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Vulnerability case study of Australia

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1 Introduction

Within the framework of the AVEC summer school entitled "Integrated assessment of vulnerable ecosystems under global change" we learned how socio-economic and ecological changes affect ecosystems and in which ways different services can influence the changes. To practise and understand the knowledge acquired about vulnerability, exposure, sensitivity, adaptive capacity, stakeholders influence and scenario development the students were divided into groups. This report will present the results of the fourth working group, whose study region was Australia.

Australia is not only a country but also a continent whose size is about 7.7 million square kilometres. Because of its size and isolation Australia's biodiversity is very large with many species that are not found anywhere else in the world. Its range of socio-economic and ecological components is also very broad. Furthermore, the climate ranges from tropical (monsoonal) in the north to temperate in the south. Australia has 19.7 million inhabitants (estimated, July 2003) with a growth rate of 1.4%. 85% of the people live in urban and 15% in rural areas.

But as in countries all over the world there are problems, e.g. soil erosion, polluted agricultural runoff, extinction of species, high amounts of greenhouse emissions and urbanisation. As a smaller study region we decided to choose New South Wales, which includes a coastal, a mountainous and a flat agricultural area.

2 Conceptual framework

In this report the following definitions will be used in drawing up the vulnerability assessment:

- the *vulnerability* of a system is the sensitivity of the system as a reaction to exposure and its adaptive capacity.
- *sensitivity* is the degree of change as a response to exposure.
- *exposure* is the set of driving forces on the system.
- *adaptive capacity* is the ability of the system to adapt to or recover from change; it comprises an autonomous adaptation of the system as well as a human management induced adaptation.

These definitions represent a causal relationship which can be explained by the following example: if a person is punched in the arm, the punch or exposure is the cause. Depending on the sensitivity of the person his or her arm will become more or less bruised (the effect). How well the person recovers, by him- or herself or with help from others, or how well the person can adapt to the new situation (e.g. by covering up his or her arm) expresses the adaptive capacity. These definitions differ slightly from the ones presented in the ATEAM project. As shared by many other approaches to vulnerability assessment, the human-environment system is seen as one system with sensitivity and an adaptive capacity. However, autonomous recovery or adaptation of the whole system is also defined as the adaptive capacity, not only the ability to implement planned adaptation methods by humans.

Schematic system: A-B example

To clarify the definition of sensitivity and adaptive capacity, a simplified, exemplary system is defined consisting of two system elements, A and B (Fig. 1). Humans can be part of the system. The elements are faced with a set of exposures from outside the system (can be anthropogenic) to which they may react in a sensitive way (positive or negative). The adaptive capacity of the elements is element-specific and may be an internal property of the system (autonomous adaptation possibly altering the sensitivity of the element) or an external effect of human management (usually called adaptive capacity). The system can vary over time (Δt) and therefore is dynamic. Stakeholders can have different interest in the elements of the system. Elements are defined as sectors, stakeholders, ecosystems or ecosystem services. Thus, humans can be take part in the system as an element of the system, as a cause of exposure and/or, of course, as people with a special interest (stakeholders).

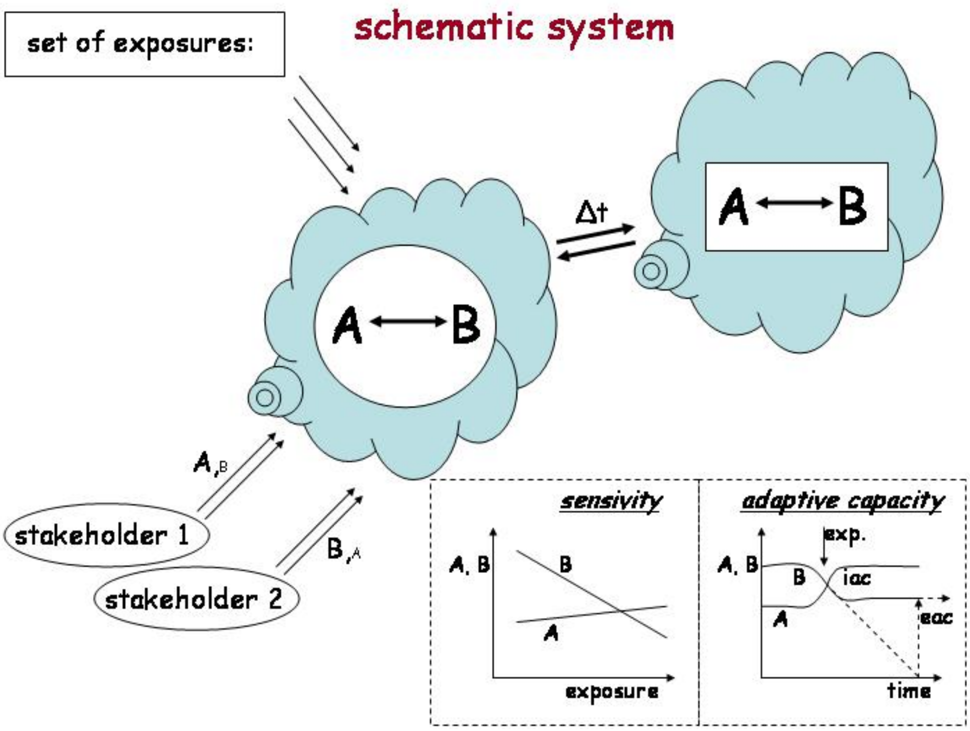

Fig. 1: The schematic system consisting of two interacting elements (A, B), their properties (sensitivity and adaptive capacity), a set of exposures and different stakeholders (1, 2). The system can vary over time (Δt); exp = exposure, iac = internal adaptive capacity (= autonomous adaptation), eac = external adaptive capacity (= human management induced adaptation).

3 Case study Australia: New South Wales

3.1 General introduction to the region

New South Wales (NSW, Fig. 2), with the capital Sydney, was so named by Captain James Cook, who thought that it looked like South Wales in Britain. The total area of the state is 800,628 sq km (800,642 including islands). The border is 4,635km in length, adjoining Queensland, South Australia, Victoria, the Australian Capital Territory and Jervis Bay Territory. The coastline is 2,007 km long, stretching from Cape Howe in the south to Tweed Heads in the north. In NSW there are more than 140 national parks, covering about four million hectares. New South Wales' regions are: Australian Capital Territory, Australia's Holiday Coast, Central Coast, Central West, Greater Western Sydney, Far West, The Hunter, Illawarra, Cooma-Monaro, Murray, New England - North West, Northern Rivers, Orana, Riverina and Sydney. The population of the state in 2002 was 6.7 million including the aboriginal population – 121,142 (28.7% of all Aboriginal people in Australia (www.nsw.gov.au, access: 26.09.03)). The longest river is the Murray Darling river system, 3,900km in length. The highest mountain is Mount Kosciuszko with an elevation of 2,228m. Extreme temperatures in NSW vary from the hottest temperature (52.8°C) in Bourke to the coldest (-23.0°C) in Charlotte Pass (not far from Mount Kosciuszko). The area with the greatest difference between its highest and lowest recorded temperatures is White Cliffs, in western NSW, with an extreme range of 57.2ºC. The wettest town is Dorrigo with an average rainfall of 2,004mm/year.

Main exports of NSW include agricultural products (dairy produce, fruit, honey, mutton, poultry, sugar, wheat, wool), forestry products (timber, woodchips), manufacturing and processing (iron and steel, machinery, motor vehicles, paper, agricultural implements, chemicals, clothing, fertilizers, glassware, textiles) as well as mining products (coal, copper, gems, lead, mineral sands, silver, tin, zinc).

New South Wales can be divided into 3 longitudinal parts representing different ecosystems. The Great Dividing Range, or Eastern Highlands, separates the coastal plains from the vast interior plains.

Fig. 2: Case study area: New South Wales

The Murray Darling catchment, which is the main part of the coastal plains, covers more than one million square kilometres, one sixth of Australia, and includes 24 major rivers. The Murray Darling system is predicted to become affected by a combination of decreased average rainfall, higher temperatures and evaporation and higher frequency of extreme events. This would reduce the stream flow (IPCC, 2001). Estimated changes in stream flow in the east-central Murray Darling basin range from 0 to –20% in 2030 and +5 to –45% in 2070 (CSIRO 2001). In relation to these impacts key issues in the Murray Darling basin on water management are: biodiversity, salinisation, water quality, rising water tables, water logging and water scarcity. This would sharpen the competition between different water users, especially where large diversions to river systems are made for industry and irrigation (agriculture). The change is expected to result in water shortages, particularly in winter rainfed systems that are already under stress. Natural values of wetlands in the Murray-Darling basin, already affected by dams and irrigation, would be placed under even more stress by the decline in rainfall.

3.2 Forest fires

Fire impacts range across all scales from local to global and potentially affect ecosystem goods and services as well as the human system that depends on them. More frequent forest fire events over time can be considered as crucial problem for the New South Wales region. Various reasons can be mentioned why this region in particular is prone to fires: the previous management regime was based on Aboriginal fire stick farming practises; the increase in temperature (1° C warmer than average); and strong variations in annual rainfall that are largely associated with fluctuations in the

El Nino Southern Oscillation index, with high ENSO years resulting in droughts of varying magnitude. As a result of global change it is believed that the strength of El Nino events determine drought events. For example, the Canberra wildfire on 18th January 2003 had quite severe ecological as well as socio-economic consequences for the local and regional as well as global scales: loss of biodiversity, change in landscape vegetation dynamics, air pollution, human health problems, etc. More frequent fire events therefore require an integrated approach that brings together ecologists, climatologists, policy makers, vegetation modellers, remote-sensing experts, managers, etc. As climate change projections indicate more favourable conditions for forest fires, fires are crucial issue to consider in this region.

3.3 The regent honeyeater *(Xanthomyza phrygia)*

The regent honeyeater (*Xanthomyza phrygia*) is the key species on the local scale of our study. This bird is recognised as an endangered species at regional, national and international levels. The regent honeyeater has declined from being a common woodland bird of the 1800s to an endangered species with a population estimated at fewer than 1,500 birds.

In our case study, a key species is defined as a species also indicating the presence of certain forest habitats and the quality of these. The regent honeyeater in our case study on a local scale (see Chapter 4) is a key species in terms of both the ecology – i.e. for monitoring the condition of remnants of formerly more widespread woodland ecosystems, and in terms of its cultural value. Defining it as a key species, we have in mind that the presence and protection of this bird species plays a vital role in the development and future of our local system. The bird is a most important factor for ecotourism flourishing in the areas which represent its remaining habitats. For example, most popular local souvenirs are decorated with the image of the regent honeyeater. The honeyeater feed on nectar from flowering trees and rely on those forests in southeastern Australia that are were particularly nectar-rich (such as White and Yellow Box woodland). The main reasons for the diminishing population of the honeyeater are:

- clearing of native open forest and woodland,
- urban development,
- fragmentation, separation and degradation of remaining viable habitats.

There are three major breeding areas of the regent honeyeater, two of which are in NSW (Bundarra-Barraba and Capertee Valley). The development of the Bundarra-Barraba area depends on this species in particular as this is the main attraction for tourists. It generally inhabits drier temperate woodlands and open forest edges, wooded farmland and sometimes-urban areas with mature eucalypts (http//ea.gov.au/biodiversity/threatened/recovery/regent-h-eater; date of access: 22.09.03).

4 Systems of interest for the Australia case study

The Australian continent as a whole was decided to be too large and too complex for a vulnerability assessment given the group's time constraints. Therefore the target region of this study was limited to the state of New South Wales. This scale is called the *regional scale*. At this regional scale the system considers not all imaginable elements, and it is regarded more generally. The system focuses on the interdependencies between the natural landscape and its inhabitants and different anthropogenic uses such as tourism, agriculture and timber production. Important elements are: tourism, agriculture, Aboriginals (they are part of the system and they are stakeholders), biodiversity, water supply, forest and landscape aesthetics (Fig. 3 a).

Nested in this regional scale system an additional *local scale* is analysed, consisting of five selected elements: (eco)tourism, farmers, the honeyeater, nature conservationists and the forest (Fig. 3 b). In this study the local scale elements show only a small part of the regional scale system. They focus on areas providing habitats for certain rare species (e.g. the regent honeyeater). These habitats are endangered by uses such as agriculture or timber, but they are also protected by certain stakeholders (nature conservationists) who are part of the system. The analysis of the local system focuses on local scale issues and needs the regional scale system conditions as the boundary condition.

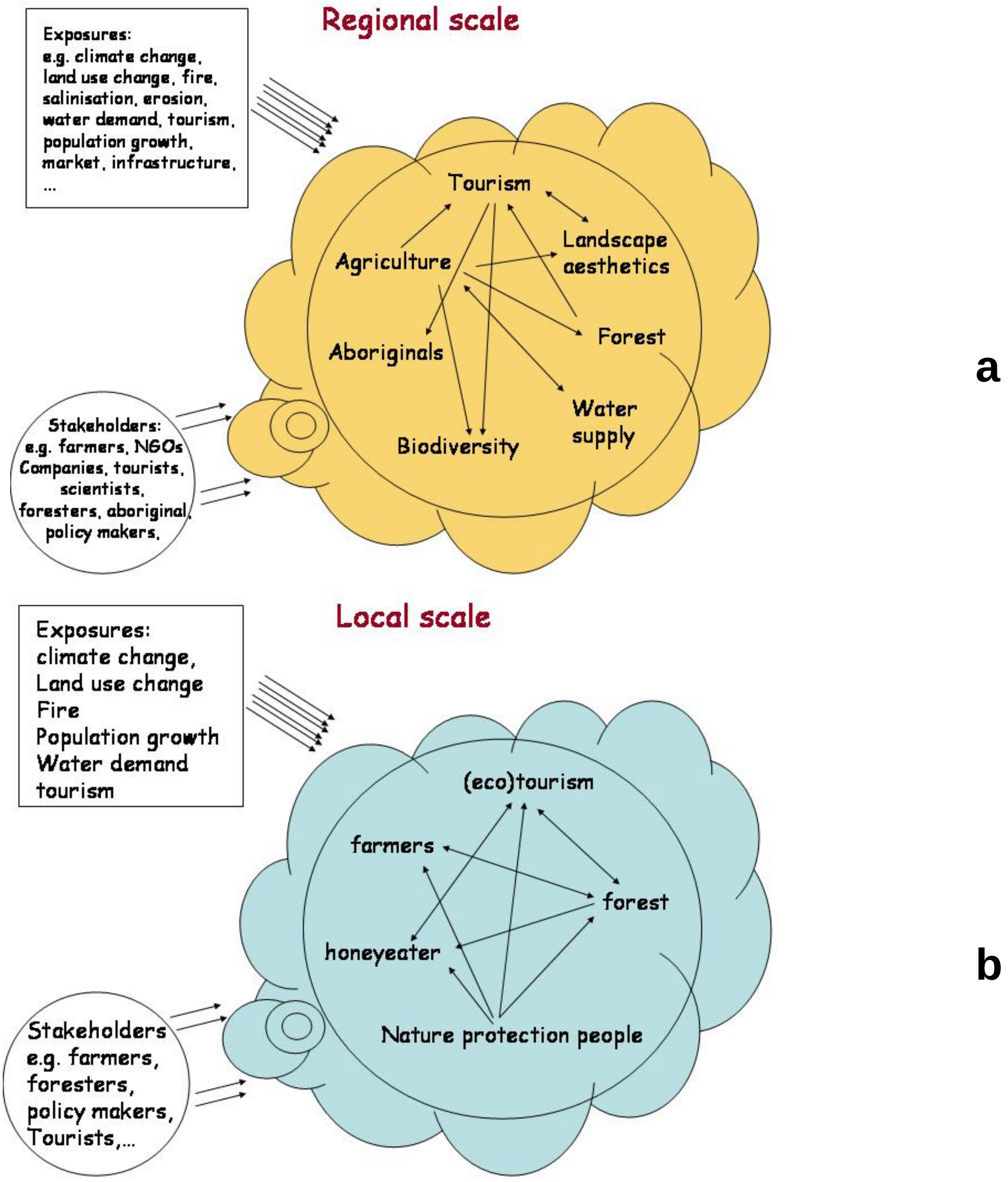

Fig. 3: Elements, exposures and stakeholders of the regional and local scale systems for New South Wales (Australia).

Tables 1 and 2 summarise the system elements, the system properties, possible exposures and indicators of the both systems at the regional and local scales. These two tables are the basis of the vulnerability assessment in the event of the change predicted by the different scenarios. The sensitivity is divided into three qualitative classes (‘L’ = low, ‘M’ = medium, ‘H’ = high) in addition to the direction of the correlation (‘+’ = positive, ‘-‘ = negative). The adaptive capacity is also divided into the three qualitative classes (low, medium, high). The classification is based on expert knowledge. Indicators have been chosen which describe the status of the system in a quantitative way. Using these indicators makes the assessment more objective and reproduceable.

Tab. 1: System elements, possible exposures, system sensitivities and adaptive capacity, and indicators on the ***regional scale****.*

Elements of the system	Exposure	Sensitivity	Adaptive capacity	Indicators
Tourism	agriculture timber tourism itself land-cover change market (prices)	M (-) M (-) M (-) M (-/+) M (-)	H H H H M/H	no profit
Agriculture	climate change subsidies market water supply	H (-/+) M (+) H (+) H (-)	M L/M M L	yield profit area no farms
Water supply	climate change agriculture population growth demand functions	H (-/+) H (-) H (-) H (+/-)	L L M M	parameters (quality & quantity) [mg/l] [l/p/a]
Biodiversity	land-cover/use change tourism Climate change	H (-/+) L (-/+) M (-/+)	L M M	species (density, number, type, …) habitat
Landscape aesthetics	Land-cover change, Tourism	H (-/+) L (-)	L M	structural heterogeneity perception statistics
Aboriginals	socio-economic changes, tourism	H (-/+) M (-/+)	M M	abundance health well being statistics
Forest	agriculture, timber drought, fires	H (-) M/H (-) L/M (-) H (-)	L/M/H (time) M/H H M/H (spec./time)	area species comp. Health

*Tab. 2: System elements, possible exposures, system sensitivities and adaptive capacity, and indicators on the **local scale**.*

Elements of the system	Exposure	Sensitivity	Adapt. capacity	Indicators
Ecotourism	honeyeater disappearance market / price	H (-) M (-)	L M/H	no profit
Honeyeater	tourism habitat reduction fragmentation nature protection people	L (-) H (-) H (-) M (+)	L L L M	abundance total area patch size
Forest	agriculture drought, fires nature protection people	H (-) L/M (-) H (-) M (+)	L/M/H (time) H M/H (spec., time) M	size species composition health
Farmers	nature protection tourist organisations market, prices, subsidies	M (-) M (-) H (+)	H H M	yield, profit area number (farms)
Nature protection people	farmers' guns	XH (-)	L	fatality rate abundance

5 Scenarios

For the regional as well as the local scales scenarios have been developed for prospective changes in the human-environment system. The time line for these scenarios is 50 years: from 2000 – 2050. These scenarios are constructed by downscaling global scenarios for climate change and emissions (SRES scenarios of the IPCC reports, 2001) to the regional level and from there to the local level. For the downscaling, the elements of the system, at both the regional and local levels, are based on the global scenarios, which describe the prospected changes in each of these elements caused by exposures as well as the interaction between the elements.

5.1 SRES-A1 scenario (regional)

There is increased globalisation, which mainly leads to decision making at the (inter)national level. Therefore, local interests are not taken into as much account. Positive aspects of globalisation are that the economy of Australia benefits from free trade and technological innovations. The Internet facilitates communication and increases access to information, trade and consumption of goods and services. In general there is an overall increase in these things, but if you look in detail you can find differences between societal groups. Rich and innovative groups will benefit much more than poor and traditional groups such as Aboriginal groups and elderly groups. For the first 30 years global population growth is very high. To feed all the people the clearing of forests takes place for agricultural areas and timber production, which leads to a loss in biodiversity, change in landscape aesthetics and overexploitation (salinisation, erosion, increased water stress). After 2030 the population declines and the agricultural land is abandoned and the former habitats, ecotypes and bio-diversity will decline. Tourists would go to the mountains, beaches and cities; thus there would be a negative impact on eco-tourism. In 2040 the government creates one large habitat reserve, which is unsuitable for the honeyeater; therefore it becomes extinct. Local knowledge about the honeyeater is not taken into account because there is no good communication link between the local, regional and national levels.

In the context of climate change the temperature will increase between 0.3 and 1.7° C. In relation to this the precipitation will decrease by 10%. In the region of New South Wales the variability in precipitation is higher and there are more extreme events. There will be heavy rains that will cause flooding and erosion. Higher temperatures and less rain have negative impacts on agriculture, water resources and biodiversity. There is higher water demand because of increased population and agriculture, which have a negative impact on the water supply. Droughts will become more severe in 2030 and therefore agriculture will not be possible in this region but products will be easily transported to that region. In the eastern part of the region precipitation tends to decrease as a result of increased westerly winds. There is a rather high risk of fires as a result of droughts that are strongly associated with the frequency of El-Nino events. The frequency of extreme forest fires will increase especially after 2020, leading to the destruction of habitats and the extinction of endangered species. Rather high technological development will partly allow the re-establishment of the forest. The extinct species will be re-introduced from the other world regions where (if!) they still exist. As a result eco-tourism will return. Since stakeholder participation is minimal, the willingness to work in the community is low.

5.2 SRES-A1 scenario (local)

Community interaction is minimal and representation of local people's interests by the national government is limited. The local farmers used the forest for timber production and afterwards for agriculture. After 2040 the productivity of the agricultural sector is too low to be profitable due to lack of water. Food will be imported from other countries. Regional scale extreme forest fires in the region will destroy the local forest. Since the habitat of the honeyeater is gone, the species becomes extinct in this area. There is no tourist attraction left and the tourists will not visit the area any more. Because of the nature protection lobby the honeyeater may be re-introduced from the other world regions if it still exists. Eco-tourism will then also return. If the honeyeater cannot be reintroduced eco-tourism could focus on areas re-established after fires showing high landscape aesthetics.

5.3 SRES-B2 scenario (regional)

Most of the decisions are made at the regional and local levels and much attention is paid to finding a balance between the ecological and socio-economic environment (e.g. eco-tourism, which contributes to the tourist sector and at the same time conserves the environment). The increase in the economy is less than in the A1 scenario. The borders are not so open and therefore there is less competition, trade and diversity in products. Food and other goods and services are more expensive. Technical changes take place at a moderate rate because information and communication are mostly at a regional level. Since technological changes are slower, more people can adapt to the innovations, so there is less difference between social groups (Aboriginal people and elderly groups are able to adapt). Because of extensive, less production orientated agriculture the products are more expensive.

Due to these facts there is a beautiful landscape with plenty of biodiversity. In the first 10 years this attracts a lot of eco-tourists but since biodiversity is all over the world people are getting bored and the eco-tourist sector will decline.

The population increases but more gradually than in the A1 scenario. Since there is not a lot of trade, the region has to produce its own food and agriculture takes over the natural areas and biodiversity declines after 2040.

In the context of climate change the temperature will increase between 0.2 and 0.8° C. In relation to this the precipitation will decrease by 5%. Higher temperatures and less rain have negative impacts on agriculture, water resources and biodiversity. There is higher water demand because of increased population and agriculture, which has a negative impact on the water supply. Droughts will become more severe in 2040 and therefore agriculture will adapt to crops that need less water. In the eastern part of the region precipitation tends to decrease as a result of increased westerly winds. There is a risk of fires as a result of droughts that are strongly associated with frequency of El-Nino events. The forest fires are as destructive as those of scenario A1 and therefore destroy only small parts of the region. In this case ecosystems can adapt naturally to the impact of the forest fires. Due to local interest in biodiversity and forest, the honeyeater stays because of the good management of local people. A problem for the whole region is that there is habitat fragmentation over a long time since there is no national vision and every local community takes its own decisions independently.

5.4 SRES-B2 scenario (local)

Local communities are very involved and stakeholder participation is high. Nature conservationists are very active on the local scale. Local policy makers have conserved and afforested the land, which resulted in the increase of the honeyeater population. Therefore, the eco-tourism will flourish until 2040. After this time tourists have no interest in the honeyeater. Local agriculture does not change over time because local community does not grow and food supply is sufficient. The local region is not affected by the regional forest fires. The habitats of the honeyeater are not endangered.

5.5 Stakeholder Dialogue

The process of stakeholders' involvement in the vulnerability assessment varies greatly for scenarios A1 and B2. The distinct differences also occur when working at different levels (regional and local).

A1 Scenario (Regional level): Stakeholders who are involved are powerful, profit oriented companies, federations (for example national farming federation), big tourism companies, and government. Scientists are involved as they solve regional problems, for example regional water problems. Nature conservation people, Aboriginals, NGOs and local farmers are not involved in the process as they are minorities. A top-down approach prevails. Decision-making is based on non-open (non-democratic) processes. Usually, discussions take place at closed meetings (expensive hotels, conference venues) and the participants are personally invited. The status of meetings could be described as a "club" of the rich and powerful where regional / national decisions are made.

A1 Scenario (Local level): Stakeholder dialogue on the local scale scarcely exists. It is possible that local farmers can express their opinions if they manage to cooperate with each other.

B2 Scenario (Regional and local level): The process of stakeholder involvement and the ways meetings are organised does not differ greatly regionally and locally. The process of stakeholder dialogue involves all interested groups and it is open to the public. Everyone is free to express his or her opinion and concerns. The diversity of opinions causes difficulties to take final decisions at the regional level. At the local level it is easier to take final decisions because the process is based on local knowledge and community vision prevails. All possible ways of communication are used in order to involve interest groups: meetings, workshops, media and the Internet. The meetings take place locally, and government officials and business representatives are involved. The meetings usually have cultural-ecological aspects, for example fairs, local festivals are organised at the same occasion in order to attract public.

6 Vulnerability assessment - change in vulnerability based on scenario implications

The concluding vulnerability assessment is based on Tables 1 and 2 that evaluate exposure, sensitivity, adaptive capacity for every element in our system on the regional as well as on the local scale and assumptions made in the SRES A1 and B2 scenarios (on the local and regional scales). The assessed vulnerability is illustrated in the following diagrams (Fig. 4 and 5), giving examples in three different ways:

1 Different intensities of one exposure;
2 Combination of exposures on one of the system elements;
3 Differences taking into account regional and local scales as well as different scenarios (SRES A1 and B2) on one system element.

Qualitative results of the vulnerability assessment are summarised in Figures 4 and 5, where the vulnerability under the two chosen SRES scenarios is compared to a reference state which is the current situation. The comparison is qualitative and comprises five classes (++ = strong increase, + = slight increase, 0 = constant, - = slight decrease, -- = strong decrease of vulnerability of a system element). For each element one arrow is drawn showing the five different qualitative states of a change in vulnerability (++, +, 0, -, --). Applying these figures the vulnerability of the system's elements can be compared for different scenarios (as done in our case for the SRES A1 and B2 scenarios). Vulnerability changes of the elements most important for the analysed system on a particular scale are presented on separate axes. Variation of vulnerability ranges as described above from '--' to '++'. The red line in Figures 4 (local scale) and 5 (regional scale) indicates scenario A1 and the green line scenario B2. Comparing these two diagrams it is evident that some issues are important at both regional and local levels, and some, such as the regent honeyeater, are crucial only on the local scale in our case study. Changes of vulnerability depending on scenarios and scales shown in Figures 4 and 5 are also explained by giving the following examples 1, 2 and 3 in Chapters 6.1 and 6.2.

6.1 Change of vulnerability at the regional scale (SRES A1, B2)

*Example 1: Different intensities of **one** exposure (climate change)*

Climate change in terms of temperature increase as well as frequency of droughts (due to El-Nino) is more severe in scenario A1 than in B2. As a result the vulnerability of agriculture shows a high increase in scenario A1, and slight increase in scenario B2 (Fig. 4), because there is still agriculture available and farmers can adapt crops that require less water. In other words it could be said that the adaptive capacity of the agricultural sector in scenario B2 is high.

*Example 2: Combination of **two** exposures (climate change and water use) on **one** of the system elements*

As an example we looked at the element of water supply on the regional scale (Fig. 4), and the result obtained was that vulnerability is rather high for both scenario A1 and scenario B2. In A1, less water is available due to climate change, but also less water is used in agriculture. However, due to a high population increase and a subsequent increase in water use, vulnerability of water supply in A1 is high. In the B2 scenario climate change is less severe, therefore more water is available, but also more is used for agriculture, as agricultural practices is still prevail. However, due to agriculture and population increase, vulnerability increases greatly.

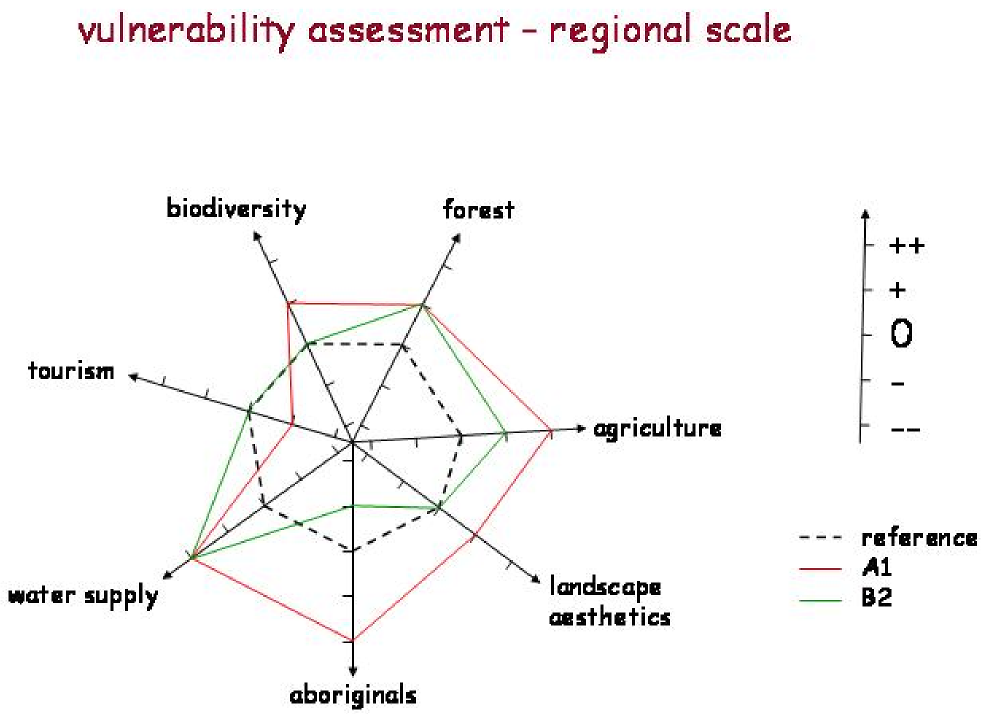

Fig. 4: regional scale vulnerability assessment due to global change scenarios (SRES A1, B2); (++ = strong increase, + = slight increase, 0 = constant, - = slight decrease, -- = strong decrease of vulnerability of a system element).

6.2 Change of vulnerability at the local scale (SRES A1, B2)

Example 3: The differences between the regional (Fig. 4) and the local scale (Fig. 5), between A1 and B2 scenarios.

In giving this example we looked at one of our system's elements – eco-tourism. In A1, regional scale, tourism is less vulnerable since the growing economy, open market and the good and cheap transportation possibilities are a positive exposure. The decline in biodiversity and forests does not have such a big influence because the adaptive capacity of the tourist sector is high. In B2, regional scale, since there is no positive exposure as in scenario A1, the vulnerability of tourism does not change.

In the A1 scenario, local scale, sensitivity of eco-tourism is high because, as one element (the regent honeyeater) is extinct, the attraction no longer exists. On this scale the adaptive capacity of tourism is low. In the B2 scenario, local scale, eco-tourism does not change because the tourist sector does not decline since the perceptions of tourists change over time and they are no longer interested in the regent honeyeater.

Resulting from the analyses for the A1 scenario the trends are the same on regional and local scales; as for the B2 scenario the trends of regional and regional scales are different. This can be explained by the different story-lines: in A1 decisions are taken at the (inter-)national level (top-down-approach) while in B2 decisions are made at local and regional levels (bottom-up approach).

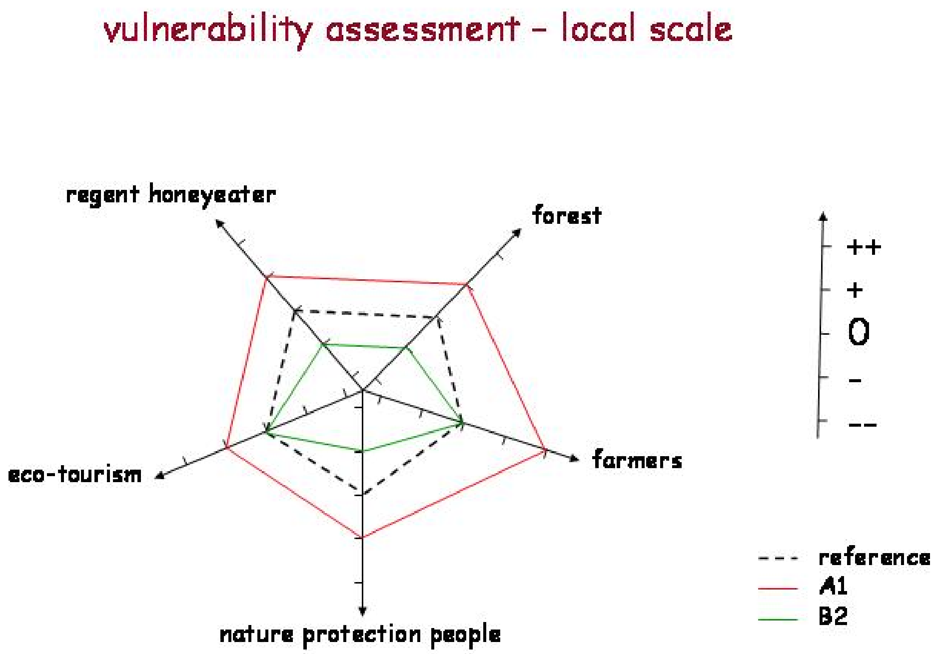

Fig. 5: Local scale vulnerability assessment due to global change scenarios (SRES A1, B2); (++ = strong increase, + = slight increase, 0 = constant, - = slight decrease, -- = strong decrease of vulnerability of a system element).

7 Conclusions and evaluation

The case study has shown that global change scenarios have a significant impact on future vulnerability. Although a consistent methodology was developed and applied focusing on an objective assessment of vulnerability, subjective assumptions and interpretations as well as uncertain data and lack of process knowledge could not be avoided. Even if an objective assessment could be carried out, the evaluation of vulnerability would be based on perceptions and values which are not constant over time and therefore subjective.

The quantification of vulnerability components turned out to be difficult. The aggregation of the results of the vulnerability assessment for different elements is also difficult in the case of variable vulnerability assessments (a decrease in one element does not automatically neutralise an increase in another element).

As shown, the scale effects play an important role in the vulnerability assessment. In the case study on the local scale it was possible to aggregate the results for the different elements because the changes for the scenario-specific changes went in the same directions (increase in vulnerability in A1, decrease of vulnerability in B2).

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