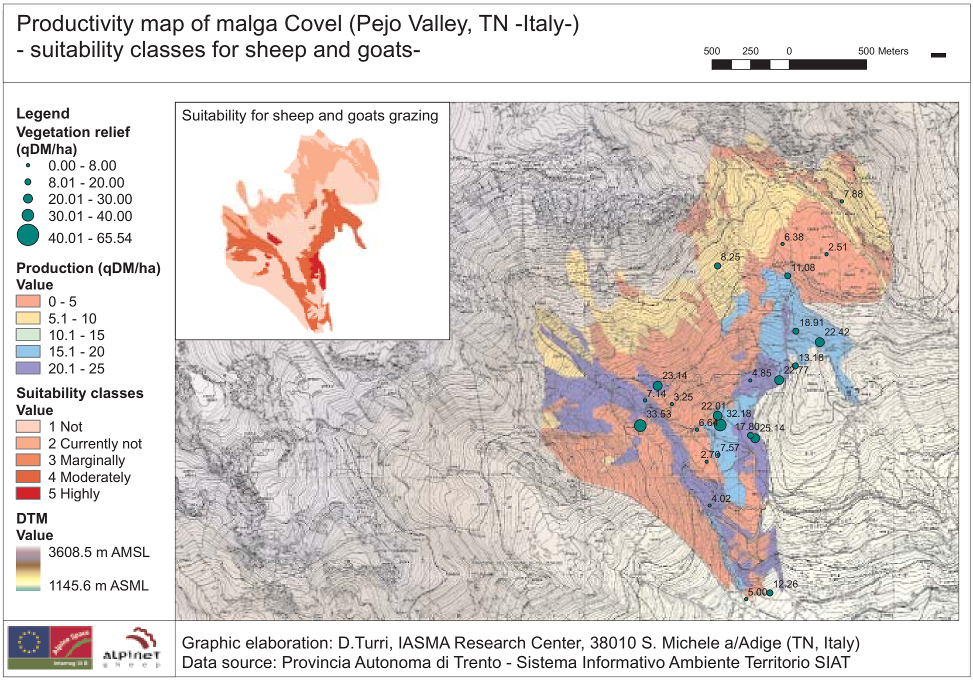

Figure 25: Map Production of malga Covel (TN-Italy)

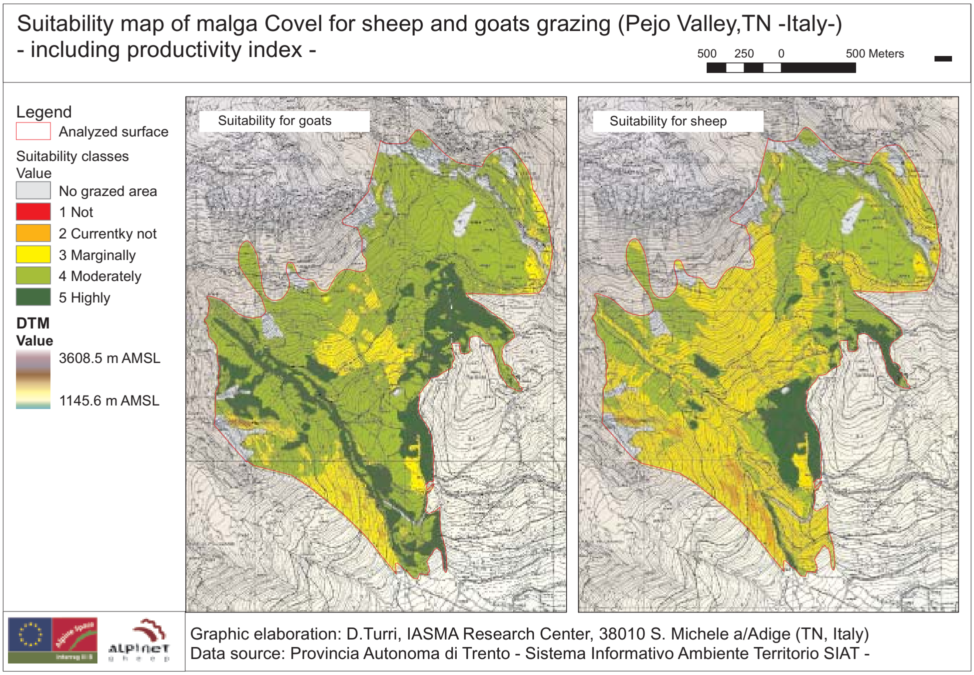

Figure 26: Suitability Map of malga Covel - application of production criteria - (TN-Italy)

ned out to be insufficient for statistical data elaboration. It is also necessary to develop, beyond production data, a forage quality analysis (energy MJ/kg DM). With regard to this, chemical analyses were done on some botanical samples, but even in this case the data set is not large enough for statistical work. So what is available is just an indicative value and for this reason, during the test trial, we have been assigning a lower weight (10%) to this indicator in comparison to the three basic criteria (30%).

Figure 25 shows an example of a production map with the relative suitability map. The low production found on tree pastures, wood and some types of rough pasture, led to insufficient suitability scores (class 1 and 2) for wide areas. In general, this would cause a decrease in the suitability scores (Figure 26) if only the criteria and values of the basic parameters had been taken into account. In spite of this, the four study areas still have a suitability that in general varies from sufficient to good.

3.3 Province of Belluno

3.3.1 Introduction

In the Province of Belluno, located in the North of the Veneto Region, sheep breeding based on forage feeding system contributes to the multi-functional approach, because it can provide benefits to the community. In this area, sheep breeding is also a significant component for revitalization of shepherding activities, for alpine and pre-alpine landscape conservation, to use pastures for grazing, for turf management, for hydrogeological stability, for a cautious use of environmental resources and for conservation of biodiversity. In the alpine area, this conceptual approach has the best chance of achieving a balance between technical-economic and landscape-nature aims.

In this study the Provincial Breeders' Association (APA) of Belluno defined some sheep rate indicators and set up management indicators by the analysis of eight study cases. The collected data can be useful to extend the analysis to the whole Province of Belluno.

In addition to the common methodology used by the project partners, the typology of the Veneto grazing areas method was adopted, as presented in „Essential features of the Veneto typology of grazing areas on and around the mountains“ (Ziliotto et al. 2004).

3.3.2 Description of the study cases

In the Province of Belluno 10 malghe, grouped in eight management units were studied, which are representative for the pastures grazed by sheep in the provincial area. The number and type of the malghe were chosen considering the location (alpine or pre-alpine), owner (public or private), substrate (carbonate or siliceous), position (quota, slope, accessibility) and management. Sheep grazing behaviour and performance were studied in the six management units where sheep are bred.

Two other cases were also considered: The management unit "Stia" grazed by dairy cows but progressively abandoned because of inadequate structures, and the management unit „Colmont“, where the highland meadows were mown but are not used now.

The alternative use of goats was theoretically taken into account at all the management units, but it is effectively feasible only in a few situations, because this kind of breeding is fairly limited in the Province at the moment.

Complete data and results concerning one management unit and main data of the remaining units are described below. The complete analysis of all eight management units, in particular the floristic and aspects of vegetation, are described on the CD-ROM. Table 34 gives a summary of the vegetation structures.

Malga unit Doana study case

Description of the malga

The malga is situated in the Cadore and covers an area of great interest to scientists, particularly because of the migratory bird species present there. The grazing area mainly lies around Col Rosolo and towards Cima Campo Rosso and Monte Verna. The malga building is located in the central part of the grazing area, just above 1,900 metres.

Vegetation

The two biotope types with the largest area are rough pastures on acidic soil, which account for almost 31.9% and rich pastures with 14.8% (table 36). In both parts there are also clusters of *Deschampsia caespitosa* present on almost 10% of the surface. The rough pastures mainly consist of *Nardus stricta* subalpine grasslands, both in a typical shape and as a rich subtype, characterized by the presence of species with already a higher fodder value. There are also fine species-rich *Nardus* grasslands between Col Rosolo and the Landro Pass, with a range of species such as *Arnica montana, Campanula barbata, Dianthus barbatus, Scorzonera rosea, Geum montanum, Gymnadenia conopsea, Pseudorchis albida, Hypochoeris uniflora* and *Phyteuma zahlbruckneri*. Here the turf is often damaged by wild boars. Some parts are characterized by *Festuca paniculata*, a robust grass, which benefits from under-use and *Festuca violacea*. Small parts of the rough pastures show special communities of *Sesleria caerulea* and *Carex sempervirens* with *Helianthemum grandiflorum, Gymnadenia conopsea, Phyteuma orbiculare, Ranunculus hybridus, Bartsia alpina, Biscutella laevigata, Gymnadenia odoratissima, Erica carnea, Betonica jacquinii, Hedysarum hedysaroides.*

Table 34: Vegetation structures for the other management units studied

Unit	Drottelle Chiastellin		Guslon		Fedaia		Colmont		Stia		Pian dei Fioc		Lebi, Valpore,Solarolo	
Vegetation structures	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Rich pasture			20.05	6.6	54.53	12.4	37.47	24.6	2.13	1.6	4.94	1.4	38.56	16.1
Rough pasture	176.81	52.8	80.47	26.7	304.51	69.3	53.04	34.8	66.93	51.0	306.45	86.4	105.75	44.3
Tree pasture	3.63	1.1	11.00	3.6	20.78	4.7	0.14	0.1	5.43	4.1			4.83	2.0
Tall herbs	11.90	3.6	3.71	1.2	5.17	1.2			1.35	1.0	5.86	1.7	6.03	2.5
Dwarf shrubs	97.29	29.1	83.53	27.7	4.90	1.1					5.42	1.5	15.36	6.4
Leaves shrubs			8.84	2.9									2.99	1.3
Shrubs of *Alnus viridis*	3.64	1.1			21.69	4.9			24.72	18.8				
Coniferous shrubs	1.99	0.6	52.52	17.4	9.23	2.1	4.46	2.9	6.36	4.8	6.00	1.7		
Forest	11.04	3.3	8.27	2.7	11.39	2.6	12.20	8.0	8.67	6.6	4.37	1.2	62.46	26.2
Non grazed area	28.45	8.5	33.26	11	7.41	1.7	44.91	29.5	15.66	11.9	21.77	6.1	2.85	1.2
Total	334.75	100.0	301.66	100.0	439.61	100.0	152.22	100.0	131.25	100.0	354.8	100.0	238.8	100.0

Figure 27: Malga Doana

Table 35: Descriptive features of the Doana grazing area

Name	Malga Doana
Location	Municipality of Vigo di Cadore
Owner	Municipal Council of Domegge di Cadore
Surface studied	150 ha ca.
Altitude	1,800 - 2,140 m a.s.l.
Phytoclimatic district	Mesalpic
Main exposure	South
Substratum	Carbonatic-terrigenous
Grazing animals	Sheep and horses
Livestock management	Guided grazing
Structures	Dairy hut and large shed

Table 36: Malga Doana - Categories of grazing areas

Category	Area (ha)	Area (%)
Rich pasture and grassland	22.20	14.8
Rough pasture and meso-microthermal grassland with neutral or alcaline soil	5.29	3.5
Rough pasture on acidic soil	47.86	31.9
Hygrophilous and marsh coenosis, cane-brake and peat bogs	0.03	0.0
Peat bogs and springs	0.19	0.1
Shrub and prenemoral vegetation replacing the pasture	8.48	5.7
Boulders, detritus and rocky environments	0.30	0.2
Reforestation	55.47	37.0
Woodland	6.51	4.3
Non-grazing area	0.95	0.6
Total	149.97	100.0

With regard to rich pastures, the most favourable situations are characterized by alpine meadow-grass (*Poa alpina*), together with *Phleum alpinum, Festuca nigrescens, Crepis aurea, Carum carvi, Taraxacum officinale, Rumex acetosa, Agrostis tenuis, Ranunculus acris, Polygonum viviparum, Trifolium pratense, Veronica chamaedrys*.

Nitrophile areas are mainly concentrated on the peaks, the crests and the saddles. These parts are either dominated by dock (*Rumex* sp.) or by *Urtica dioica* and *Chenopodium bonus-henricus*. This part was a grazing area with *Festuca paniculata*; the continued presence of the sheep has transformed it into a nitrophile area.

Table 37: Vegetation structural types

Vegetation structures	ha	%	Main type of grazing land
Rich pasture	22.20	14.8	Community of alpine meadow-grass (*Poa alpina*); Knautio-trifolietum; semi-rich, subacid *Chaerophyllum* pasture; fescue grasses; overproductive, with *Poa trivialis*
Rough pasture	47.38	31.6	*Nardus stricta* subalpine grasslands; community of *Festuca paniculata*; community of *Festuca violacea* gr.; community of *Sesleria caerulea* and *Carex sempervirens*; variations with *Avenula pubescens*; plant communities of springs
Tree pasture	15.10	10.1	Sparse neoformations of *Larix decidua* and *Picea abies*
Tall herbs	8.68	5.8	Dock; nettles; degraded nitrophile areas; large sedge bush area with *Carex paniculata*; cluster of *Deschampsia*
Dwarf shrubs	8.48	5.7	Community of Alpenrose (*Rhododendron ferrugineum*)
Coniferous shrubs	37.08	24.7	Dense neoformations of *Larix decidua* and *Picea abies* recolonizing the grazing areas
Forest	9.80	6.5	Larch trees
Non grazing area	1.25	0.8	Malga facilities; coenosis of the carbonatic detritus
Total	149.97	100.0	

Other areas like these are common in front of the Malga Doana with a large area of dock. Also near the malga, in a little deep valley on the west side, a range of nitrophile plants can be found growing alongside each other forming a mosaic (Nettles, Cicely and *Geranium*). Examples of excessive manuring are the areas with meadow fescue and tufted hairgrass and the over-productive pasture with *Poa trivialis*. For the shrubs, most common is *Rhododendron ferrugineum*, which is mainly found on Col Rosolo.

In regard to the original vegetation of the grazing area, also vast areas of larch (reforestation) are present together with secondary high-mountain populations of spruce.

Water supply

There is a good water supply. The springs situated in the area around the malga and a water catchment area guarantee the water supply throughout the grazing area for the entire season.

Table 38: Description of the water supply

Water distance (Km)	Suitability classes	Surface (ha)
0.0 - 0.5	5	96.63
0.5 - 1.0	3	53.34
1.0 - 1.5	1	
> 1.5	0	

Morphological characteristics

Gentle morphology and moderate mountainside inclinations offer a wide range of management possibilities and do not constitute a limiting factor for the grazing suitability of the area.

Accessibility

The Malga Doana buildings and the grazing areas which belong to it can be reached by following a forest road with authorized off-road vehicles.

Estimation of sheep stocking rate for the eight study cases

The methodology based on the 3 main criteria (land cover, water availability and slope) for the evaluation of pasture suitability was applied to the 8 study cases. Furthermore, a practical application was obtained by the estimation of the sheep stocking rate.

In order to give a useful tool to the breeders, starting from one-dimensional data describing the pasture suitability classes, stocking rate indicators were applied to obtain the pasture suitability as number of heads.

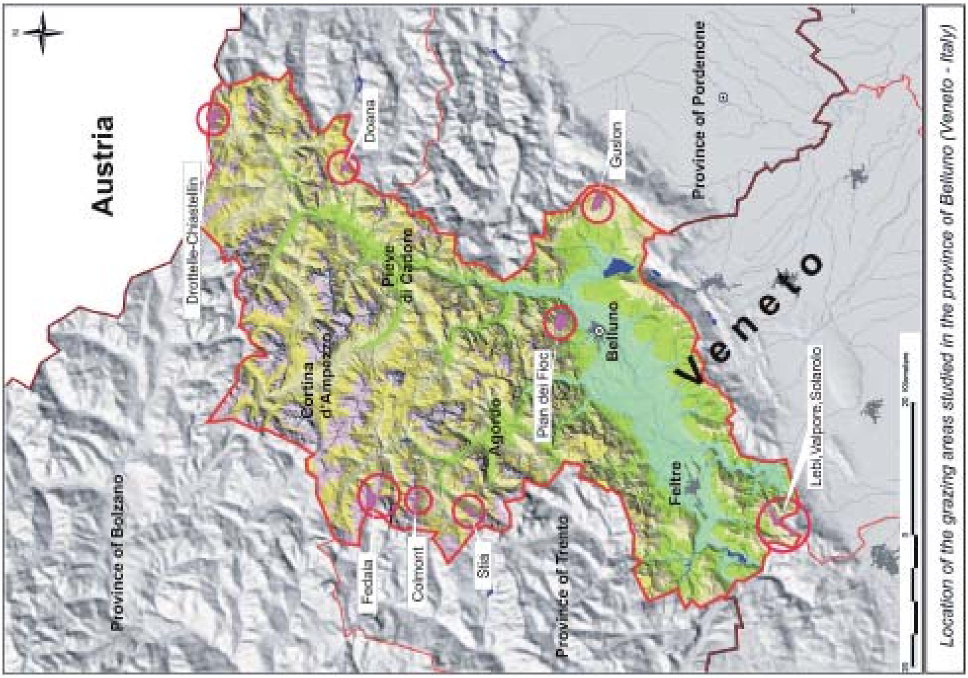

Figure 28: Location of the grazing areas studied in the Province of Belluno (Veneto - Italy)

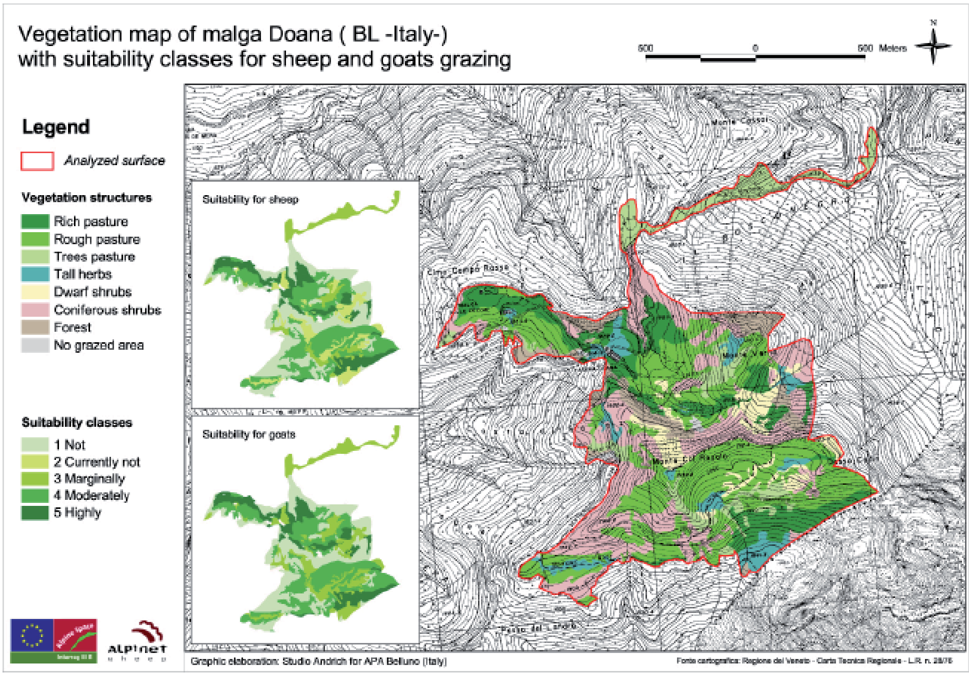

Figure 29: Vegetation map of malga Doana (Belluno - Italy) with suitability classes for sheep and goats grazing

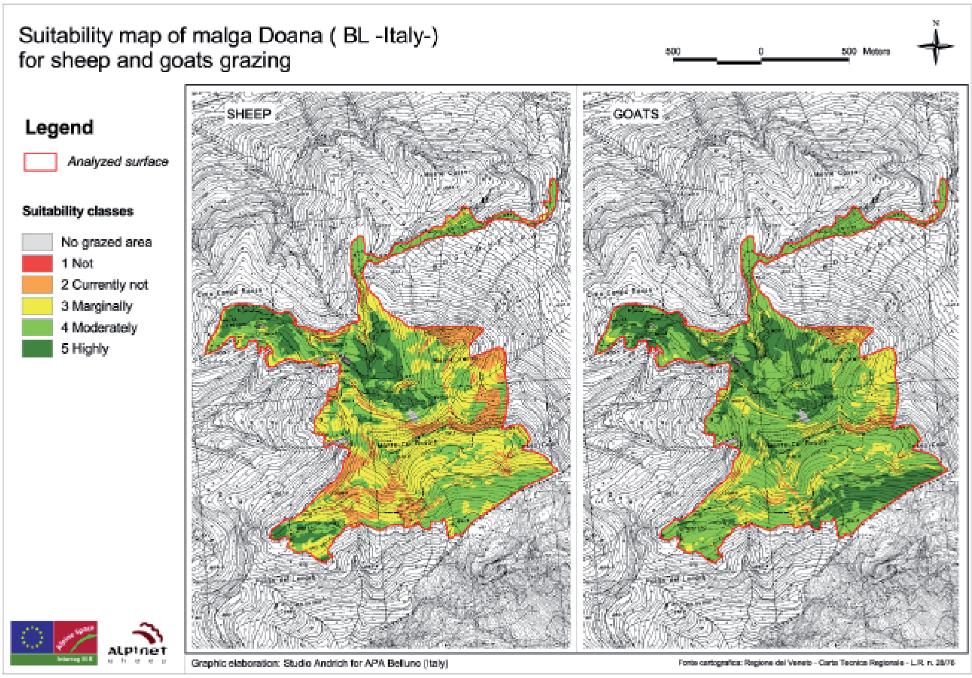

Figure 30: Suitability map of malga Doana (Belluno -Italy) for sheep and goats grazing

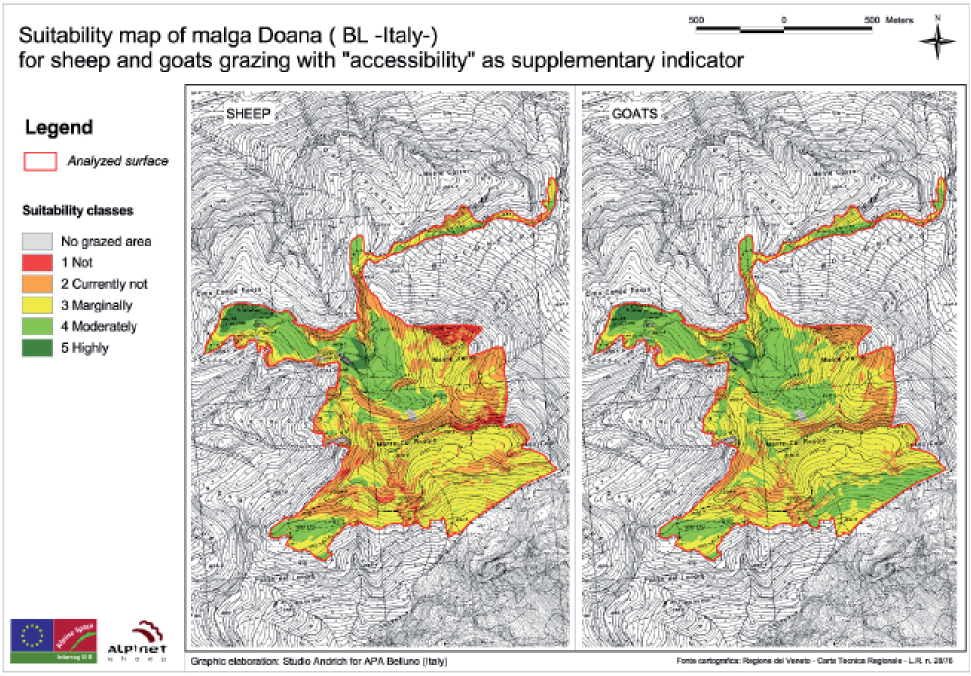

Figure 31: Suitability map of malga Doana (Belluno - Italy) for sheep and goats grazing with accessibility as supplementary indicator

Table 39: Description of the slope characteristics

Inclination(sheep)	Suitability class	Surface (ha)	Inclination(goats)	Suitability class	Surface (ha)
0° - 20°	5	40.10	0° - 20°	4	40.10
21° - 45°	3	91.34	21° - 40°	5	91.34
> 45°	1	18.53	41° - 50°	3	16.32
			50° - 60°	2	2.10
			> 60°	1	0.12

Table 40: Description of the accessibility characteristics

Means of access	Quality judgement	Suitability class	Surface (ha)
Asphalt or mountain road, accessible by car	Good	5	5.02
Mountain/cartway, accessible by land rover	Medium	3	38.98
No road, accessible on foot	Poor	1	105.97

Table 41: Indicators of sheep stocking rate according to Andrich (2007)

Suitability class	Indicators of sheep load/ha
5	8.4
4	6.6
3	5.1
2	3.4
1	1.4

The forage productivity under different ecologic conditions was used to identify the indicators, which requires a comparison between the data on vegetation types and field assessment.

Each suitability class obtained using the three basic criteria was compared with the areas defined according to the methodology of Ziliotto et al. (2004).

This study allowed to measure the average production of 160 different vegetation typologies and to relate them with the optimal (e.g. without causing damage to the quality of the vegetation) number of grazing sheep.

For each suitability class an average sheep stocking rate indicator was calculated after proper checks and arrangements.

Table 42: Area and sheep stocking rate on different pastures

		Suitability class						
Pasture	Parameter	0	1	2	3	4	5	Total
Malga Doana	Sheep (n)		7	152	339	191	32	721
	Area (ha)	1.25	4.66	44.8	66.55	28.95	3.79	150
Malga Drottelle-Chiastellin	Sheep (n)		1	308	1023	93		1426
	Area (ha)	28.45	0.94	90.7	200.6	14.05		335
Guslon	Sheep (n)		135	557	44			735
	Area (ha)	33.26	96	164	8.58			302
Fedaia	Sheep (n)		1	554	642	460	611	2269
	Area (ha)	7.41	0.84	163	125.9	69.68	72.8	440
Colmont	Sheep (n)		6	96	365	19		486
	Area (ha)	44.91	4.6	28.3	71.61	2.83		152
Malga Stia	Sheep (n)		20	145	194	132	5	497
	Area (ha)	15.66	14.2	42.7	38.07	20.02	0.63	131
Malga Pian dei Fioc	Sheep (n)		6	354	1114	40		1515
	Area (ha)	21.77	4.29	104	218.5	6.07		355
Lebi. Valpore and Solarolo	Sheep (n)		6	236	762	85		1089
	Area (ha)	2.85	4.42	69.3	149.4	12.85		239
Total	Sheep (n)		182	2403	4484	1020	648	8737
	Area (ha)	156	130	707	879	154	77	2103

The number of sheep was obtained multiplying the stocking rate indicator by the suitability classes' areas.

This approach provides acceptable and quick results even if an analytical approach was needed to obtain more detailed results. The analysis requires a long period of observation and validation (over a few years) about animal performance and their effects on turf.

3.4 District Liezen

3.4.1 Study area

Location

The Schladminger Tauern study area is situated in the Southwestern part of the district of Liezen (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 Schladminger Tauern (Western part). In this area (from East to West) the Sölk valley, the Untertal, the Obertal and the Preunegg Valley are found. The alpine pastures in the Northern area of the Enns Valley belong to the fringe of the Dachstein Plateau.

Figure 32 shows the study area and its relief by means of a Spot satellite image. The grey border polygons depict the regional borders of the studied valleys. Due to the resolution, the area shown in the following depictions is reduced to the scope of the green box. In this way the maps approach the visual possibilities of humans.

Geology

The bedrock South of the Enns varies according to the geological map of Styria (scale 1:200,000, Geologische Bundesanstalt 1984) between phyllitic mica-schist (Wölz mica-schist complex) and areas containing paragneiss. The Northern areas tectonically lie on the fringe of the Northern Limestone Alps; the Southern areas in the greywacke zone or already within the area of bare silicious bedrock (also compare Schmiderer 2002). South of the Enns there are also carbon-rich hornblende granite or seams of marble (Teppner 1975 and Schmiderer 2002).

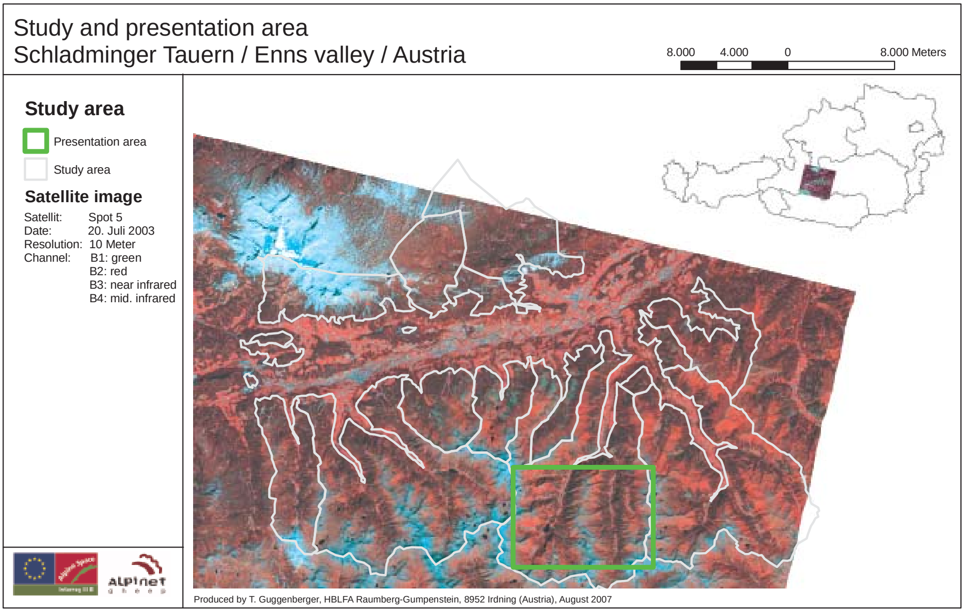

Figure 32: Study area and depiction area

Geomorphology

The study area is characterised by precipitous, strikingly high-alpine forms of terrain, mostly with cliff formations. This high relief energy can be seen in figure 32. The area of the Niederen Tauern is known for frequently changing geological circumstances, which reflect in varying forms of terrain and an increase of species diversity (compare Teppner 1975 or Schmiderer 2002). The pastures in the study area are situated at altitudes between 1,200 and 2,200 metres. They are in the South, and are part of the North-South-oriented side valleys of the Enns and thus the predominant share is exposed either to the North or to the West. Southern expositions also appear North of the Enns at the foot of the Dachstein Plateau. All of the pastures have flat parts; the steepest areas reach an inclination of up to 60 degrees. A (theoretic) average inclination for all of the pastures lies between 20 and 30 degrees.

Climate

As it is typical for this part of Austria, main weather influences generally come from the Northwest to West. Generally an inter-alpine transitional climate is found. 1,500 to 1,700 mm of precipitation can be estimated for an altitude zone at 2,000 metres. Due to the location in the rain shadow of the Northern Limestone Alps, these figures are somewhat lower than those otherwise being usual for this altitude zone. This is a mountainous climate with severely decreasing gradients especially in the six months of summer. The following figures are given for an altitude of 2,000 metres: January -7°C, July 8°C, yearly average 0°C to 1°C. The number of frost days amounts to 200-220 and there are 110 ice days/year. Additionally worth mentioning are influences of warm winds from the south. Contrary to the zones of the side valleys, due to low-lying clouds the climatic conditions in the higher zones also include a great deal of mist (at 2,000 m about 180 days/year, at 2,500 m 230 days/year) (LUIS - Landes-Umwelt-Informationssystem of Styria).

Land cover

There are 108 pastures with a total area of 246 km² in the area. They could not completely be surveyed during the botanical investigations. However, a representative selection from the entire study area was recorded.

These pastures (from East to West) are: the Mesneralm, Planneralm, Riesneralm, Gstemmerscharte, Hintere Mörschbachalm, Zachenschoberl, Starzenalm, Kaltenbachalm, Mautneralm, Hohenseealm, Schwarzensee, Schimpelsee, Preintalerhütte, Brandalm, Neualm, Kerschbaumeralm, Neualm, Planai, Giglachalm, Rinderfeld and Hochfeld.

The vegetation on the pastures closer to the Enns is mostly dominated by the local silicate flora. The pastures generally lie in the area of the subalpine pine forest, nevertheless with a markedly high share of larch (*Larix decidua*) in some parts, which could be a sign for re-forestation. One finds significant shares of green alder (*Alnus viridis*) and dwarf pine (*Pinus mugo*) on water-bearing slopes and avalanche stretches within the treeline. Vegetation above the forest line comprises rich alpine pastures, mat grass grasslands and heather communities with blueberry (*Vaccinium myrtillus*), cranberry (*Vaccinium vitis-idea*) and rusty-leaved Alpenrose (*Rhododendron ferrugineum*). High-mountain grasslands appear in higher zones, mostly with curved sedge (*Carex curvula*) or the wood small-reed subspecies (*Calamgrostis villosa*). These plant communities are simply summarised and depicted as rich pastures, rough pastures, dwarf-shrub heathland and forests in the land-cover map.

The knowledge gained from the 21 closely inspected pastures builds up the basis of monitored classification in the remote-sensing process.

These results can be seen in figure 33. The yield-forming classes were not evenly distributed. Rich pastures comprise only 2.3% of the productive area, rough pastures 52.2%, and dwarf-shrub heathland 45.5%.

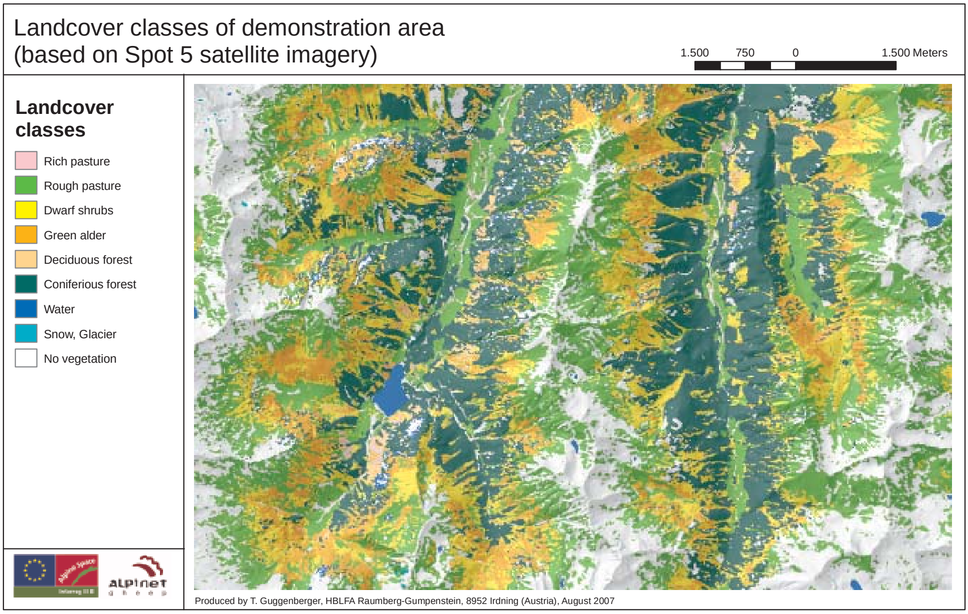

Figure 33: Classes of ground cover

3.4.2 Alpine-pasture farming

Pasture areas are created and kept open through many years of continuous farming. The pastures incorporate a broad spectrum of different kinds and intensities of usage. About 3,700 large animal units (LAU) are annually driven up to the study area. The dominant animal species is cattle and represent a share of 85%. Then follow sheep at about 11%, goats are practically insignificant. The remaining 4% can be allocated to horses. The relationship of pasture area to animal stocks can be given in the LAU/ha coefficient. On average this amounts to 0.88 LAU/ha, enormous variance is nevertheless to be observed (0.4 standard deviation). Together with agricultural use, tourism plays an important role in the case of some of these pastures, in summer as hiking areas, but also as skiing areas above all in winter. Hunting, which requires the maintenance of an open landscape, is a subsidiary use of the pasture areas.

3.4.3 Results

One of the final results of the project is the qualitative assessment of individual spatial entities. In a scale from 0-5 (5.5) points, the assessment factors, which reflect the needs of the animals, have an alternating effect. But overall it can be assumed that high points guarantee the best conditions, while increasingly poor conditions are evident in the medium- and lower sectors. Assessment can also parallel run to the needs of the animal species. Cattle, above all diary cows, have high demands, sheep and goats have medium demands. Wild animals can also survive in an extensive area. The following limits are set for these three animal species, which are now described as usage classes.

- High: cattle including diary cows, more than 4.25 points
- Medium: sheep and goats, between 3.25 and 4.25 points
- Low: wild animals, less than 3.25 points

The original land-cover classes are to be found in differing shares in the usage classes. The „High“ usage class is formed to 15.6% of rich pastures, to 83.3% of rough pastures and to 1.1% of dwarf-shrubs. The „Medium“ usage class comprises 2.3% of rich pastures, 63.5% of rough pastures and 34.2% of dwarf-shrubs. The „Low“ usage class comprises 37.7% of rough pastures and 63.3% of dwarf-shrubs.

Forage yield (dry matter)

The productivity of the original classes of rich pasture, rough pastures and dwarf-shrub heathland were presented in chapter 2.3.3. Determined by the length of the vegetation period at different altitudes, zones and the dominating land-cover classes, a wide spectrum of variation of the areas is given, which ranges from almost 0 to about 3,700 kg/ha. An average yield of 1,860 kg (+/- 821) is achieved in the „High“ usage class, 1,010 kg (+/- 580 kg) in the „Medium“ class, and 820 kg (+/- 280) per hectare in the „Low“ range. The reference material of the „Höhenprofil Johnsbach“ shows that a yield of 1,840 kg is achieved in a comparable average altitude zone with „High“ suitability of usage, and 1,180 kg DM for „Medium“ suitability of usage (Gruber et al. 1998) for a similar classification of usage. The scientific knowledge could also comparatively well be put into practice.

Energy concentration

Similar to the forage yield, the energy content of the plants in the plant community is also bound to their preferred altitudinal zone. The energy content of plants at an ideal grazing time amounts to 9.9 MJ ME/kg DM for the „High“ usage type, 9.1 MJ ME/kg DM for the „Medium“ usage type and 8.4 MJ/kg DM for the „Low“ usage type. The optimum grazing time on pastures is reached when the animal stocks are well-adapted to the size of the area. If animal stock is insufficient, the average forage quality will decrease and a reduction of energy content will be necessary. The amount of decrease can be defined by LAU/ha of animal stocks. In relation to the PEM, a maximum reduction of 1.6 MJ ME is practical. Reductions are linearly undertaken from a stock of 1 LAU/ha. In consideration of these aspects, the following energy contents are achieved: „High“ 9.0 MJ ME/kg DM, „Medium“ 7.8 MJ ME/kg DM and „Low“ 7.0 MJ ME/kg DM. The range matches the analysis results from 701 forage samples in the „Forage Index Table for Basic Ration in the Alps“ (Resch et al. 2006).

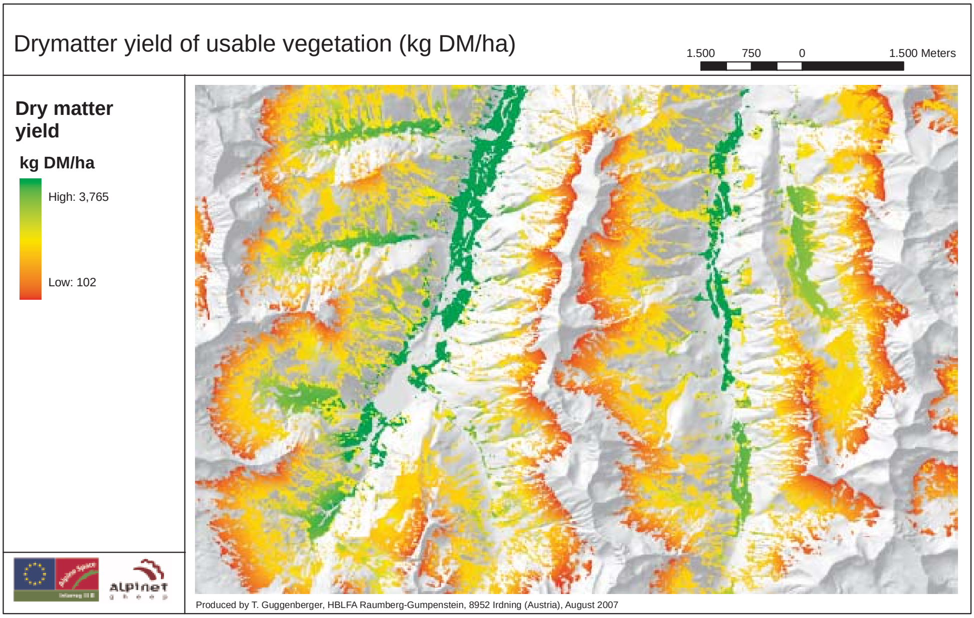

Figure 34: Local forage yield

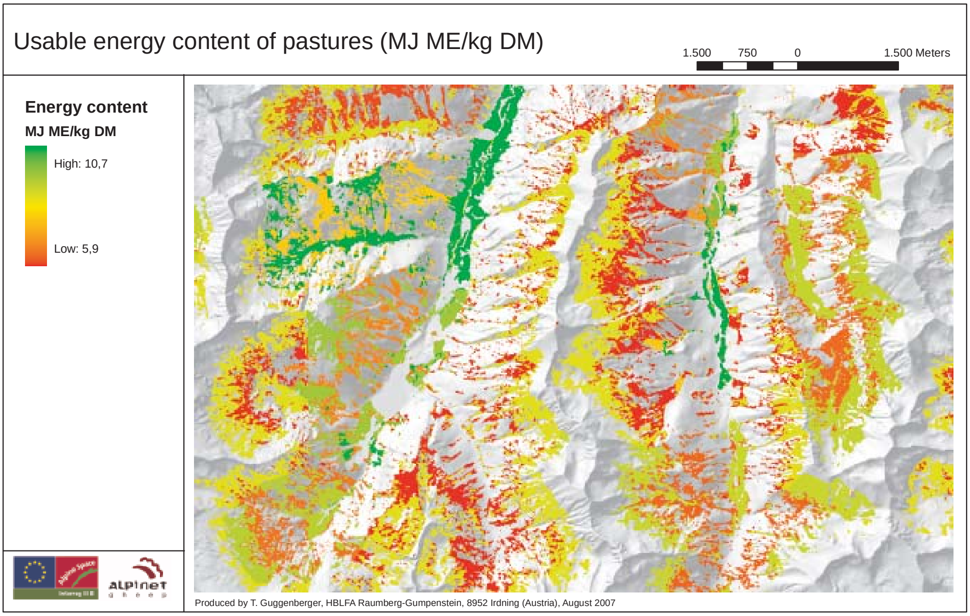

Figure 35: Local energy concentration

Quality

Following the implementation of the quality check in the examination region, a perfectly normal curve of distribution shows its turning point at 2.72 points in intervals of 0-5.5. In the „High“ usage types (intervals 4.25-5.5), an average value of 4.5 (+/- 0.25) points is achieved, 3.6 (+/- 0.27) points in the „Medium“ usage type (intervals 3.25-4.25), and 2.4 (+/- 0.6) points in the „Low“ usage type

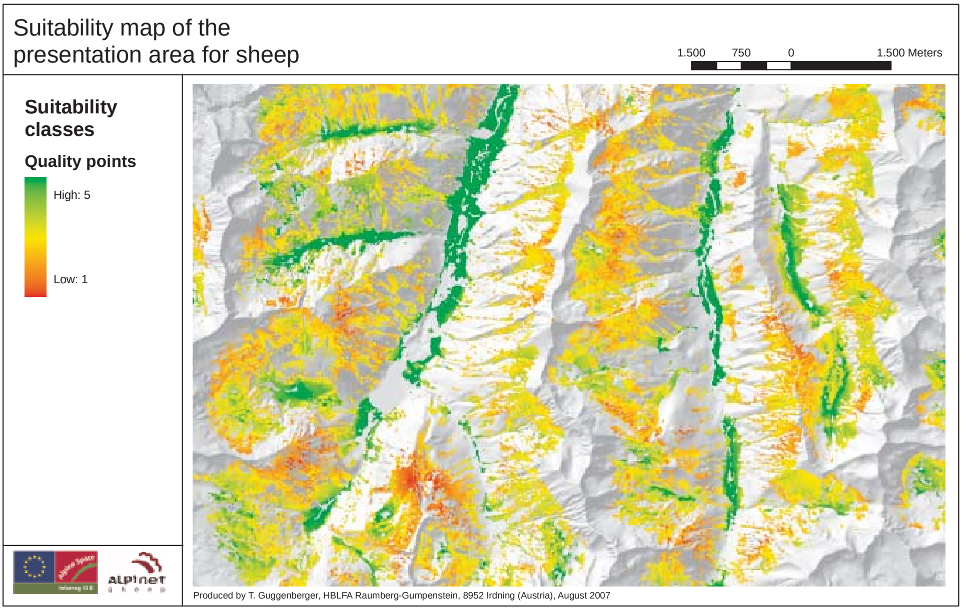

Figure 36: Quality of alpine pastures (sheep)

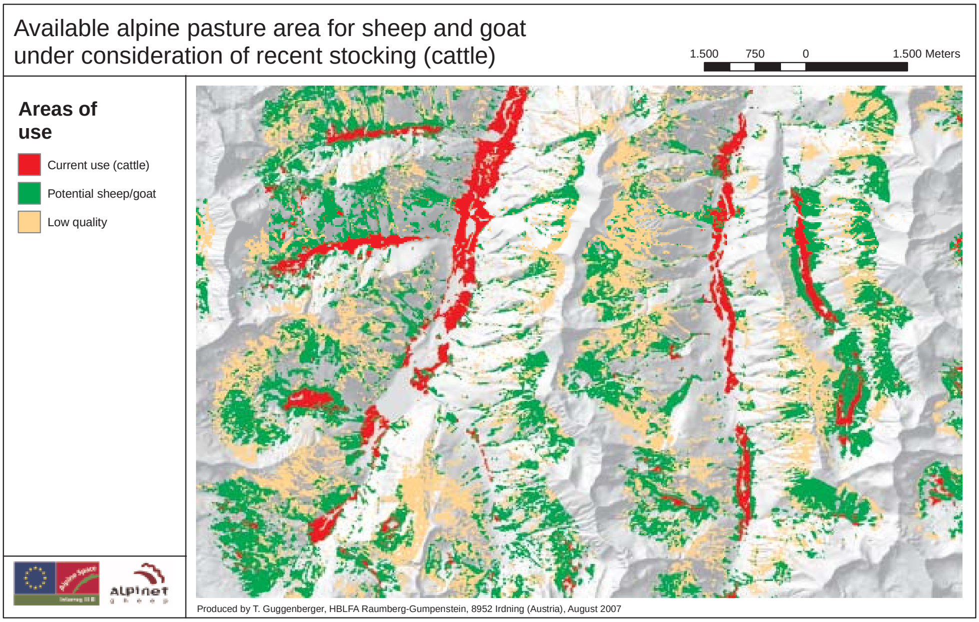

Figure 37: Current use and future potential

(intervals 0-3.25). In all, 7.9% are shown to be highly suitable, 42.1% are of medium suitability and 50% of low suitability as alpine pasture for domestic animals.

Energy requirement of grazing animals

An estimation as a basis for planning has to take into account the current usage of the pastures. There are hardly any milk-animal pastures in the region of the Schladminger Tauern, thus nutrition for cows is only set according to keeping needs. For diary cows with a live weight of 650 kg, for example, there is a need of 62 MJ ME per day, from 13 MJ ME for sheep. The enormous energy volume of total 29 400 GJ/ME is used within the whole study area, 87% of which are consumed by cattle. For the determination of potential areas, those which have already been used in respect of the quality assessment should be excluded for the respective animals. These are shown in red in the following illustration.

The remaining potential after substraction of the current energy requirements is divided into two parts - regions suitable concerning quality for sheep and goats, and regions for wild animals.

Extended planning case

The forest line in the Alps is naturally determined by a thermal border, above which germination of seeds of woodland species is not possible anymore. Additional anthropogenic influences define the local position. Climatic warming and the moderate intensive grazing offer optimum possibilities in the future for the upward expansion of the forest. Schaumberger et al. (2006) have calculated a rise of the forest line from 1,970 m to 2,415 m by 2050 for the Schladminger Tauern region. If no significant management measures are undertaken, we will loose almost the entire open grassland region above the current forest line. This can permanently and naturally be realised through the regular, monitored grazing by larger flocks of sheep and herds of goats.

For the area of the Kleinsölk Valley, this planning process has been started: For manu-

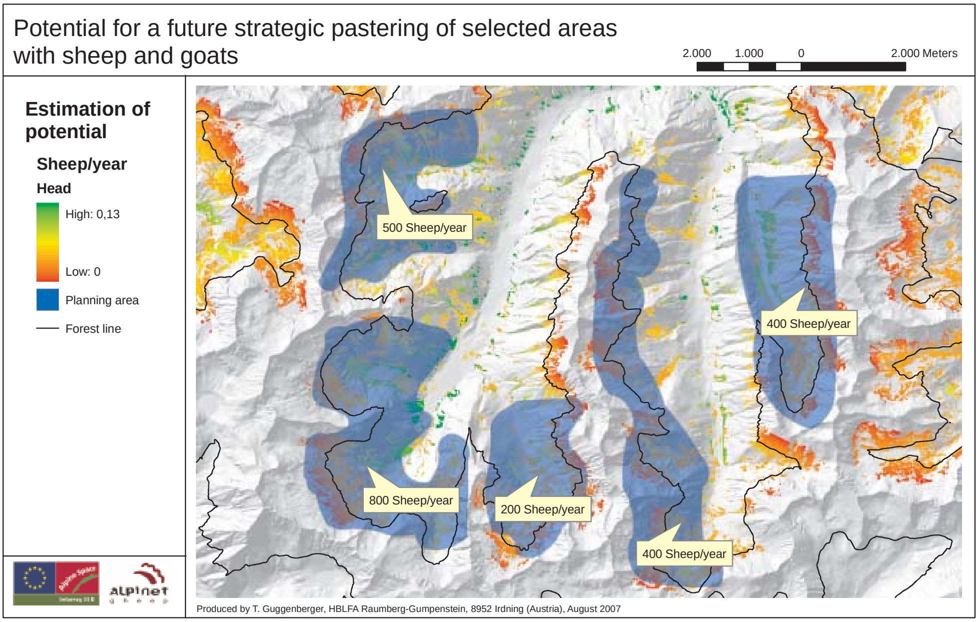

Figure 38: Number of additional sheep in the regions

ally selected pasture zones the potential, the possible number of sheep has already 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. Thus with sustainable methods, humans can counteract the climatic change in pasture regions, insofar qualitatively suitable forage is available and the supply of water is ensured for grazing with sheep and goats. The basis for planning the realisation was created within this project, the management methods must locally be developed.

4. ENEALP 1.0 Beta Planning software for the grazing of alpine regions

4.1 Introduction

Implementation of the discussed models is complex and intensive work. Differing parameter settings, moreover, lead to results that cannot be compared. The focus of the INTERREG IIIB ALPINET Gheep project is drawing up of practical approaches that can be used in the entire region of the Alps. These factors led to the decision to depict the entire working model in a cohesive software package. ENEALP deals with the analysis of flows of energetic material on alpine pastures (ENE = energy, ALP = alpine). The aim is to provide information on additionally useable capacities in existing pasture regions.

As a planning tool, for example, ENEALP calculates the number of animals that can be driven up to the pasture in addition to already existing farming. Enormous additional potentials are very often calculated that can hardly be covered in current practice. But in connection with rising forest lines, grazing offers the only effective protection of the biodiversity of these pastures. ENEALP is free of charge available as a Beta version with a reduced level of data resolution (minimum pixel size: 50 metres; maximum number of pixels: 10,000). No liability is assumed for all and whatever forms of demands of and for the program, as well as the local correctness of the calculations. Some calculations require some investment of time.

4.2 Technical prerequisites

ENEALP was implemented in C# based on the .NET framework, which has to be installed on your computer in version 2.0. If this is not already the case, it can free of charge be downloaded from the Internet and be installed. In its GIS analyses, ENEALP is based on the classes of the Arc Objects tool package from ESRI. The functionality of the grid analysis and the overlay techniques are taken from there. Therefore, ENEALP is not able to work without the GIS-Suite ArcMap. Moreover, in combination with the installation of ArcMap it is recommended to install the ESRI .NET classes. ArcMap version 9.1 is currently supported.

- Sources: ArcMap: www.esri.com
- .NET: www.microsoft.com/download (Select the Redistributable Package (x86))

4.3 Installation

The latest version of ENEALP can be acquired from the HBLFA Raumberg-Gumpenstein (www.raumberg-gumpenstein.at) service webpage. A zip file of about 3 MB can be downloaded via the Service - Download - Software menu sequence. After decompressing with the standard WinZip program, you will receive the two folders „Software“ and „TestData“. The „Software“ folder contains the setup.msi and setup.exe files. You can start the installation with both. There is a series of files in the “TestData” folder that have been used for illustrations found in this book. The ENEALP functionality can directly be tried with the test data. To run the application, please start the file ENEALP.exe from the folder you have created during the installation.

4.4 Necessary datasets

ENEALP uses a series of standardised input data and reads the necessary values for analysis. For this data formats, structures and types are accessed that cannot be given without selection. Moreover, the user must take the highest care in structuring the data. The following basic rules are mandatory. All geo-datasets must be defined in the same geographical system of coordinates.

The spatial extent of the grid data (digital elevation model, land-cover class, precipitation) must be identical. At the same time the entire vector data range (alpine pastures, outer limits, rivers and lakes) is to be covered. All grid data must be in the same pixel resolution.

The name of the standard data field of the grid data are read as value. The datasets of the terrain model and the precipitation per year, or during the vegetation period, are available as floating point grids, the land-cover classes as a signed integer. The terrain model and the land-cover data must individually and locally be created by the user. The precveg and precyear precipitation datasets were taken from the freely available data in the ALP-IMP project (http://www.zamg.ac.at/ALP-IMP/). The basic data for local interpolation can be taken from the Time Services Gallery section.

The vector dataset is available as a point object and can also incorporate springs or other non-linear waters. Alpine lakes are generally small enough to be depicted by a representative point. Rivers are linear waters, a topological network is not necessary.

Pasture borders are given as a polygonal dataset that depicts the legal borders of the alpine pastures. The following fields (data types) must be available.

- FID (Object ID) allocated
- Shape (Polygonal)
- ID (Long)
- Type (Short) : 1 = core pastures, 2 = total pastures
- Shape_Area (Double): area
- Name (String)
  FID and ID can contain the same data

Regional borders are given as a polygonal dataset of the large alpine areas (valleys…).

The following fields (data types) must be available.

- FID (Object ID) allocated
- Shape (Polygonal)
- GRIDCODE (Long)
  FID and GRIDCODE can contain the same data

4.5 Resulting data

All results of the GIS analysis are filed in the gisdata subdirectory of the installation directory. These data is preferentially given in the ESRI grid format and can directly be used for further analysis. All numerical calculations related to the pastures and vicinity objects are in the MS-Access database/databases/BasicParameter.mdb in the installation directory.

Description of selected grid datasets (see table 43)

The structure of the Pastures and Outside tables contains a series of data fields, which describe the data input as well as the numerical results. Some fields are described in table 44.

4.6 Program description

4.6.1 System settings

1. Program interface: The basic element of the program is a row of tabs that should gradually be worked through from left to

Table 43: Results of the grid datasets

Name	Description
yieldres	Result of the estimation of dry matter yield (dt/ha)
enenet	Result of the energy estimation (MJ ME/kg DM)
energypixel	Energy yield/pixels (MJ ME)
quality	Quality assessment (Notes 1-5)
outintensi	Additional possible capacities (grazing animals/year) in the high quality share in the regional analysis
outextensi	Additional possible capacities (grazing animals/year) in the medium quality share in the regional analysis
outused	Percentage of the currently used grazing potential (%) of the region
pasintensi	Additional possible capacities (grazing animals/year) in the intensive quality share on individual pastures
pasextensi	Additional possible capacities (grazing animals/year) in the extensive quality share on individual pastures
pasused	Percentage of the currently used grazing potential (%) of an individual pasture

Table 44: Results in the database

Fieldname	Description
TotalEnergy	Total energy requirement/day
TotalEnergyYear	Total energy requirement/grazing period
EnergyYieldSumYearIntensiv	Energy yield of the pasture in the intensive quality class (MJ)
EnergyYieldSumYearIntensiv	Energy yield of the pasture in the extensive quality class (MJ)
EnergyPotentialIntensiv	Free energy volumes in the intensive quality class (MJ)
EnergyPotentialExtensiv	Free energy volumes in the extensive quality class (MJ)
EnergyPastUnitIntensiv	Additional possible capacities (grazing animals/year) in the intensive quality sphere
EnergyPastUnitExtensiv	Additional possible capacities (grazing animals/year) in the extensive quality sphere
PotentialUsed	Percentage of the currently used grazing potential (%)

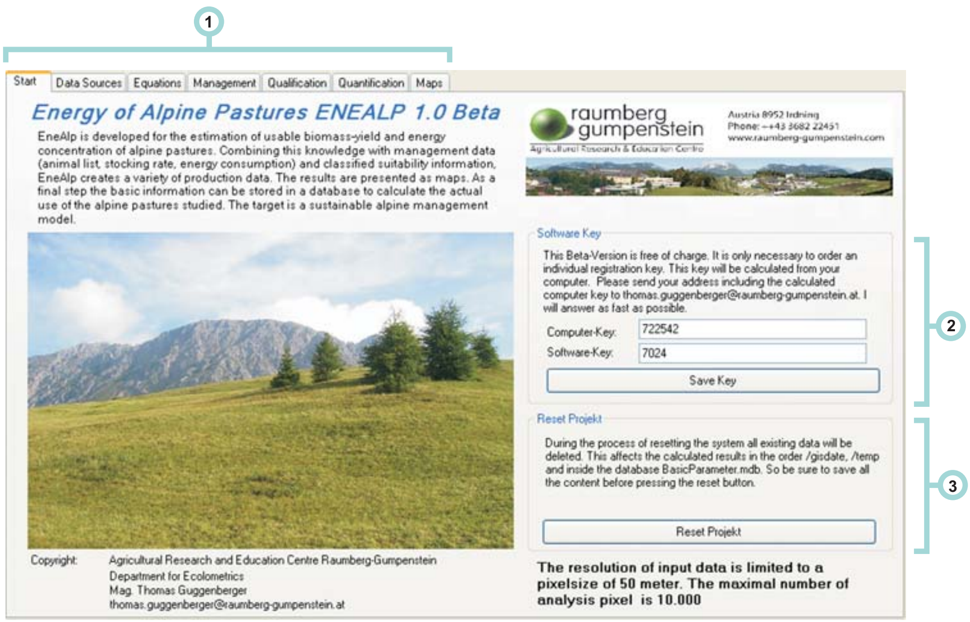

Figure 39: System release and reset

right. The beginning is in the „Start“ tab, followed by „Data Source“, and so on, until the last „Maps“ tab. Program errors are to be expected if individual tabs are skipped.

2. Software key: A software key for the program has been calculated to document the distribution of the software. This key is necessary to use the software and is calculated by a computer key. You can acquire the software key from thomas.guggenberger@raumberg-gumpenstein.at by stating your name, address, planned field of analysis and your computer key. Enter the returned key (e.g.: 7024) and store it with the „Save“ key.
3. Resetting the system: The entire system can be reset via „Reset Project“. This means the loss of all data, and therefore the old volume of data must definitely be stored first.

4.6.2 Data sources

1. Grid data sources: The dataset in question can be loaded via the respective buttons. The selection for grid datasets ends with the grid dataset folder (e.g.: C:\TestData\dhm50). Vector data can be loaded via your file (e.g.: C:\TestData\River.shp).
2. Two MS Access databases are required for implementing the software. These are found in the /database directory after installation. The name of the system file is BasicParameter.mdb. The name of the GI objects is Feature.mdb.
3. Land-cover classes: All of the land-cover analysis inputs can be loaded into the system with the „Load Land-cover Classes“ button. Be sure to enter the name of the ID field (this is normally called „value“).
4. With the „Test and save all data connections“ button, the content of all paths are stored and all structure data are read in. The progress diagram bar always shows the extent of already completed work (5).
5. Progress bar and description of the activity
6. After storing the path, the surface distance to the water must be calculated. This task may need some time.

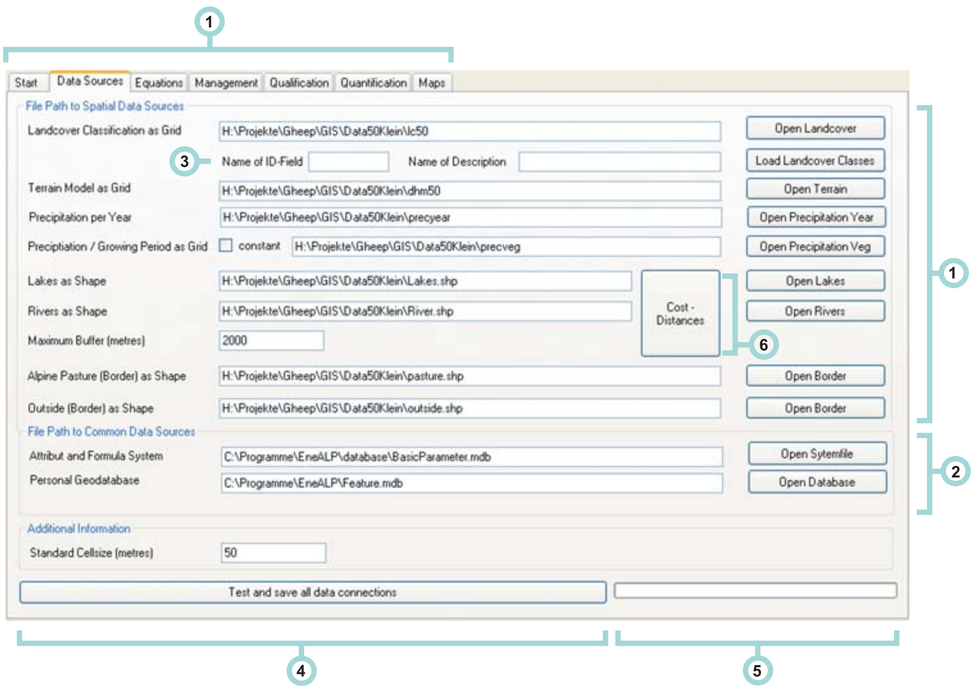

Figure 40: Setting the data paths

4.6.3 Comparative estimations

1. Estimation of the length of the vegetation period: The length of the vegetation period is defined via the local altitude. A quadratic function is generally used here. A broad variation of regional formulas is offered for Austria to achieve a local adaptation. A separate comparative estimation must be created for areas not to be covered. A region can be selected from the list - activating the check box selects its formula. Conclusion is executed with the „Save“ button.
2. Estimation of the maximum possible forage yield: Selection of the individual land-cover classes takes place via a mouse click on the cell in the LandCoverClass column. The following additional attributes must subsequently be given.
3. Name: name of the class (e.g.: rich pastures)
4. Yield type: an entry can be taken from the dropdown list. Some entries are executed in the way that all field types (yield types a, b1 and b2) are independently filled in.

Execute with the „Save“ button.

5. Estimation of the maximum possible energy content: selection of the individual land-cover classes takes place via a mouse click on the cell in the „LandCoverClass“ column. The following additional attributes must subsequently be given.
6. Name: name of the class (e.g.: rich pastures)
7. Quality type: an entry can be selected from the dropdown list. Some entries are executed in a way that all fields (quality types a, b1 and b2) are independently filled in.

Execute with the „Save“ button

8. Selection sphere of the data
9. Formulas to be allocated
10. Decision concerning the calculation behaviour of the system

Close with the „Basic GI Calculation I“ button!

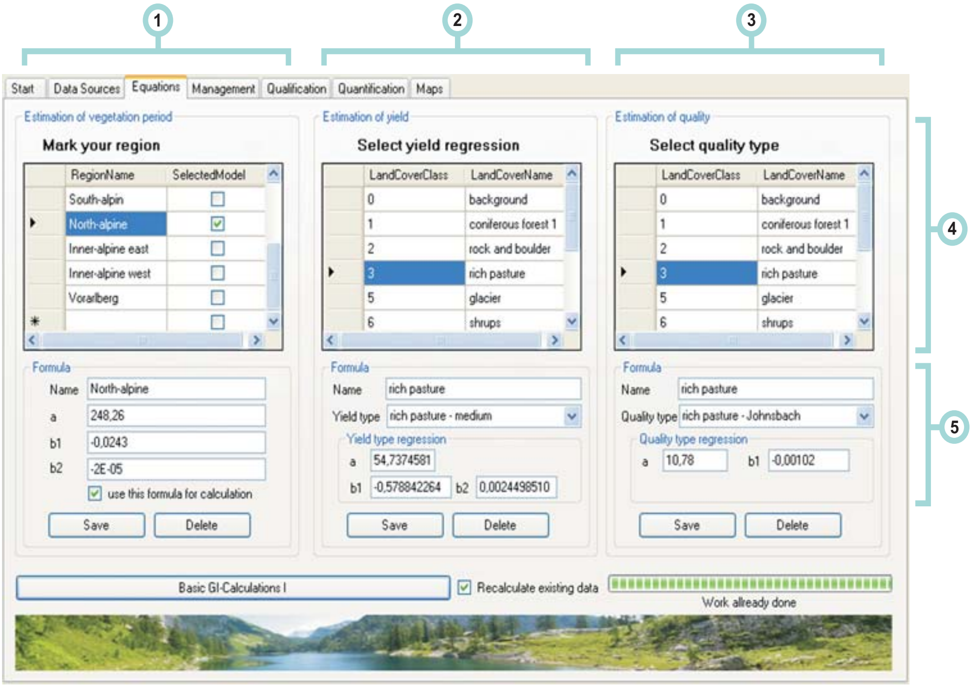

Figure 41: Comparative estimations and examination region

4.6.4 Management data

1. The selection of individual pastures enables input of the currently grazing animals. These are to be entered in the given fields according to category. Of great importance is the indication of the grazing type. There are several possibilities here. A fixed category can be allocated through the selection of a standard type as defined in Point 2. The only variable category reads „Depending on livestock“. With this category, a linear function is activated that calculates the quality reduction of forage dependent on animal stock.
2. Standard types of grazing
3. After all information has been entered, the „Estimation from animal list“ calculates the current animal stock and the energy reduction.

Close with the „Basic GI Calculation II“ button!

4.6.5 Quality assessments

1. Quality levels of slope inclination (in degrees): As for all quality parameters, the individual assessment classes and a quadratic formulation of the same can be given here. Through the input of a value, its „from“ and „to“ allocation is subsequently stored by pressing the „Save“ button. Through the selection of an ID value, the value can be reactivated and further processed. Formation of the regression must be carried out in an external statistics program. The individual weight of the slope-inclination classes can be defined above the data grid. One also ensures (if necessary) defining a class with 0 points, which is defined from the last possible value to the maximum value (0 points = 2,000 to 3,000 metres). Thus unsuitable sectors can be excluded.
2. Quality levels of water supply (given in metres): as for 1.

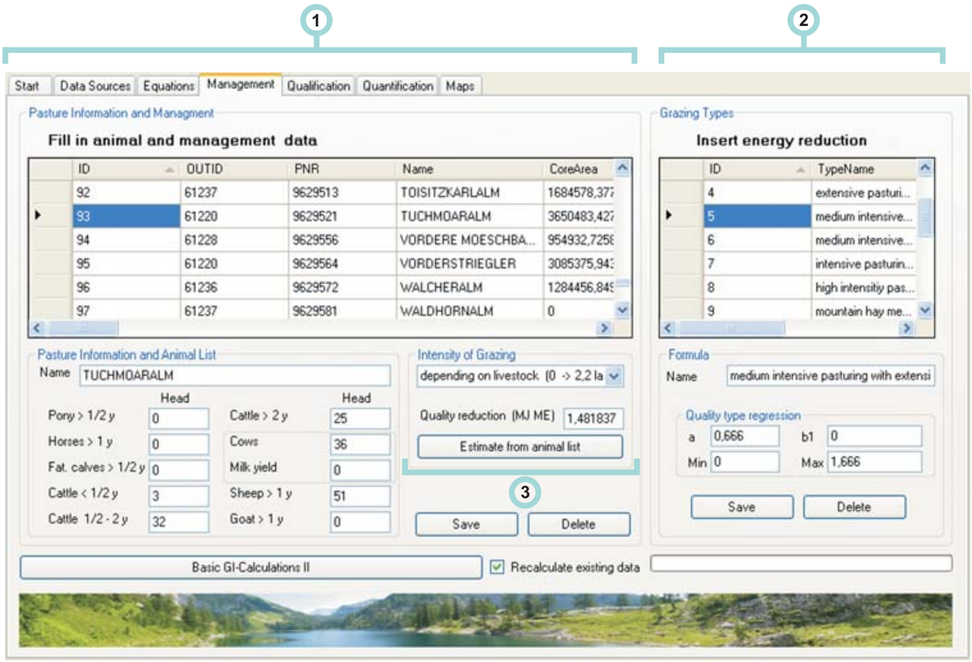

Figure 42: Management data

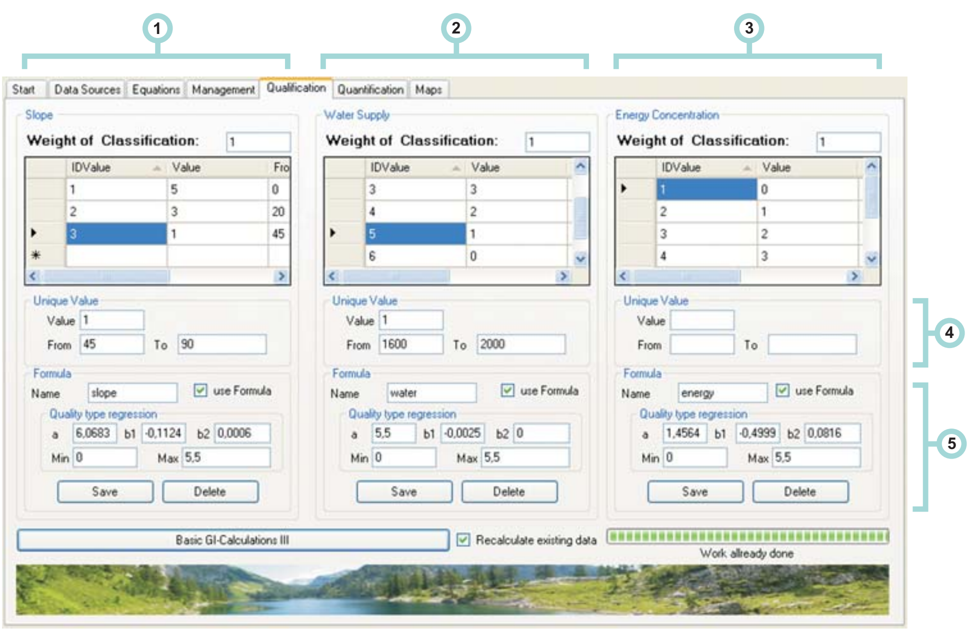

Figure 43: Quality levels

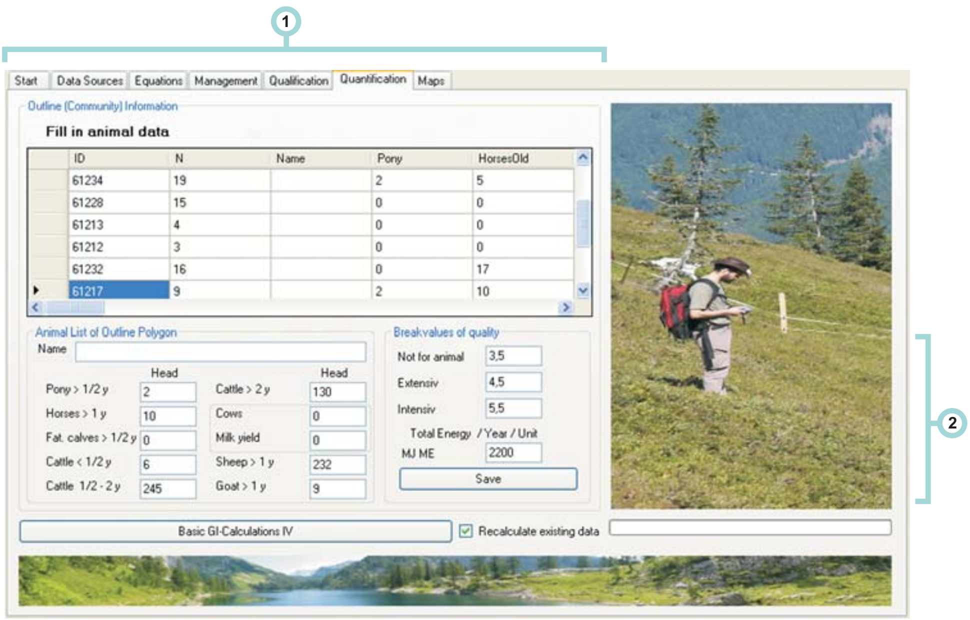

Figure 44: Quantity calculation and usage classes

3. Energy concentration (given in MJ realisable energy ME): as for 1.
4. Entry sphere of the assessment classes
5. Entry sphere of the formulas

Close with the „Basic GI Calculation III“ button!

4.6.6 Quantitative calculations

1. Regional information: Individual alpine pastures are categorised in regions. These can be used to derive recommendations. The structure of the alpine pastures in the datasets of the pasture borders must therefore be undertaken as fully as possible. The following limit values and consumption volumes must be given for the planned assessment of potential.
2. Limit value for unsuitable qualities: these regions should not be considered. Here, for example, classic hunting practices should take place (e.g.: < 3.5).
3. Extensive use: the upper-limit value for use by sheep and goats (e.g.: 3.5-4.5).
4. Maximum value: the highest possible class value
5. Total number of animals

Close with the „Basic GI Calculation IV“ button!

4.6.7 Result maps

1. Selection of the theme areas and individual maps (drop-down list)
2. Map: Serves only for the control of the existence and forming of results (rough analysis)

5. Conclusions

The methods presented in this manual can be useful, starting from basic information about a mountain area and its exploitation, to rank the suitability and to measure the potential for sheep and goat grazing.

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.

The methods used, as well as the software ENEALP contained in a specific CD ROM, are potentially applicable in the whole Alpine Space Area. As shown by the results obtained in the study areas in Friuli Venezia Giulia (I), Province of Trento (I), Province of Belluno (I) and Schladminger Tauern (A), the model can give objective indications on the type of animal most suitable for a certain pasture and on its optimal animal stocking rate. These indications can be an operational decision support both for territorial planning and alpine management of pastures. Public administrators, who were identified as the main target group of this work, are able to have better knowledge about the best way of pasture utilisation in order to contrast area abandonment as well as environment and landscape degradation. On the other hand, pasture managing bodies and breeders can also benefit from this information for a sustainable management of their animals.

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 space regions is a prerequisite for model qualifying and implementation. Furthermore, the model can not substitute the training of breeders and the extension services proposed to the pasture management and its importance on cultural, naturalistic and socio-economical points of view.

Finally, this study represents a first step that could become a useful tool for territorial evaluations. 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.

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The methods presented in this manual can be useful, starting from basic information about a mountain area and its exploitation, to rank the suitability and to measure the potential for sheep and goat grazing. 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. As shown by the results obtained in the study areas in Friuli Venezia Giulia (I), Province of Trento (I), Province of Belluno (I) and Schladminger Tauern (A), the model can give objective indications on the type of animal most suitable for a certain pasture and on its optimal animal stocking rate.

These indications can be an operational decision support both for territorial planning and alpine management of pastures.