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Vulnerability to changes in ecosystem services of the "Eisenwurzen" Alpine region under global change

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Objectives

The aim of this study is to assess the possibility (risk) of harm caused by different future natural or social changes that can affect people of a selected alpine region by 2050 in relation to their environment.
The assessment will include following considerations:
1) sensitivity of the region's services exposed to specific pressures in the future;
2) identification of the stakeholders' adaptability to the expected changes.
For this study vulnerability is defined as the possibility to harm stakeholders by changes in the environment.

Methods

The region, its services and stakeholders

The region called "Eisenwurzen" was first delineated by the inhabitant's perception of being part of it. (Heintel and Weixelbaumer 1998). Then all municipals being at least partly within this area and fulfilling other criteria, constituted the boundary (Fig. 1). The area is in the centre of Austria covering approximately 5000 km^2. The elevation ranges from 400 to 2500 m above sea level. The climate is typical for the Northern Alps with warm summers and cold, snowy winters, highly dependent on the elevation. Agricultural activities range from the lowlands, with grassland for livestock and different crops, to high alpine areas above tree-line, with summer grazing on pastures. Forests predominate in the mountainous area and forest management was or is taking place basically in every forest patch. The area has undergone significant socio-economic changes during the last centuries. The "Eisenwurzen" was one of the most important European iron ore deposit until the 19th century. After that, and of course influenced by events of the 1st and 2nd world wars, the iron production decreased and the exploitation of ore will be abandoned completely during next 10 years. These changes brought about unemployment, population decrease and aging, decrease of agricultural production, and decrease of wood production, but increase in the economic importance of tourism. The area now includes two national parks and a series of other protected areas.

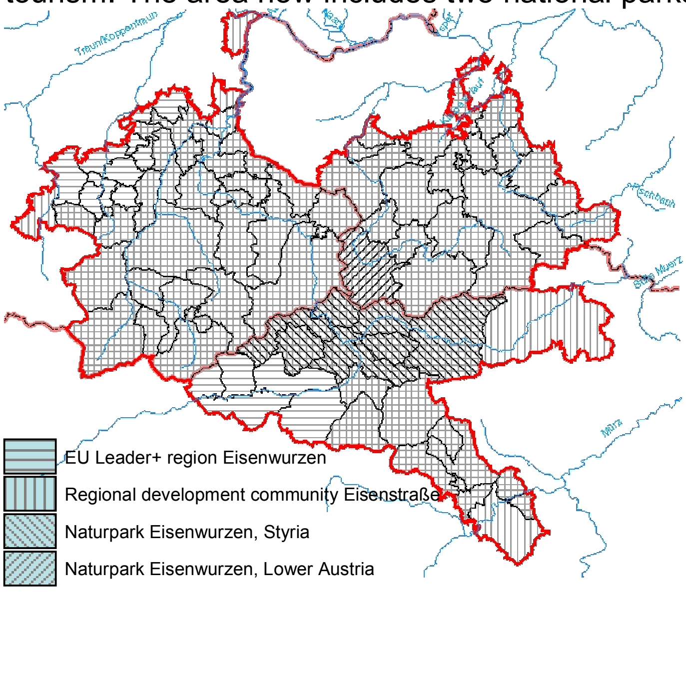


Fig. 1: The region Eisenwurzen in the central part of Austria covering approx. 5000 km^2. Municipals with different regional development initiatives constitute the boundary of the region.

We defined the following **services** to be important for our region:

Provisioning services:

- Food production: farming focuses mainly on livestock, but also crops are grown
- Wood production: large part of the area is covered with forests
- Drinking water provisioning: limestone catchments are important source of drinking water for the whole country

Regulating services:

- Flood regulation: retention of water in soils of forested areas
- Climate regulation: mainly a function of forested area as well
- Biodiversity: supports the self-regulation ability of ecosystems and landscapes

Cultural services:

- Landscape aesthetics and biodiversity: closely related to landscape heterogeneity and composition, which offers experience of beauty and harmony
- Recreation and tourism: diverse landscapes offer possibilities either for summer or winter tourism

Several groups of **stakeholders** were selected to represent various interests in the region Eisenwurzen. They are the addressees of the vulnerability assessment and are those primarily affected by changes of services:

- regional developers: as the economic and social representatives of the community; they are an interface group with multiple interests (tourism, employment, identity, etc.)
- local farmers: individually or represented by their lobby groups
- protected areas managers: national parks, wilderness areas, etc.
- water suppliers: private/state bodies managing water resources (for Vienna and other areas)
- regional and national government
- flood risk management: official bodies responsible for flood prevention
- forest managers
- enterprisers: managers of small to large enterprises, (in some cases driven by global processes)

Other groups were either not considered influential, or significantly vulnerable to expected shifts in services.

Pressures

We focused on the most important pressures, which are expected to affect services in the area of interest:

- **Temperature increase**: important global pressure with regional effects
- **Precipitation change**: expected change in amount of precipitation, as well as change in its annual pattern
- **Droughts**: extreme event that can be expected as a result of climate warming, precipitation change

- **Floods**: another extreme event that is likely to be driven by precipitation and land cover changes
- **Heavy windstorm**: hardly predictable extreme event with potential impact for forests
- **Nitrogen deposition**: increase of the total deposition of nitrogen leading to eutrophication
- **Tropospheric ozone increase**: can directly harm plants and humans
- **Ambient CO_2 increase**: due to global increase of carbon emissions
- **Land abandonment**: as a result of migration of inhabitants from rural areas to the cities
- **Urban sprawl and building of infrastructure**: especially in the vicinity of bigger cities

Scenarios of pressures

Two distinct scenarios for the future development of the selected pressures were chosen according to ATEAM (Schröter et al. 2004, Table 1). The climate variables were based on the set of four adjacent grids from the ATEAM database and results of the general circulation model (GCM) HadCM3 were used.
The A1 FI scenario (henceforth called “A1”) describes a future world of strong globalization with very rapid material growth, market capitalism, low population growth, and the rapid introduction and transfer of new and more efficient technologies. However, the energy system remains fossil fuel based. **The B2 scenario** describes a world in which there is an emphasis on local solutions to economic, social, and environmental sustainability. It is a world with moderate population growth, intermediate levels of economic development, and less rapid and more diverse technological change than in the A1 narratives.

Technical workflow

The first matrix (Fig. 2) describes the interactions between selected pressures and services in the case study region and thus indicates the sensitivity of individual services to the pressures. It was used to reduce the listed services to a reasonable number. The relationship between the environmental services and selected stakeholders is depicted by the second matrix, which serves as an indicator of service importance (value) for a given stakeholder. The adaptive capacity (the ability to respond) of each stakeholder to the shifts in individual services is described in the third of the matrices. The combination of the first and second matrix allows determining the most sensitive services together with stakeholders that are likely to be affected by the possible change in the service. Incorporation of the third matrix into the scheme enables us to assess the vulnerability of a given relationship between environmental service and stakeholder, if subjected to a pressure of defined intensity.

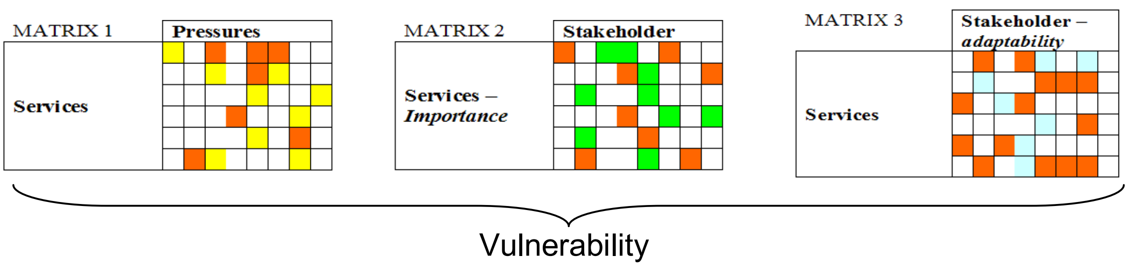


Figure 2: Workflow for estimating levels of sensitivity of services and adaptability of stakeholders to changes in order to assess vulnerability. Matrix 1 depicts the sensitivity of individual services to the pressures, matrix 2 the importance of services for stakeholders, and matrix 3 the stakeholder's adaptability to changes in services

Service indicators

We used total wood storage in the forests of the region as an indicator of wood production . Data from the Austrian forest inventory (http://www.bfw.at) was used to calculate present and expected future values according to the A1 and B2 scenario based on forest area. This does not take into account changes in forest biomass per area due to changes in age structure, CO_2-fertilisation or climatic factors. Food production was estimated from calculated trends in climatic conditions and expected reaction of grassland productivity to changed climatic conditions including assumption that grassland species will react similarly to other C_3 plants. In accordance with a literature (e.g. Amthor, 2001) we assumed approximately 8% water limited yield increase per 100 ppm of ambient CO_2 increase during seasons with non-extreme weather conditions. However exact quantification of the forage yield changes under future climate would require a study of its own. As the alpine rivers are the main source of drinking water for large area, the runoff pattern would have a major influence. Trends were depicted from the most comparable area, Hirschbichl, of an alpine wide impact assessment (Zierl and Bugmann 2005). The number of overnight stays of tourists for the year 2000 was taken from "Statistik Austria" (www.statistik.at) and it was used as a recreation and tourism service. Under A1 scenario we expect lower number of overnight stays, due decreased landscape diversity. On the other hand changes expected under B2 scenario may bring more tourists to the region while the region is supposed to develop more rapidly and offer more service businesses. As extreme "dry" and "wet" events are perceived as potential risk to most of the services under future climate we applied Palmer´s Z-index for determination of dry events and Standard precipitation index (SPI) to determine wet ones. Both indices were used in the version proposed by Dubrovský et al. (2005). The modified indices allow for computation of the number of drought (and exceptionally wet) events under expected climate using the present state as a reference. The index value was calculated for 40 years worth of data (1961-2000) under present conditions and then modified using HadCM3 GCM model outputs for the Eizenwurzen region. The percentages of months during these 40 years of record with value of Z-index below -2 (drought) and SPI above +1.5 (extremely wet) were calculated for each month of the year. The major advantage of the method is the ability to reflect temperature and precipitation changes. The index outputs were then used for qualitative assessment of impact of extreme events on all considered services. Despite the fact that the monthly data utilization leads to an important caveat as runoffs in smaller catchments are better estimated by daily data the conclusions based on the monthly data proved to be valid in numerous other studies (e.g. Hisdal and Tallaksen, 2003).

Adaptation capacity

A qualitative assessment was applied by considering a proactive and reactive response attitude of stakeholders. The adaptability of stakeholders could vary between "strong" and "weak" (or none/not known). It could also differ if applying proactive or reactive attitude. By "proactive response attitude" we meant acting in advance, not passively waiting for changes to happen. The “reactive response attitude” represents opposite approach, when the stakeholder would react after a change would occur.

Vulnerability assessment

Vulnerability was assessed for each of the selected pressures taking into account two potential adaptive strategies of stakeholders (i.e. reactive and proactive). The algorithm and results of the vulnerability assessment are described in the following text.

Results and discussion

Sensitivity of services

Changes in pressures

Table 1: Expected change of environmental pressures in the region “Eisenwurzen” according to the results of the ATEAM scenario modelling.

	summer precipitation* (mm)	winter precipitation** (mm)	max.summer temperature* (°C)	forest cover change (%)	GDP (US$/cap)
Baseline***	523	279	20.3		16677
A1-scenario	-53	+24	+3.6	+1.1	+45474
B2-scenario	-26	+28	+2.7	+1.4	+23598

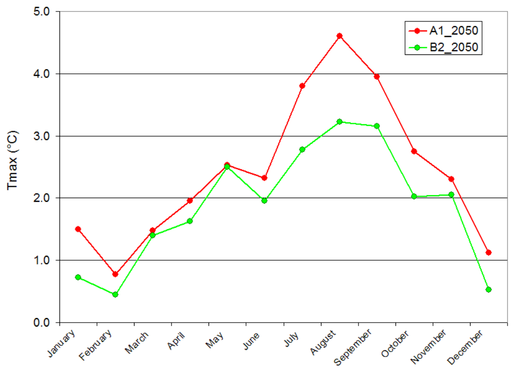
* from June to September, sums in the case of precipitations and monthly means in temperature

** from December to March

*** according to averages between 1960 and 1990

A1FI scenario: As apparent from Fig. 3 there is a marked increase in the maximum temperature (TMAX) especially during summer months and a decrease in precipitation during the same period. For winter precipitation an increase of up to 20% is estimated (see also Table 1).

B2 scenario: Compared to the A1FI scenario the temperature and precipitation changes are less pronounced especially in case of precipitation (Fig.2, see also Table 1).



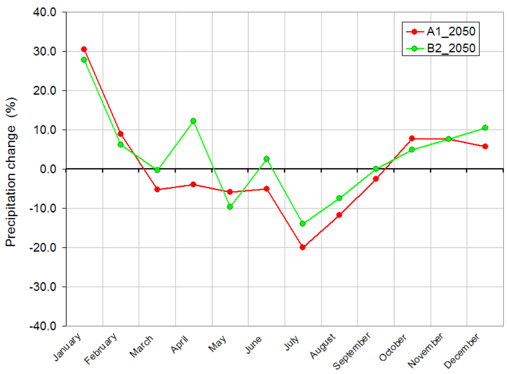
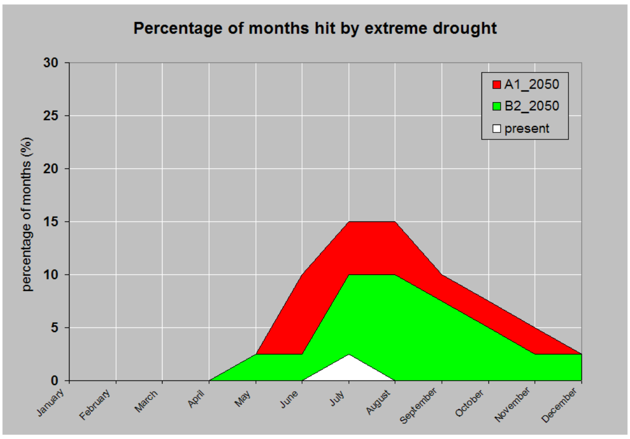


Figure 3: The monthly anomaly of maximum air temperature and relative change of precipitation compared to the baseline (1961-1990) predicted by the HadCM3 model for grid points representing the Eisenwurzen region.

Percentage of months affected by severe and extreme drought events will significantly increase according to both scenarios compared to the present conditions (Fig. 4). Especially the impact of the increase in extreme drought events might have a detrimental effect on a number of services that are important for the region. The number of drought events peaks during summer due to the significant increase of the air temperature during summer months combined with a precipitation decrease.



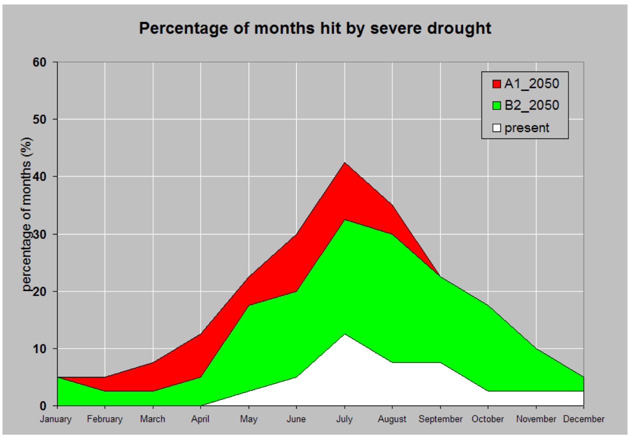


Figure 4: Percentage of months influenced by severe or extreme drought under present and expected climatic conditions (HadCM3 model by 2050) for the locality Gumpenstein (700 m a.s.l.) using the relative Z-index (Dubrovsky et al. 2005).

Proportion of exceptionally wet months assessed by relative 1 month SPI index under present and expected climatic conditions was used as an indicator of a flood risk change in the area of interest. As it is apparent from Fig. 5 there is a slight increase in the occurrence of extremely wet months during winter months with a slight decrease of the wet events during summer.

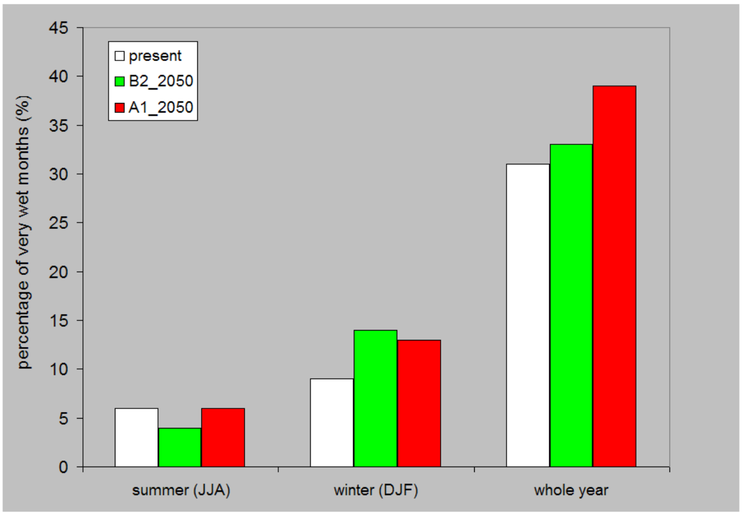


Figure 5: Proportion of very wet months assessed by relative 1 month SPI (Dubrovsky et al. 2005) under present and expected (based on HadCM3 GCM model) conditions at the Gumpenstein weather station.

Future changes of services

Table 2 shows baseline values and changes in indicator values for the A1 and B2 scenario.

Wood production

Wood production is supposed to increase by the order of 1-2% by 2050. Under A1 food production in Europe is supposed to increase due to open markets whereas under B2 only moderate increases for food production are estimated. As a result B2 shows twice as much land abandonment and reforestation than A1. Wood production is not only influenced by land abandonment and the resulting timber growth but by climatic changes as well. Temperature increase and drought events are expected to negatively influence Norway spruce growing in lower altitudes (Lexer et al. 2002). Tree line shifts due to climate change were excluded due to low expected effects within the next 50 years (Dullinger et al. 2005). Increased wood storage has a contrasting influence on different stakeholders. Whereas the tourism and agricultural sector is negatively affected by the degradation of landscape esthetics and loss of agricultural land, the forestry profit from having more forest area.

Food production

Increased temperature in combination with higher ambient CO_2 concentration will result in general improvement of the growing conditions of the main forage crops. The overall precipitation decrease and change in precipitation distribution will have limited impact in most of the season (Table 1). However the increase in proportion of months hit by extreme drought episodes from June to August will likely cause crop failures as it happen during the growing season of 2003. Increased winter precipitation will negatively influence workability of the soil during late fall and early spring possibly offsetting potential gains arising from prolonged vegetation season. The increased likelihood of winter floods that might affect also smaller tributaries will require repositioning of the present production infrastructure from flood plains to higher grounds. Based on the SRES scenarios and ATEAM projections of land use changes we do expect reduction of the agricultural land area, however, this will not affect the total amount of agricultural production due to assumed abandonment of marginal land.

Drinking water

Drinking water provision is affected in both scenarios because of an overall precipitation decrease and because the runoff peak is shifted earlier in the season, weakening water provision in summer (Table 2). Therefore in summer less water can be expected. Under both A1 and B2 scenarios the runoff peak will be lower compared to the current stage (ca 170 mm). Under A1 the decrease will be more significant in the very beginning of spring (ca 150 mm) and also the summer runoff is expected to be lower. Under B2 the runoff peak will be even lower (ca 140 mm) and not as pronounced. Reforestation will counteract the negative changes due to an increase in water retention. Here scenarios show the opposite trend, i.e. B2 shows more reforestation than A1. However, according to the scenarios land use change is small (ca 1-2%), and would affect water runoff very slightly.

Recreation and tourism

The annual sum of overnight stays for the three counties of Eisenwurzen together (21.8 Mio) made up 19.2% of the annual stays of whole Austria. In 2000 52.7% of the total Austrian annual overnight stays (113.6 Mio) accounted for the summer season, 47.3% for the winter season. For the Eisenwurzen region summer tourism is probably even more important, since winter tourism plays a minor role (pers. comm. T. Dirnböck). About one third of the summer tourists for the whole of Austria are natives (30.7% in 2000) and the major part of foreign tourist is made up by the “nearby” country Germany (63.4% in 2000) and also by the Czech Republic (pers. comm. M. Trnka).
For the year 2050 a slight increase in tourist numbers (overnight stays) is expected following climate change, as observed for summer 2003. This summer was very warm and dry and the overnight stays for the whole of Austria increased by 2.5% with respect to the summer of 2000. By 2050 the summer season will be longer and thus generate an increased demand. This increase will be slightly higher for the A1 scenario than for the B2 scenario. Under the globalization scenario A1 population and GDP will increase and the percentage of foreign tourists will probably rise. Under the regionalization scenario B2 there will be a higher focus on environmental protection but also a higher probability of an increasing demand of alternative vacation destinations of “nearby” countries due to a less stable world.

Table 2: Changes of service indicators based on the pressure scenarios A1 and B2

Service	Wood production	Food production	Drinking water	Recreation/Tourism
Indicator [unit] (change)	total timber storage [1000 m^3] (% change)	Total production of forage crops	Shift in runoff peak [days]	Summer overnight stays [Mio] (% change)
baseline	881	-	May	21.8
A1 2050	891 (+ 0.9)	No change to slight increase	< 60	22.7 (+ 4%)
B2 2050	902 (+ 1.8)	No change to slight	< 40	22.3 (+ 2%)

		increase		

Final sensitivity matrix (matrix 1)

The exposure of the services to the pressures and their sensitivity was assessed separately for conditions expected under the ATEAM scenarios A1FI and B2. From the original list of pressures only three dominant pressures were selected for the final evaluation (Fig. 5). The reduction was applied also for the number of services; omitting the services flood protection, landscape aesthetics and species biodiversity. These decisions were based on the semi-quantitative assessment of the importance of individual pressures and services to the Eisenwurzen region.

ECOSYSTEM SERVICES	**PRESSURES**						
	Potential impact	Drought		Floods		Land abandonment	
	Scenario	***A1***	***B2***	***A1***	***B2***	***A1***	***B2***
	Food production	--	-	-	-	-	--
	Wood production	-	-			+	++
	Drinking water	--	-	-	-	+	++
	Tourism/recreation	--	-	--	--	-	--

Legend	Description
--	High negative sensitivity
-	Low negative sensitivity
	Not affected
+	Low positive sensitivity
++	High positive sensitivity

Figure 5: The estimated sensitivity of the ecosystem services to the pressure exposure under SRES scenarios A1 and B2 by 2050.

In general we do expect higher potential impact of drought under A1 scenario due to significantly higher number of extreme drought events. On the other hand, the land abandonment followed by forest area expansion is expected to be more pronounced under B2 scenario (ATEAM results). There is no significant difference in the potential impact of the changes in the frequency of floods, as their overall changes under both SRES scenarios will have similar intensity.

Adaptive capacity

Importance of services for stakeholders (matrix 2)

Matrix 2 enabled us to quantify interests of the stakeholders in the selected ecosystem services and thus helped in the later assessment of adaptive capacity and vulnerability. As apparent in Figure 6 the local and national governments are the most important stakeholders in the region followed by farmers and regional developers (representing also tourist industry). Other stakeholder groups do have considerable interest only in a smaller range of services that are directly connected to their particular area of business.

ECOS YSTEM	**STAKEHOLDER**							
	Importance	Farmers	Develop-ers	Protected area managers	Drinking water providers	Govern-ments	Forestry managers	Enterprises

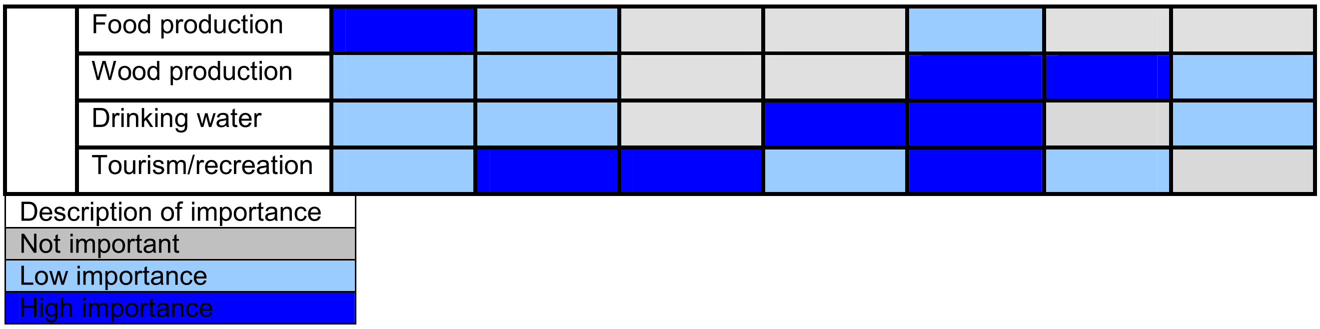


Figure 6: The importance of the selected ecosystem services to the main stakeholders in the Eisenwurzen region.

Assessment of adaptive capacity (matrix 3)

The adaptability of stakeholders to the potential changes in services was assessed within the range of “strong” to “weak” to “no” (or “not known”) adaptability *under both reactive and proactive approach* (Fig. 7). Their adaptive options were listed together with conditions of their application. The option to stop an activity (i.e. no adaptability) was not considered as all stakeholders were found to have at least weak adaptability in services that are relevant for them. Only the selected services were considered. Flood risk managers were omitted from the assessment, as the selected services are irrelevant from their point of view. In assessing adaptive capacity we took into account a GDP increase, and a population decrease as influencing factors (Table 1). There are obvious differences in adaptive capacity of stakeholders if acting in proactive or reactive way, in general, the adaptive capacity is lower when stakeholders would respond in reactive way.

Local farmers have a weak adaptation capacity for changes in wood production and in drinking water provision. If necessary, they can change their production strategies (e.g. start growing more suitable species of trees) and replant the burnt or pest-affected area, even though with additional costs. In this they are quite limited. They are also limited in facing a potential lack of drinking water, however they can build new wells, keep less livestock or decrease water pollution by lower use of fertilizers. The last two options would lower their income, which is a long-term constraint. Local farmers are strongly adaptive to induced changes in food production and in recreation/tourism. They can change production strategies (e.g. switch crops, apply irrigation, fertilizers, benefit from ecological farming and eco tourism) or change technology.
The adaptive capacity of **regional developers** is week in food, wood and drinking water provisioning services. In case of decrease in regional food and wood production their possibilities are very restricted (e.g. organize local products markets). They can promote building new infrastructure for drinking water provisioning or influence the planning in this sector. They are strongly adaptive to changes in the tourism/recreation sector by means of advertisement, increase in the quality of offered services and promotion of new attractions.
For **managers of protected areas** only recreation and tourism is relevant but in this case they have strong adaptability. Their options are similar to those of regional developers: advertisement, increase in the quality of offered services and promotion of new attractions.
For **water suppliers** the two relevant services are the drinking water provision and recreation/tourism. In both cases their adaptability is strong. They can for example take water from other locations or catchments, build more reservoirs and new pipelines or raise prices of water.
The **national or regional governments** have strong adaptive capacity to changes in all four selected services. They can regulate food production by means of EU or national

agricultural policies, as well as offer subsidies for reforestation or protection of forests against threats. They also can regulate prices of drinking water and stimulate tourism by subsidies, advertising and enhancing the quality of its services.
The **forestry managers'** adaptability is weak in respect to increase of the tourism sector and thus increased pressure on forests to be used as recreation areas. Their answer to the pressures is limited to lobbying or regulation of tourism activities (in the forest). Forestry managers have a strong adaptive capacity in facing wood production changes. They have the same options as local farmers, but at the same time more money to realize them: change production strategies (e.g. start growing more suitable species of trees) and replant the burnt or pest-affected area.
Enterprisers are weakly adaptable to shifts in the drinking water provision. They could bring water from other areas, increase water efficiency, but it will require additional costs. They have strong adaptability to changes in the wood production sector as they can import wood from other regions or countries.

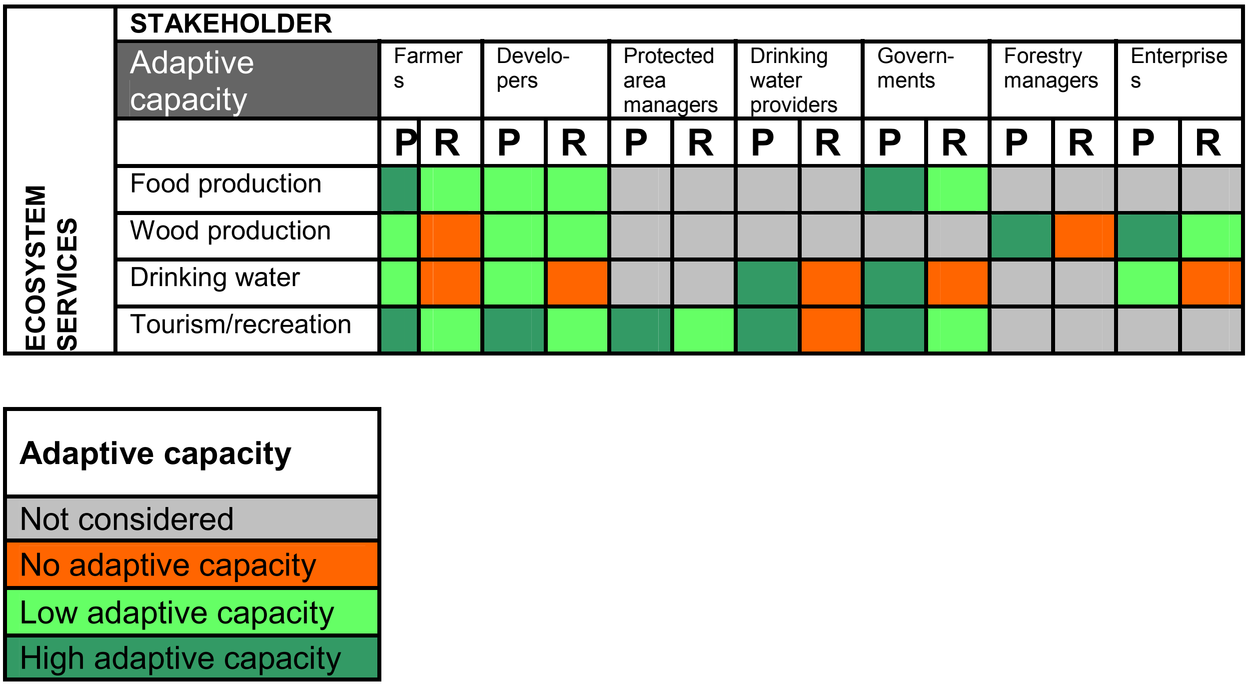
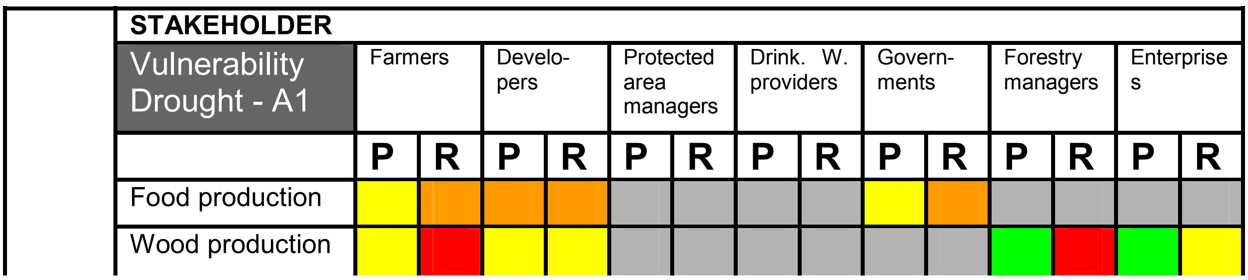


Figure 7: Adaptive capacity of stakeholders to changes in ecosystem services under both pro-active (P) and re-active (R) approach.

Conclusion

Figure 8 to 12 give detailed results for the level of vulnerability of stakeholders to environmental changes.



	Drinking water														
	Tourism/recreation														

Adapt./Pressure	Low	High
Non-existent	High vulnerability	Extreme vulnerability
Weak	Medium vulnerability	High vulnerability
Strong	Low vulnerability	Medium vulnerability

Figure 8: Vulnerability of stakeholders to changes in ecosystem services caused by droughts under the A1 scenario.

	STAKEHOLDER														
	Vulnerability Drought – B2	Farmers		Develo-pers		Protected area managers		Drink. W. providers		Govern-ments		Forestry managers		Enterprises	
		P	R	P	R	P	R	P	R	P	R	P	R	P	R
ECOSYSTEM SERVICES	Food production														
	Wood production														
	Drinking water														
	Tourism/recreation														

Figure 9: Vulnerability of stakeholders to changes in ecosystem services caused by droughts under the B2 scenario.

	STAKEHOLDER														
	Vulnerability Land-abandonment A1	Farmers		Develo-pers		Protected area managers		Drink. W. providers		Govern-ments		Forestry managers		Enterprises	
		P	R	P	R	P	R	P	R	P	R	P	R	P	R
ECOSYSTEM SERVICES	Food production														
	Wood production														
	Drinking water														
	Tourism/recreation														

Figure 10: Vulnerability of stakeholders to changes in ecosystem services caused by land abandonment under the A1 scenario.

	STAKEHOLDER														
	Vulnerability Land-abandonment B2	Farmers		Develo-pers		Protected area managers		Drink. W. providers		Govern-ments		Forestry managers		Enterprises	
		P	R	P	R	P	R	P	R	P	R	P	R	P	R

	Food production														
	Wood production														
	Drinking water														
	Tourism/recreatio n														

Figure 11: Vulnerability of stakeholders to changes in ecosystem services caused by land abandonment under the B2 scenario.

	STAKEHOLDER														
	Vulnerability Floods - A1, B2	Farmers		Develo-pers		Protected area managers		Drink. W. providers		Govern-ments		Forestry managers		Enterprises	
		P	R	P	R	P	R	P	R	P	R	P	R	P	R
ECOSYSTEM SERVICES	Food production														
	Wood production														
	Drinking water														
	Tourism/recreatio n														

Figure 12: Vulnerability of stakeholders to changes in ecosystem services caused by floods under both the A1 and B2 scenarios.

The most significant conclusions are as follows:

- **Local farmers** are highly vulnerable with regard to changes in the service drinking water supply (as affected by droughts) even in a proactive response attitude. Under a reactive response attitude their vulnerability is extremely high including also the service wood production.
- **Regional developers** are highly vulnerable with regard to a change in food production and drinking water under a proactive response attitude. Recreation and tourism services emerge with the same level of vulnerability under a reactive response.
- **Protected areas managers** are vulnerable only with regard to a change in recreation and tourism services.
- **Drinking water providers** are highly vulnerable to changes in the supply of drinking water and changes in tourism services under a proactive and extremely vulnerable under a reactive response attitude (as an effect of increased droughts and floods).
- **The Government** is highly vulnerable to a change in the drinking water service under a proactive response and extremely vulnerable under a reactive response attitude. In the latter case the government is highly vulnerable also to a change in food production and tourism.
- **Forest managers** are extremely vulnerable to a change in services only under a reactive response attitude (as an effect of drought).
- **Enterprisers** are highly vulnerable to a change in the drinking water service under a proactive (as an effect of drought) and extremely vulnerable under a reactive response attitude.

Generally the vulnerability is more pronounced in the A1 than in the B2 scenario. The local farmers and regional developers are the most vulnerable stakeholders even when responding proactively to expected negative changes in services. However, each stakeholder is vulnerable in at least one service. Extreme climate events are the most important pressures for vulnerability.

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