CLISP - Climate Change Adaptation by Spatial Planning in the Alpine Space

WP 6 Risk Governance & Risk Communication

$CC_{MOUNTAIN}$Fitness Guidance

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$CC_{MOUNTAIN}$Fitness Guidance

Introduction

The requirements in natural hazard risk management procedures are becoming higher due to climate change. In view of the heterogeneity of stakeholders, levels of governance and the sectors involved in modern risk governance frameworks, static planning instruments are not feasible anymore. A more dynamic planning procedure, also incorporating regional development strategies, seems more promising to meet the challenges of climate change. In order to facilitate an easy implementation of new ideas in existing decision making structures, decision tools are indispensible. $CC_{mountain}$Fitness Guidance developed by Karl Kleemayr (BFW) offers practice-related decision support for the identification of climate change impacts on natural hazard processes, i.e. an estimation of the sensitivity of hazard processes to changes in climatic stimuli. The tool will give guidance on how to analyze the status quo of natural hazard processes within a region, their sensitivity to climate change, and the related uncertainties. The main user groups of the tool are natural hazard experts (mainly public authorities), whereas the results will be important for all spatial planning decision makers, like mayors or planners at the municipality level.

The $CC_{mountain}$Fitness Guidance complements the results of CLISP WP5 in the regard that its intention is rather on the local implementation than on specific spatial planning instruments. In contrast to the vulnerability analysis in WP4, which focuses on the regional level, here the focus is on process level.

Objectives of $CC_{mountain}$Fitness Guidance

The CC-Fitness Guidance strongly concentrates on climate change induced spatial planning problems with special focus on mountain regions.

The objective of the $CC_{mountain}$Fitness guidance is to support decision making authorities:

- to check spatial planning instruments in mountain regions – both instruments that are in force as well as during a revision process - whether the **most important climate, society and vulnerability factors** have been **included in the decision development process;**
- to distinctively address the most **sensitive and vulnerable issues;** and
- to work out adaptation strategies fostering the resilience capacity.

Furthermore the $CC_{mountain}$Fitness guidance aims at:

- increasing the awareness of climate change impacts on mountain societies;
- increasing the sensitivity for adaptation deficits; and
- increasing the preparedness for new and alternative counter measures and risk management strategies.

Method

The applied method is qualitative to semi-quantitative. The $CC_{mountain}$Fitness concept comprises four assessment steps, which are shown in Figure 1. It should be noted that the risk concept as established in the natural hazard and disaster risk assessment community differs from the vulnerability concept as applied in the climate change community. The method presented here is an approach to integrate climate change in the hazard and risk assessment process as it is common to natural hazard experts.

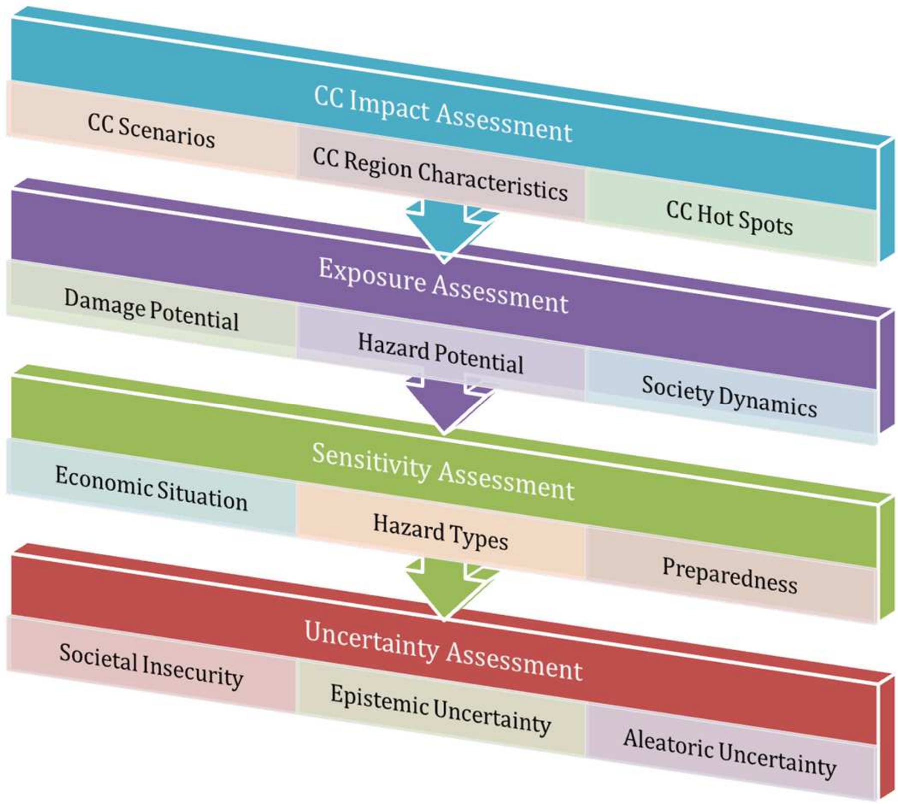

Figure 1. Elements of $CC_{mountain}$Fitness concept

1. Climate change assessment

Climate change – models, data and results

For the vulnerability analysis in CLISP WP4, climate change scenarios for each model region were identified. The used climate models included: Global Climate Models (GCM), i.e. ECHAMS, HadCm3, ARPEGE and Regional Climate Models (RCM) REMO, CLM, RegCM3, ALADIN. The selection depended on the availability over all participating Alpine Space countries. Consequently, higher resolution models available in some countries could not be used. For the application of the $CC_{mountain}$Fitness Guidance, especially for the climate change impact analysis regarding natural hazards, it is important to work with more local data. In Austria, data in a 10 km grid are available from the project reclip:more and are further used in this study. For details on other models please refer to the WP4 synthesis report.

The global average temperature will rise and the precipitation patterns around the world are likely to change in the next decades. For further impact studies more detailed data about the changing climate on a regional scale are needed. The following three projects, HISTALP, PRUDENCE and reclip:more provide such data for the Alps.

The reclip: more (research for climate protection: model run evaluation) project offers high resolution climate change scenarios for the Greater Alpine Region (Loibl et al. 2007). The scenarios represent the changes in the mean temperatures and precipitation values for the period 2041-2050, relative to 1981-1990. The spatial resolution of the model grid is 10 km. Simulations have been done with two different RCMs (MM5, ALADIN) driven with data from one GCM (ECHAM5). The GCM simulations are based on the “business as usual” scenario IS92a according to the IPCC report 2002 (IPCC 2000). The IPCC IS92a scenario specifies equivalent Green House Gas (GHG) concentrations and sulphate aerosol loadings from 1850 to 2100. Climate change data are available for a 10 km grid and seven sub-regions. Further information is available on the homepage http://foresight.ait.ac.at/SE/projects/reclip/.

Table 1. Projected seasonal trends of changes in temperature (TEMP) and precipitation (PREC) per decade for the Alps and for the case study municipality Gasen (Loibl et al. 2007).

Model (Region/Season) Period	TEMP [°C/decade]	PREC [%/decade]
reclip:more (Alps/winter) 2041-2050 vs. 1981-1990	0.32	1.3
reclip:more (Alps/spring) 2041-2050 vs. 1981-1990	0.37	0.2
reclip:more (Alps/summer) 2041-2050 vs. 1981-1990	0.38	-2.1
reclip:more (Alps/autumn) 2041-2050 vs. 1981-1990	0.45	-2.3
reclip:more-MM5 (Gasen/winter) 2041-2050 vs. 1981-1990	0.33 to 0.42	2,5 to 3,3
reclip:more-MM5 (Gasen/spring) 2041-2050 vs. 1981-1990	0.42 to 0.5	-0.8 to 0.8
reclip:more-MM5 (Gasen/summer) 2041-2050 vs. 1981-1990	0.33 to 0.42	-0.8 to 0.8
reclip:more-MM5 (Gasen/autumn) 2041-2050 vs. 1981-1990	0.42 to 0.5	-4,2 to -5
reclip:more-ALADIN (Gasen/winter) 2041-2050 vs. 1981-1990	0,17 to 0,25	4,2 to 5
reclip:more- ALADIN (Gasen/spring) 2041-2050 vs. 1981-1990	0.33 to 0.42	-0.8 to 0.8
reclip:more- ALADIN (Gasen/summer) 2041-2050 vs. 1981-1990	0.42 to 0.5	0,8 to 1,7
reclip:more- ALADIN (Gasen/autumn) 2041-2050 vs. 1981-1990	0.33 to 0.42	-3,3 to -4,2

Temperature and precipitation changes according to the reclip:more dataset for the Alps

For the Alps and especially for Austria, regional climate data from the reclip:more project are available for the period between 2041-2050 and are compared to the period between 1981-1990 (Loibl et al. 2007). Projected temperature increases in the Alpine region ranges from 1.9°C (0.32°C per decade) in winter, 2.2°C (0.37°C per decade) in spring, 2.3°C (0.38°C per decade) in summer and 2.7°C (0.45°C per decade) in autumn (Loibl et al. 2007, Table 1). The temperature change pattern shows a distinctive trend toward larger increases at higher altitudes. In this case just a rough estimation of the uncertainties can be given, because in the reclip:more project only three regional simulations have been performed, which are all based on the same global simulation. The comparison of the three different RCM shows a range of ±0.21°C. According to Déqué et al. (2007) the contribution of the RCM simulation failure to the overall failure in the Alpine region is 20 to 25 %. Hence, the uncertainties respectively the range of the projected temperature changes in the reclip:more simulations is about ±1.25°C (Gobiet 2010). This means that at least the direction of the temperature trend is highly significant.

The reclip:more simulations predict an increase in precipitation of 7.9 % (1.3 % per decade) for winter and of 1.2 % (0.2 % per decade) for spring. However, for summer and autumn decreases in the precipitation values are projected by 12.3 % (2.1 % per decade) and 13.9 % (2.3 % per decade) (Loibl et al. 2007, Table 1). The range of the three RCM used in reclip:more is ±5%. According to Déqué et al. (2007) the failure of the RCM contributes 30 to 50 % to the overall failure of the precipitation changes in the Alpine region. Hence the uncertainty respectively the range in the predicted precipitation changes is ±10 to ±15 % (Gobiet 2010). This means that neither the values nor the directions of the projected precipitation changes are significant.

Because the reclip:more simulations apply to the middle of the 21st century and the PRUDENCE simulations to the end of the 21st century, they are not directly comparable. Basically both simulations show the same characteristics: Comparable values of temperature increase, with the highest changes projected for spring and autumn. Decreasing precipitation values in summer and autumn and increasing values in winter. However, the values named here are averages over the whole Alpine region and can vary significantly from region to region. For example, the predicted precipitation patterns for the Alps show increasing values north of the main ridge of the Alps and decreasing values in the South.

Temperature and precipitation changes according to the reclip:more dataset for Austria

The reclip:more project offers detailed information about the future climate changes for Austria. The average annual temperature increase will be 2 to 2.5°C (0.33 to 0.42°C per decade) and along the main ridge of the Alps even higher (Loibl et al. 2009). The annual precipitation amounts will generally decrease in the South and East of Austria, while in the North and West of the main ridge of the Alps the annual precipitation amount will slightly increase (Loibl et al. 2009). Additionally the regional changes in temperature and precipitation for Austria are given for the different seasons (Loibl et al. 2009). For winter the projected temperature increases range from 1.3 to 1.8°C (0.22 to 0.3 per decade) in the North and East of Austria and from 1.5 to 2.0°C (0.25 to 0.33°C per decade) in the South and the West. In spring the temperatures in the western part of Austria and in the whole Alpine region will increase by 2 to 3°C (0.33 to 0.5°C per decade), whereas in the rest of Austria the predicted values are between 1.8 and 2.5°C (0.3 to 0.42°C per decade). For the summer a general temperature increase of 2 to 2.5°C (0.33 to 0.42°C per decade) is projected. Again the increase in the western part of Austria and in the Alpine region will be higher with values between 2.5 and 3°C (0.42 to 0.5°C per decade). In autumn temperatures are predicted to rise between 2.3 and 3°C (0.38 to 0.5°C per decade) in the West of Austria, whereas this time the increase for the rest of Austria is slightly higher 2.5 to 3°C (0.42 to 0.5°C per decade).

For winter, increasing precipitation values from 15 % to 30 % (2.5 to 5 % per decade) are projected for Austria. In the western part of Austria the precipitation will increase by 10 % (1.7 % per decade), whereas in other parts of Austria a decrease of up to 15 % (2.5 % per decade) is predicted. In spring the precipitation values will increase by 5 to 25 % (0.8 to 4.2 % per decade) over the main ridge of the Alps. However, in the East a decrease of 15 % (2.5 % per decade) is projected. In summer a wide range of changes, from -20 to +15 % (-3.3 to +2.5 % per decade) in the Alps and in the East even -15 to +30% (-2.5 to +5 % per decade) are predicted. For autumn the precipitation values over the main ridge of the Alps will stay constant, whereas for the North and East decreases from 25 to 35 % (4.2 to +5.8 % per decade) and in the West and South increases around 15 % (2.5 % per decade) are projected.

Changes in extreme events according to the reclip:more dataset (Austria)

Besides the projected changes of the temperature and precipitation the changes in the number of extreme events can also be derived from the reclip:more data (Loibl et al. 2009). The average number of frost-days (Tmin < 0°C) will decrease up to 50 % in Austria, whereas the number of summer-days (Tmax > 25°C) will double until 2050. The average number of heat-days (Tmax > 30°C) will quadruple in the East of Austria and will become a common phenomenon in the rest of Austria. Heavy precipitation events with more than 50 mm precipitation per day will increase on average by one to two events per year, along the main ridge of the Alps even by two to three events. Due to a decreasing tendency of the precipitation values, it must be assumed that in the future precipitation events in general will become less frequent, but more intense.

2. Exposure assessment for natural hazards

The aim of the exposure assessment procedure is

- to have a clear idea of vulnerability
- to know what the most critical objects and sectors are now and in the future assuming an ongoing climate change
- to know where adaptation of land use strategies is required most

The exposure assessment basically consists of three steps:

- Assessing the hazard potential: all dangerous processes have to be listed and evaluated. Typically, the processes concerned are torrents, mud flows, landslides, erosion processes, avalanches and rock-fall.
- Assessing the damage potential: values of all endangered objects,
- Assessing the expected society dynamics: the societal dynamics – with and without climate change – strongly influence the exposure development.

Hazard Potential Assessment

For all possible hazards in a given regions the following information should be assessed[1]:

- Size of the red zone, number of buildings in the red zone
- Size of yellow zone (blue zone), number of buildings in it
- Number of buildings bordering the yellow zone (e.g. within 100m of yellow zone)
- Amount of hazardous events in the last 100 years (chronicle, hazard cadaster)
- Summarised area of protection forests
- Area of protection forests directly protecting objects like buildings or infrastructure
- Percentage of built-up area

Damage Potential Assessment

- Amount of damages in the last 100 years
- Amount of protection measures in the last 100 years
- Percentage of settlement, infrastructure and industry area in the outlined hazard zones
- Value of buildings in the red zone
- Value of buildings in yellow zone
- Value of building bordering the yellow zone

Dynamics Assessment

- Population growth in the community
- Economic dynamics of community (e.g. in terms of over all tax development)
- Development of single sectors (tourism, industry, ...)
- Migration trend
- Availability of free land
- Drinking water resources

Adjacent questions which should be taken into account

- Are there already problems in protection forests (biotic or abiotic damages)?

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[1] In Austria, the following categories of hazard zones are designated in the hazard zone maps of the Torrent and Avalanche Control Service:

- *Red Hazard Zones* (mandatory): Areas threatened by torrents and avalanches that are not suitable to be permanently used for settlement and transport activities. The relevant design event for designation of the Red Zones is the 150 year return interval of disaster events.
- *Yellow Hazard Zones* (mandatory): All other areas threatened by torrents and avalanches whose permanent land use for settlement and transport activities is restricted by the exposure.
- *Blue Reservation Areas* (mandatory): Areas that are earmarked for structural and other active protection measures and shall thus be kept free from other building activites or may require special land use management.
- *Brown Index Areas* (optional): Areas where threats by other natural hazard processes than torrents and avalanches (e.g. rockfall) are indicated.
- *Violet Index Areas* (optional): Areas whose present state must be preserved in order to ensure protective functions.

- Are there already existing land use conflicts?
- How high is the energy autarky of the region?
- Sustainability of tourism – overuse of natural resources, impacted landscape scenery?
- Economic sensitivity of community: multi-sectoral or single-sectoral economy?

General suggestions for further development

- The hazard potential has to be defined not only for the reference event. In reality the hazard is a more or less stochastic continuous process ("more or less" dangerous and not "danger – no danger"). All event probabilities – from frequent to very rare - have to be outlined
- Different types of control measures i) technical – permanent ii) temporary and iii) planning have to be assessed taking the different overall costs and efficiency into account (development of support tools like Riskplan)

3. Sensitivity assessment

The sensitivity assessment process evaluates three different types of sensitivity.

Hazard sensitivity

Different watersheds, avalanche tracks or rock slopes react differently on increasing temperature, precipitation or storms. Even though a standardised assessment is difficult due to fact that all natural hazards are complex systems, simple generalised rules can be found. The main question is "assuming climate change what system properties favour the generation of i) more frequent or ii) bigger or iii) more frequent AND bigger hazardous events?"

This has to be listed for all natural hazard types.

1) Size of a homogenous release area (->magnitude)

2) Slope of the release area (-> frequency)

3) Slope of track (-> magnitude)

Economic sensitivity

The economic situation of a community strongly influences the adaptive capacity. The assessment hypotheses is that mountain communities with

- ulti-sectoral income,
- Low migration trend,
- Sustainable tourism,
- High energy autarky,
- …

have lower vulnerability because of higher adaptive capacity.

Preparedness

Vulnerability is generally lower if people are prepared. An adequate "prophylactic" awareness-raising and communication process is sometimes difficult to carry out but one of the most efficient ways to reduce vulnerability. For mountain region communities the following topics are essential:

- Do contingency plans exists?
- Have inhabitants been informed and are they aware of possible negative developments?

- Have inhabitants have been informed about possible personal and individual adaptive measures?
- Do inter-communal communication and control processes exist?

4. Uncertainty assessment

The uncertainty assessment procedure consists of three steps:

Societal insecurity

There are different reasons for insecure feeling of the society:

- No information about possible negative developments
- No information of control strategies
- Uncoordinated information of media
- Negative experiences in the past
- ….

For an efficient implementation of adaptation strategies with acceptance and high willingness of stakeholders and people affected to contribute, it is essential to inform people and give them a feeling of safety and capability to handle the future.

Empirical uncertainty:

If a hazardous process cannot be described in exact words or with exact models, empirical uncertainty remains. This uncertainty is necessary to be described if the derived activities impact the endangered people in a negative way. Empirical uncertainty is high if:

- The hazardous process is very difficult to describe (e.g. the wateshed has a complex geomorphology hampering a precise run-off calculation)
- Many hazardous process are overlaid
- The efficiency of control measures is not clear
- ….

Aleatorical uncertainty:

Aleatoric uncertainty arises if the "random character" of a process is negatively high. All natural hazards are stochastic, but watersheds and avalanche tracks with higher frequency give a feeling of lower aleatorical uncertainty. If observations are rare, uncertainty is high for the "unlikely event" to happen nevertheless.

Where / what are the most vulnerable buildings and sectors?

- Update of land-use hazard maps
- Adaptation of contingency plans
- Additional retention areas
- Additional safety areas
- Awareness-raising actions
- Protection forests are under observation
- Optimised control measures (technical, temporary, planning)
- Adapted tourism strategy
- Development of sealed areas is under observation

Application in CLISP: Study area Gasen

1. Climate change assessment

Temperature and precipitation changes according to the reclip:more dataset for Gasen

Table 7 shows the data for the test site Gasen, corresponding to the simulations of the RCM MM5 and ALADIN. The test side Gasen is located in the north-western part of Styria/Austria. The greatest temperature increase is projected by the MM5 model for spring and autumn and by the ALADIN model for summer and not for autumn. With regard to the projected precipitation values, Gasen shows a very similar trend than that of the Alps or Austria. The results of both RCM show that precipitation is projected to increase in winter and decrease in autumn. Especially remarkable is the high projected increase in winter and lower projected decrease in autumn in the simulations with ALADIN, compared with those from MM5. In spring no significant changes are projected by MM5 and ALADIN. ALADIN shows increasing precipitation values in summer, whereas the results of the MM5 simulation show no significant trend for this season. In the case of MM5 the annual precipitation is projected to decrease, whereas the results of the ALADIN simulation point at increasing annual precipitation for the region.

In comparison to the general climate trend in Austria the community of Gasen therefore is exposed to climate change in an "average" way: a tendency to drought events and a slight tendency to more precipitation in winter.

Table 2. Projected seasonal trends of changes in temperature (TEMP) and precipitation (PREC) per decade for the case study municipality Gasen

Model (Region/Season) Period	TEMP [°C/decade]	PREC [%/decade]
reclip:more-MM5 (Gasen/winter) 2041-2050 vs. 1981-1990	0.33 to 0.42	2,5 to 3,3
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2. Exposure Assessment

The rural community of Gasen is located in the eastern part of Styria (around 60km north-east from Graz) in the range of the "Fischbacher Alps", a low mountain range mostly covered by forests and alpine grazing areas. Approximately 950 inhabitants populate an area of 34 km² resulting in a comparably low population density of about 28 inhabitants/km² (on average 100people/km² for Austria).

The community of Gasen attracted special attention from scientists and professionals in the field of natural hazards in 2005 when a series of landslides (300) occurred after a sustained precipitation period.

Analysis of present situation for the model community

The following figures and tables reflect the present state of the exposure situation for the model community of Gasen. The analysis is based on information obtained from the following data sources:

- land use plan
- hazard maps

- digital elevation model with 10m raster resolution
- orthophotos
- road network information

Basic information

Due to the steep, mountainous topography, concentrated settlement areas are restricted to the valley bottom and gentle hill slopes (see Figure 2 and Figure 3) which leaves only 3.76% of the total community area suitable for settlement.

Table 3. Basic data for the model community Gasen

Area	33.95 km²
Area suitable for settlement	1.276 km²
Percentage of area suitable for settlement	3,76 %
Range of elevation	690m – 1470m
Inhabitants	ca. 950
Number of torrents	24

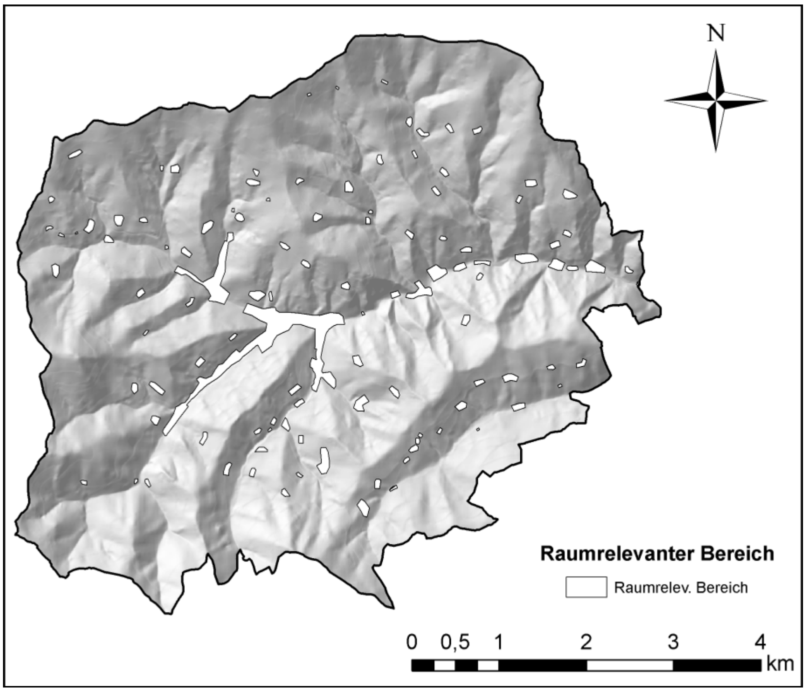

Figure 2. Overview of the area suitable for settlement (depicted in white) for the model community, which accounts for 3.76 % of the total community area.

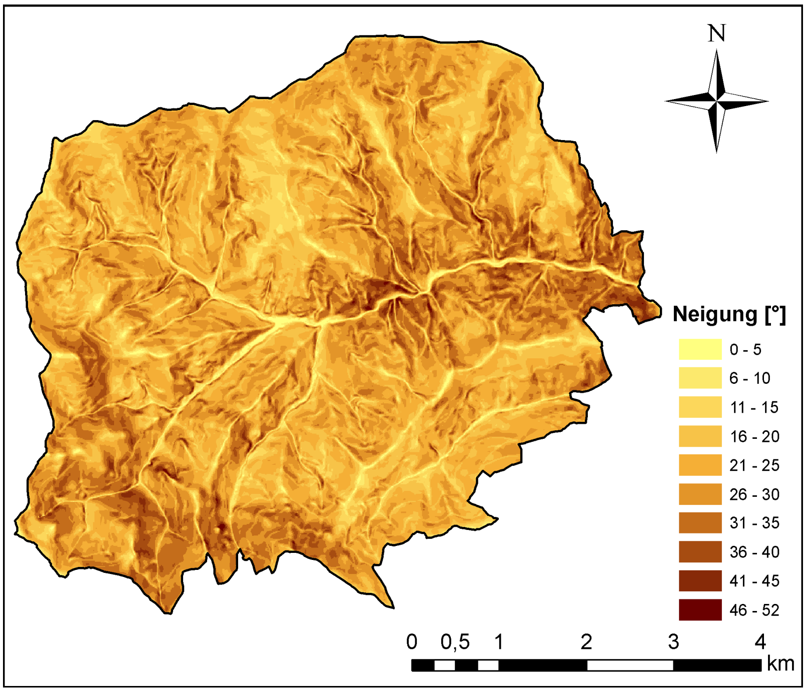

Figure 3. Inclination map for the model community – the valley is bottom mainly used for settlements (see fig. 2) and is bordered by relatively steep slopes prone to mass movements

Hazard Zones

Relevant hazard zones for Gasen include red and yellow hazard zones for torrents, yellow hazard zones for avalanches and brown hazard zones for landslide processes (Table 4; Figure 4). With respect to brown hazard zones, Gasen can be considered a showcase example in Austria since landslide mapping has been conducted for no other community on a comparable level of detail.

Table 4. Hazard zones for the model community considering areas affected by more than one process in km2

zone	**area**
red hazard zone for torrents AND brown hazard zone	15926 m²
yellow hazard zone for torrents AND brown hazard zone	11924 m²
yellow hazard zone for avalanches AND brown hazard zone	6082 m²
red zone for torrents	91557 m²
yellow zone for torrents	82330 m²
yellow zone for avalanches	14601 m²
brown zone	1199969 m²
total area in hazard zones	**1.42km²**

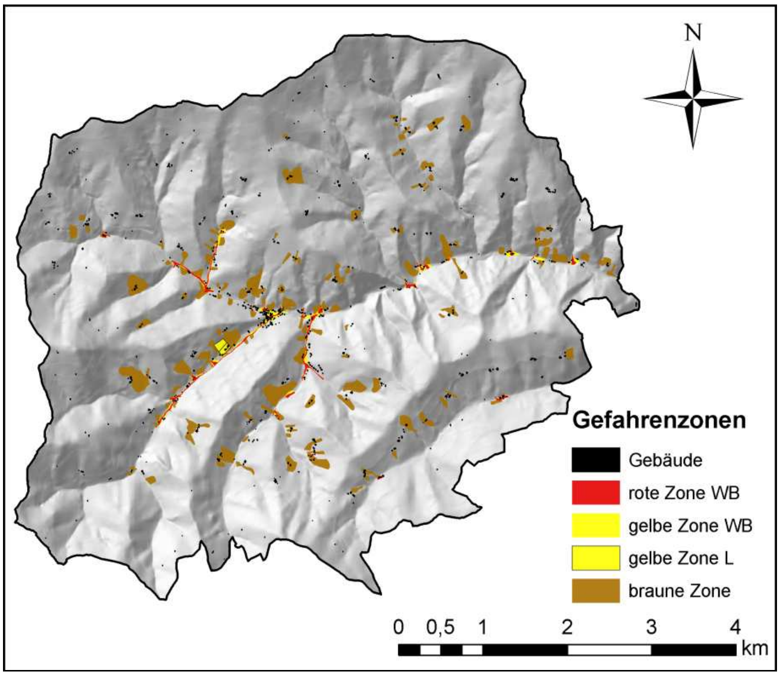

Figure 4. Hazard zones for the model community - buildings are indicated by the black signature

Land use

Table 5. Designated areas for settlement, industry, business and traffic for the model community

type	**area**
settlement area	0.0109 km²
industrial and business area	0.0237 km²
transport area	1.0264 km²

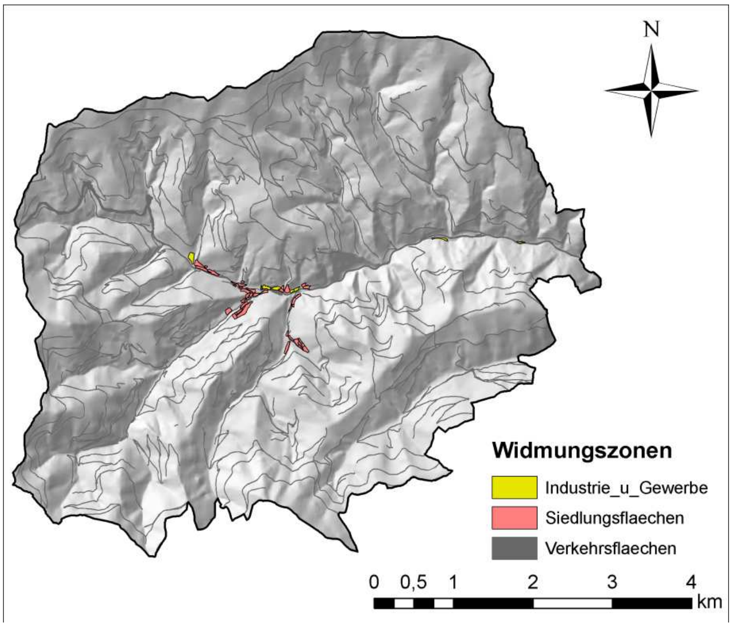

Figure 5. Designated areas for industry and business (yellow), settlement (pink) and transport areas (grey) for the model community

Buildings in endangered zones

The number of buildings in identified hazard zones can serve as a measure indicating the exposure of a given community to natural hazard processes. The figures shown in Table 6 indicate that in the model community around 31 % of all buildings are located in hazard zones. For industrial buildings the percentage is considerably higher with 68.75 %.

Table 6. Number of buildings in hazard zones for the model community of Gasen

hazard zone	area [m²]	number of industrial buildings in zone	number of other buildings in zone
red zone torrents	91557	5	31
yellow zone torrents	82330	2	56
yellow zone avalanches	14601	0	2
red torrents and brown	15926	0	6
yellow torrents and brown	11924	0	3
yellow avalanche and brown	6082	0	3
brown	1199969	4	107
no hazard zone		5	479
totals:	**1422390**	16	687
number of buildings in hazard zones:		11	208
% of buildings in hazard zones		68.75	30.28

Forest

More than half of the community area of Gasen is covered by forest stands. About one third of the forest area covers terrain steeper than 30° and can thus be classified as stands with mainly protective functionality (Table 7; Figure 6).

Table 7. Area covered by forests in % of the total area of the community

category	area
Total area covered by forests	19.31 km²
% of forest areas compared	56.9 %
Forest covering areas steeper than 30°	6.55 km²
% of forest steeper than 30°	33.9 %
% of forest steeper than 30°	19.3 %

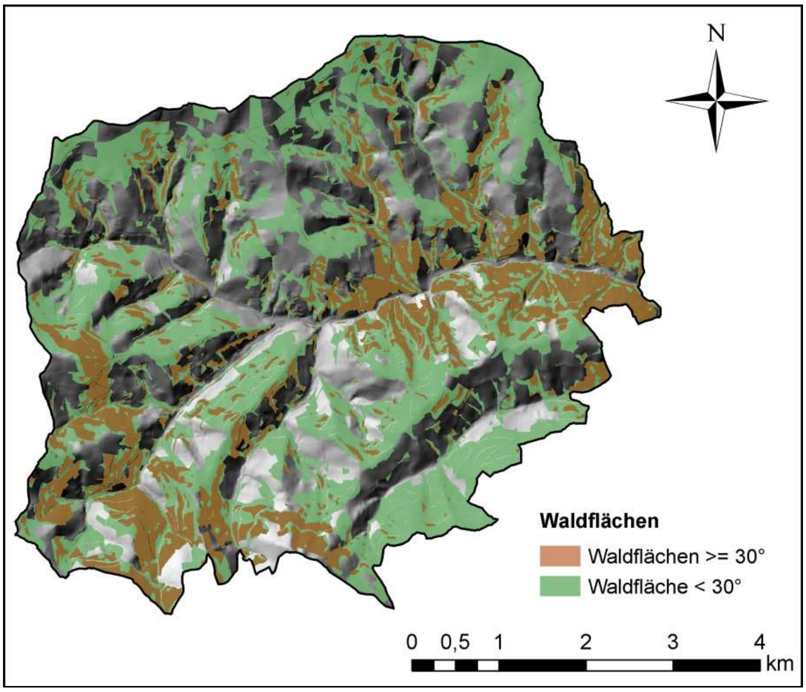

Figure 6. Areas covered by forest – the brown signature indicates forest stands on terrain inclined 30° or steeper

Road infrastructure in hazard zones

The total length of road infrastructure for the model community accounts for approximately 86.7 km of which around 48.6 km account for private roads and 18.2 km and 7.1 km for community roads and state roads respectively. Table 8 indicates the lengths of road stretches affected by hazard zones.

Table 8. Road infrastructure affected by hazard zones – the last column indicates the percentage of total roads located in the respective hazard zones

hazard zone	length affected	private roads	community roads	state roads	% of total
red zone torrents	2161 m	481 m	838 m	842 m	2.49
yellow zone torrents	3173 m	614 m	1586 m	973 m	3.66
yellow zone avalanches	103 m	103 m	0 m	0 m	0.12
red torrents and brown	240 m	146 m	0 m	94 m	0.28
yellow torrents and brown	283 m	159 m	110 m	14 m	0.33
yellow avalanche and brown	39 m	39 m	0 m	0 m	0.05
brown	6774 m	5891 m	780 m	104 m	7.81
within zones	12774 m	7433 m	3314 m	2027 m	14.74
outside zones	73915 m	48630 m	18186 m	7099 m	85.6
Total:	**86690 m**	**56064 m**	**21500 m**	**9126 m**	**100**

3. Sensitivity Assessment

Hazard Sensitivity

In 2005 about 300 landslide events endangered the community of Gasen. 30 landslides with a volume of > 1000 m³ caused significant damage. Five of these landslides had already been observed earlier, but past event cadastres give no indication to a catastrophic event comparable to that of 2005. Geology and geomorphology clearly show a general disposition for landslides and the community is generally aware of these problems. However, most of the hazardous events in the past have included torrents. Therefore technical control measures with the respective intensity focused on the control of flood damages. Concerning the expected changes due to climate change, the community of Gasen has – in relation to other Austrian mountain communities – a low sensitivity with respect to torrents and floods. Concerning landslides, the sensitivity lies above average and developing a continuous monitoring of the landslide prone areas is necessary.

Economic sensitivity

The population of Gasen (~1000 inhabitants) has remained constant for the last 15 years. The amount of families has not changed much since this time, however, the number of persons per family has decreased, which is typical for rural areas. The community income is based on two sectors: steel engineering and carpentry enterprises on the one hand and tourism on the other (all of which are medium-sized and in economically stable situations). Beside these companies the typical community infrastructure (grocery, bank, kindergarten, etc.) exists.

In Gasen one of the first bioenergy powerstations of Styria has been running for the last 20 years, fuelled only by wood of the community. 75% of Gasen's warm water is supplied by this powerstation. The springs within the community area easily yield its requirements of drinking water.

Thus, it can be expected that the economic stability and the quality of life in the community is quite high, easily buffering some negative developments due to climate change. The economic sensitivity therefore is low.

Preparedness

For the community of Gasen both a hazard map and a contingency map exist. After the events of 2005 the awareness of torrent and landslide problems increased not only for the decision making authorities but also the population in general. In numerous public discussions the issues have been discussed with the inhabitants. The events of 2005 also lead to an integration of "landslide prone areas" in the hazard map, land use map and partly also in the contingency plan. Due to the fact, that the neighbouring communities like Haslau also have been heavily impacted, the inter-communal communication is relatively high. Thus also the preparedness of the community is - at least currently – very high with respect to possible natural hazards and damage potentials. Under guidance of the recent mayor, a similar preparedness can also be expected for the next years.

4. Uncertainty Assessment

Societal insecurity

With the catastrophic events of 2005 and the professional communication process mainly guided by the mayor the problems, fatalities and damages have been discussed very openly and transparently. The people of Gasen are aware of the problems, but are not insecure. Furthermore, during the events there have been nearly no cases of bad media information, mutual accusation or other conflict issues. This can be ascribed to the good crisis management of the community, the district and the torrent and avalanche control service during and shortly after the events (although there have been significant damages and fatalities).

The community of Gasen therefore is aware of the problems now and in the future, but they do not feel insecure due to the positive crisis management and the adaptation measures.

Empirical uncertainty

In Gasen only two natural hazard types are relevant: Torrents (floods and debris flows) and landslides. There are no avalanche or rock fall problems and also other risks e.g. from the steel enterprise are very low. Torrents and landslides are both strongly dependent on weather conditions in frequency and intensity and thus can be described, predicted and controlled in a quite reasonable way. Empirical uncertainty therefore again is very low in Gasen.

Aleatoric uncertainty

The aleatoric uncertainty for the two natural hazard processes differs: The numerous torrent events in the last century have led to a high problem awareness, a high willingness to pay for control measures, and preparedness. This subsequently allows for a low aleatoric uncertainty. However, the numerous damages of even small landslides clearly indicate an underestimation of landslide risks. Five years after the catastrophic events, the risk situation is much better under control, but the low frequency character of the landslides clearly indicates high aleatoric uncertainty. It would therefore be recommendable for the community to regularly inform the inhabitants about the possible problems and to actively work against the trend of "societal memory loss".

Outlook

The assessment process demonstrated in this chapter outlines the method in a qualitative way. For the future an assessment tool should support this process in a quantitative and semi- quantitative way. Using these methods, comparisons between communities could be performed and action plans derived in a more specific manner.