Participatory socio-economic scenario development for land use change: a methodological approach

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Abstract: For the elaboration of adaption strategies to long-term developments, socio-economic changes need to be included. Participatory scenario methods are a creative and flexible approach to consider uncertainties and serve as a transdisciplinary tool for mutual learning. Therefore, socio-economic scenarios provide comprehensive descriptions of future trends enriching climate scenarios. This paper illustrates an applied approach of participatory bottom up generated socio-economic scenarios, which serve in combination with climate scenarios as a base for hydrological modelling. The applied approach resulted in a useful method to include local tacit knowledge and further to activate the dialogue between scientists, practitioners and policy makers. Therefore, we conclude that a participatory scenario development approach is a mean for transdisciplinary research.

Keywords: *climate change, storylines, community resilience, hydrological modelling, local knowledge, regional stakeholders, mutual learning, transdisciplinary integration*

Introduction

Adaption strategies to long-term developments, like climate change, need to consider not only the climate, but also social, economic and other environmental drivers that influence the adaption capacity. Especially social aspects play a crucial role in decision-making processes (Riahi et al., 2017) and furthermore, they frame the practices of stakeholders in the short and medium term more than climate change. Therefore, scenarios serve to project the future of complex, dynamic systems. Whereas climate scenarios refer to uncertainties of physical and biogeochemical systems, socio-economic scenarios refer to uncertainties of the economic, social, political and cultural systems (Berkhout et al., 2013).

The paper contribute to the development of methods for participatory scenario building and describes the process to reveal possible futures of socio-economic changes coupled with climate change scenarios as a base for hydrological modelling. Such encompassing visualizations of possible futures potentially enhance local adaptation and allow regional stakeholders to improve the design for measures to deal with the projected changes. First, the paper gives an overview about scenario methodology. Thereupon, we will present the applied methodological approach for participatory scenario development in detail. After a brief presentation of the hydrological modelling results, we will reflect the methodological process and link those to transdisciplinary research.

Scenario Methods

With the raise of the application of scenario methods, also the definitions as well as the number of different approaches increased (van Notten et al., 2003). Scenarios do not forecast or predict the future, instead they describe a possible future considering several parameters of change. They represent a creative and flexible method to consider uncertainties; however, therefore they need to be plausible and consistent. Plausibility refers here to logical descriptions and explanations of the future; additionally internal consistency between the identified key drivers is important (Mahmoud et al., 2009). In practice, scenarios serve multiple functions: to support research, to facilitate public learning and discussion, and to support political decision-making (Reed et al., 2013)

Socio-economic scenarios conduce to complement climate scenarios and are defined as “plausible representations of the future based on coherent, and internally consistent, assumptions about the evolution of key social and economic drivers. Examples of these drivers are economic growth, technological development and population. They are not intended to be predictive, but are designed to explore the implications of different futures“(nature, online). Additionally, the climate change research community added so-called ‘Shared Socioeconomic Pathways’ (SSP) into the new scenario framework, which are quantitative projections of major socioeconomic, demographic, technological, lifestyle, policy, institutional, and other trends complemented by narratives to make those trends more concrete and easier to understand. The narratives of the different SSP are based on alternative socio-economic developments considering main social and economic scenario drivers mentioned above (Riahi et al., 2017). We distinguish socio-economic scenarios from the above mentioned SSP, as they do not necessarily include quantitative information and can also be completely based on qualitative information.

Several methods serve to generate socio-economic scenarios or SSP. Nilson et al. (2017) distinguish between top-down and bottom-up approaches. Whereas top-down approaches start from the global perspective (e.g. global SSP), bottom-up approaches are based on the perspective of a local region. Subsequently, bottom-up approaches include local tacit knowledge whereas the others rely on global expertise. Thus, narratives of the socio-economic scenarios are in the top-down approach developed by experts and in bottom up approaches by local stakeholders. However, participative research methods translate local knowledge into suitable data for further use (Bay-Larsen and Hovelsrud, 2017).

The integration of local knowledge in participative approaches contributes further to increase the legitimacy of the socio-economic scenarios (Nilsson et al., 2017). Moreover, the development process of participative scenarios facilitates to bridge gaps; not just between experts, decision-makers and other stakeholders, but also towards the research community (Mallampalli et al., 2016). Reed et al. (2013) identify a generally increased awareness for the necessity to include stakeholder participation for scenario development, however, the degree as well as the form of participation varies greatly. Underlying scenario content either derives from expert information (O’Neill et al., 2017), from researcher knowledge or from participatory approaches (Reed et al., 2013). The local knowledge deriving from participatory approaches may in any case validate or deepen research-based scenarios (Walz et al., 2007). An advantage of participatory scenario development is that it potentially makes the scenarios more relevant to stakeholder needs and priorities, extends the range of the elaborated scenarios, develops in depth scenarios through the integration of local and scientific knowledge, and finally, encourages adaption to future change among the stakeholders (Reed et al., 2013). The degree of participation differs from a single to several workshops. In addition, methods of participatory stakeholder engagement vary from facilitated discussion and ranking exercises, multi-criteria evaluation to conceptual system or mediated systems modelling. However, the choice of involved stakeholders strongly influences the outcome of the scenarios, and therefore age, gender and background (e.g. socio-economic status) should be considered in the selection of stakeholders (Reed et al., 2013).

In the scenario development, different forms of scenarios occur. Whereas a baseline scenario develops the ‘business-as-usual’ state further, climate scenarios highlight future projections of the climate, and socio-economic scenarios comprise the complex configurations of a socio-economic system (based on social and economic capital). An environmental scenario integrates environmental factors and its consequences for natural ecosystems or social-ecological systems (McCarthy et al., 2001). Especially the environmental future is linked to other domains, thus depends on the future pathway of socio-economic and climate change. Therefore, credible environmental scenarios include socio-economic and climate drivers (Mahmoud et al., 2009). A comprehensive scenario should include biological, physical as well as human factors and is based on a combination of data, information, experiences and estimations (van Notten et al., 2003; Palang et al., 2000). The scenario funnel (see Figure 1) illustrates the characteristics of the scenario approach. Within the funnel, the present lies at its narrowest point and the future develops along the funnel. The bigger the funnel becomes, the more insecure is the assumption about the future. Within the funnel, different alternative futures are portrayed. The trend scenario in the middle describes a continuation of the current situation into the future without considering any particular changes; above it, different positive alternative futures whereas the lower scenarios symbolize possible negative futures (Mahmoud et al., 2009).

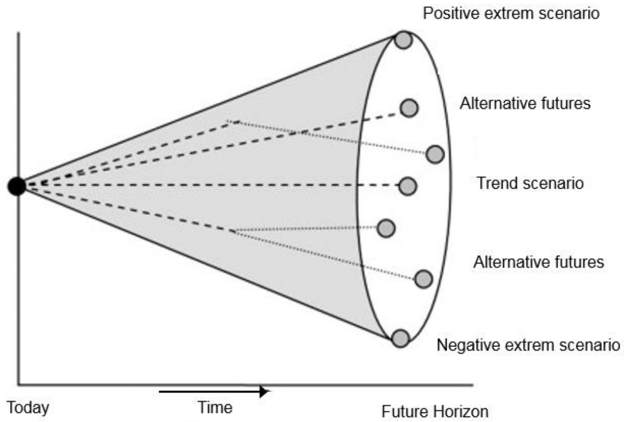

Figure 1. Conceptual diagram of a scenario funnel. Source: adapted after Mahmoud et al. 2009

So-called wicked problems, such as climate change, demand for creative solutions that are going beyond disciplinary approaches. Therefore, inter- and transdisciplinary research based on stakeholder integration are needed (Bernstein 2015). As presented above, there are several methodological frameworks for scenario development, some of them do not simply require the interaction of several scientific disciplines, but also involve stakeholder knowledge. Processes potentially extend the simple query of knowledge, and favour a process of mutual learning. Melanie Kröger and Martina Schäfer (2016) argue that scenario development is a tool for interdisciplinary knowledge production and mutual learning among researchers. However, no universal ‘recipe’ for application in any given research context exists. In contrast, transdisciplinary approaches always demand an adaptation to the particular context of its setting. Finally, the context guides the principles and methods to apply (Lang et al., 2012). In the implementation of such transdisciplinary research processes, participative approaches demand considerable resources of money and time. The latter does not just concern researchers; the proactive stakeholder engagement throughout the project duration needs also their commitment (Bohunovsky et al., 2011). Moreover, there is the challenge of quantifying qualitative information described in narrative scenarios for scientific modelling. Mallampalli et al. (2016) present several methods for translating narrative scenarios into quantitative data of land use change. Depending on the scale, purpose, level of participation and the given budget, appropriate methods include agent-based modelling, fuzzy cognitive maps, pairwise comparison or Bayesian networks. In conclusion, they argue that an appropriate approach for scenario development is a creative combination and adaption of the presented methods and that a comprehensive scenario approach demands rather a creative combination or an adaption of those methods.

Applied scenario approach

This paper builds on an empirical study, where bottom up generated socio-economic scenarios serve in combination with climate scenarios as a base for hydrological modelling of water run off in a defined catchment area. Starting from qualitative socio-economic scenarios, a transformation of information is needed for the sub-sequent spatial modelling of the land use changes and consequences for water run-off. The project “Storylines of Socio-Economic and Climatic drivers for Land use and their hydrological impacts in Alpine Catchments, STELLA”, funded by the Austrian Climate and Energy Fund within the Austrian Climate Research Program (6^{th} call) investigated the co-evolution of coupled climate and land use change, especially for forest management, and the related impacts for the hydrological cycle of the Alpine catchment Brixental (Kitzbuehel Alps, Austria). Additionally to the scientific objectives, the results of the project provide a basis to local decision makers for future land use planning and water management. Project partners included two groups at the University of Innsbruck (Department of Geography as project leader and responsible for the hydrological modelling, and the Department of Sociology responsible for developing the socio-economic scenarios), and the Institute of Meteorology at the University of Natural Resources and Life Science in Vienna, responsible for providing downscaled climate scenarios. The project examined the hydrological impacts of changing climatic conditions combined with land cover and land use changes connected to different socio-economic patterns.

This paper focusses on the method of participatory local scenario development. Extending the claim from Kröger and Schäfer (2016), we show here that scenario development has the potential to be a tool for transdisciplinary integration, as shared knowledge production and mutual learning does not just occur among different disciplines, but also between scientists and non-scientists, such as practitioners and decision-makers. We will further point out that the coupled storylines of socio-economic and climate change scenarios, elaborated on land use and its consequences for the hydrology, provide concrete illustrations for a desirable future development and may result in tangible measures for adaptation to climate change launched by participating stakeholders.

The rest of the paper is structured as follows: After an introduction into the project site and the situation of forests and forestry there, we elaborate in the main part of the paper the method to develop the socio-economic scenarios in detail. The last section describes the results and discusses the implication of the participative stakeholder process on further steps to implement them in regional planning processes.

Project Site

The project site is located in the east of the federal province of Tyrol/Austria, a part of the Eastern Alps. The area of investigations covers the topographic catchment area of the Brixentaler Ache and its tributaries, an area of 322 km² (see Figure 2). The altitude differs from 525 m above sea level at its lowest point and 2494 m at the highest elevation. The area includes the political communities of Brixen im Thale, Westendorf and Hopfgarten im Brixental as well as parts of Itter, Kirchbichl, and Wörgl. Today, forest covers 43% of the Brixental catchment (BMLFUW, 2007). Due to the extensification of Alpine pastures, forest re-growth can be observed in many areas (Tasser et al., 2007). It has to be noted that in the project area the present tree line has been lowered artificially by agricultural activities, to establish alpine pastures. Forests would even by now potentially cover the area up to the highest ridges. The proportion of the total forestland area in Tyrol has increased from the 1960s to 2010 by almost 3% and is currently at 41.2%. Since the 1960s, the forest area in Tyrol is growing annually by approximately 800 ha. This is mainly due to the effects of socio-economic change in agricultural land use: while fields in the valley, where machinery can be used, are cultivated more intensely, hillsides and mountain areas requiring manual labour are abandoned of agricultural use and reforested. The effects of climate change and agricultural extensification of marginal land accelerate this process, also above the present tree line. Thus, the largest increase of forest is presently observed in the subalpine and alpine regions. This process is a result of individual farm strategies. On the one hand farmers need to run the farm more and more in part time arrangements with additional (or most often even the main) income from off-farm employment, and on the other hand they have to intensify their land management to stay competitive and economically viable. However, both strategies lead to forest encroachment in Alpine pastures. From the societal perspective, interest in forest for natural hazard protection and as carbon sink is increasing, while at the same time economic considerations become more and more important. Special awareness is arising for the forest as a resource for renewable energy production and timber as a natural construction material. Increasing numbers of harvested timber volumes per year underpin this trend. Therefore, forestry is an important contribution to the local farm income. Nevertheless, forest ownership is changing. Whereas in former times, mainly farmers and farming associations were forest owners, there are a rising number of in-active farmers' forest owners. The differing ownership results in different interest for the forest.

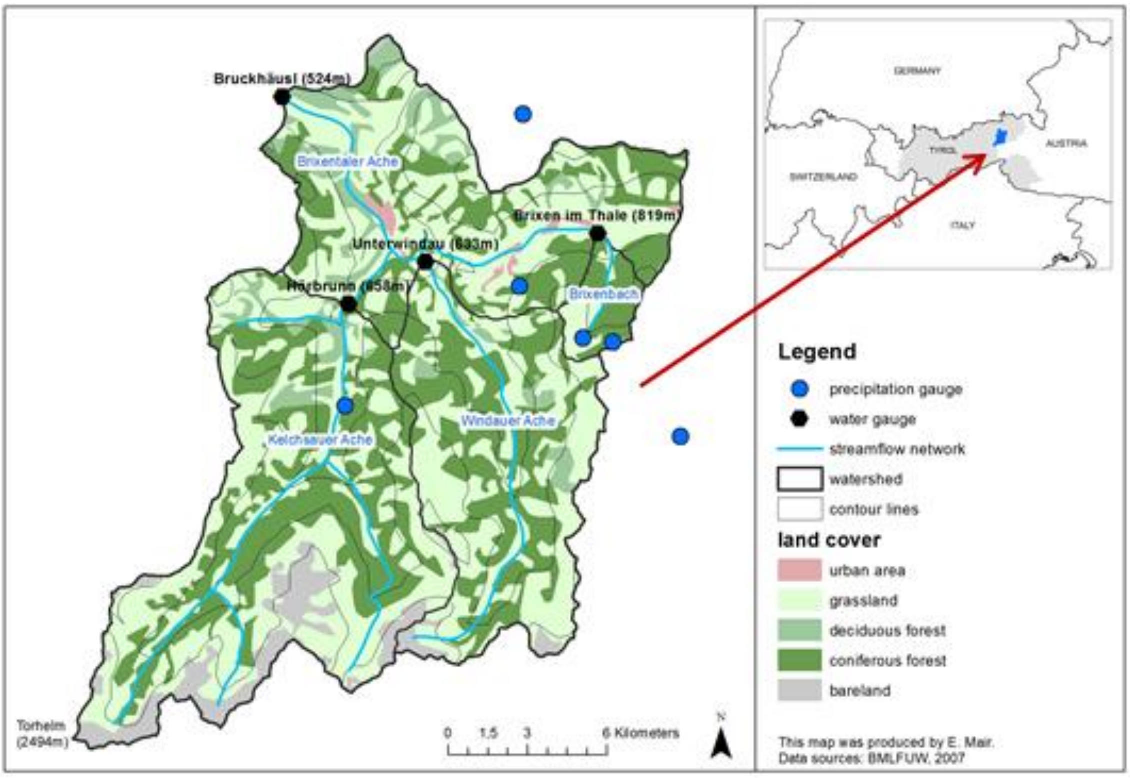

Figure 2. The catchments Brixentaler Ache, Kelchsauer Ache, Windauer Ache and Brixenbach with precipitation and discharge gauges. Precipitation and water gauges operated by the Hydrographic Service of Tyrol.

The participatory development of scenarios

For the elaboration of the socio-economic scenarios in the Brixental we applied the following mixed methods approach: (a) characterization of the forestry system by literature research and expert interviews with local or regional stakeholders, (b) quantitative online survey among local forest owners and (c) development of socio-economic scenarios, which were integrated with climate scenarios.

a) In the beginning of the process, we analyzed scientific publications, public government document and media reports. To gain an overview about the current situation of forest management in Tyrol and to discern actors involved in the forest community, we conducted expert interviews. An expert here is considered as a person with specific knowledge of the field of interest, who represents a certain group of interest (see Bogner et al., 2014). First, two explorative expert interviews were conducted to get access to the field. Therefore, we selected two interview partners with knowledge of the values and behaviour of forest owners and managers, and additionally with expertise of the formal institutional aspects concerning forest management. After those two explorative interviews, the semi-structured interview guideline has been adapted for six subsequent expert interviews. The sample includes rangers and foresters representing the public administration of forests, a timber merchant typifying the economic interest in the wood, a mayor representing the municipalities as forest owners, stakeholders of woodlands, and a forester of the Austrian Federal Forests (ÖBf), all of them based in the project area. The interviews focused on the economic aspects of local forestry, the use of woods, local tree species, obstacles in forest management, legal restrictions, communication and collaboration among stakeholders, future trends, and the impact of climate change. Subsequently, verbatim transcripts of the expert interviews served for their further evaluation. After structuration of the content in economic, ecologic and sociocultural categories, approx. 140 assumptions on the forests function, change and management have been extracted from the transcripts.

Generally, the results of the expert interviews stress the forest as an actively negotiated space, which refers to a vigorous dissemination of information, a dynamic communication, and further to an extensive regulation and organization. Individual perspectives on the forest depend whether the stakeholder has economic, public or mere professional interests in the forest. Futher, human activity has a significant influence on the development and well-being of the forest, which counterbalances 'natural' parameters like climate change. Interviewed experts demonstrated a sceptical perception of the climate change, and understand it most of all as a stimulation process for forest cultivation. However, the capability for a sustainable management system strongly depends on policies as well as short-term events (e.g. economic crises, monetary crises). Consequently, forest owners' management activities influence the forest structure. The timber industry represents a dominant actor in the forest governance. Among the stakeholders, especially between forest owners and public bodies, but also private 'users' (leisure), an ongoing conflict emerged.

b) The ensuing quantitative questionnaire (see Kirchhoff, 2010) aimed to validate (or refute) the previous findings presented in (a) among all forest owners in the project area. Therefore, the 140 assumptions deprived from the qualitative expert interviews served as a base. The questionnaire was created with the software Lime Survey, to be filled in online. The sample included all forest owners of the four municipalities situated completely in the catchment area of the Brixentaler Ache (some municipalities are only partly located in the catchment). Of a total of 902 forest owners, 838 private and 64 legal institutional forest owners, 45 couldn't be contacted, as they recently moved or passed away. All other forest owners were contacted via formal letter with a link to the corresponding questionnaire. The possibility to win a paraglide flight over the project region served as an incentive for participation. Additionally, a short article in the local newspaper with an invitation for the survey was published and the agricultural advisor sent an e-mail inviting all forest owners with agricultural background to participate in the survey.

With 7.1% (n = 64) response rate, the quantitative survey resulted in a low return. Among the respondents, 87.5% were farmers. The size of the forest property of the respondents ranges from 0.4 to 38 ha (arithmetic mean 0.9 ha). 81.3% of the owners lived within 5 km of their forest property, only 4.5% resided in a distance of more than 20 km. Forest owners rated the protective function of forest against natural hazards as very important and appreciated the forest's function to be more important than its economic benefit. In conclusion, the results of the questionnaire analysis underpinned the 140 assumptions, generated on the base of the expert interviews.

c) We based our approach for developing socio-economic scenarios on the concept of community resilience by Geoff Wilson (2012), defined as the capacity of a (geographically bounded) community to absorb natural or anthropogenic disturbances and to reorganize in times of change (see Figure 3). Different social, economic and environmental capitals represent the availability of such resources. Capitals here refers to an elaborated form of Bourdieu's (1986) notion of capital merged with the concept of the three pillars of sustainability (e.g. Baker 2007). Therefore, the resilience of a community, which is under pressure of globalization processes, may react with different configurations of environmental, economic and social capital within the community and result in different strategies towards globalization (relocalized, glocal or super-globalized). Subsequently, a well-balanced configuration of dominant economic, social and environmental capitals contributes to a strong resilience. Whereupon a weak configuration of capital results in vulnerable communities.

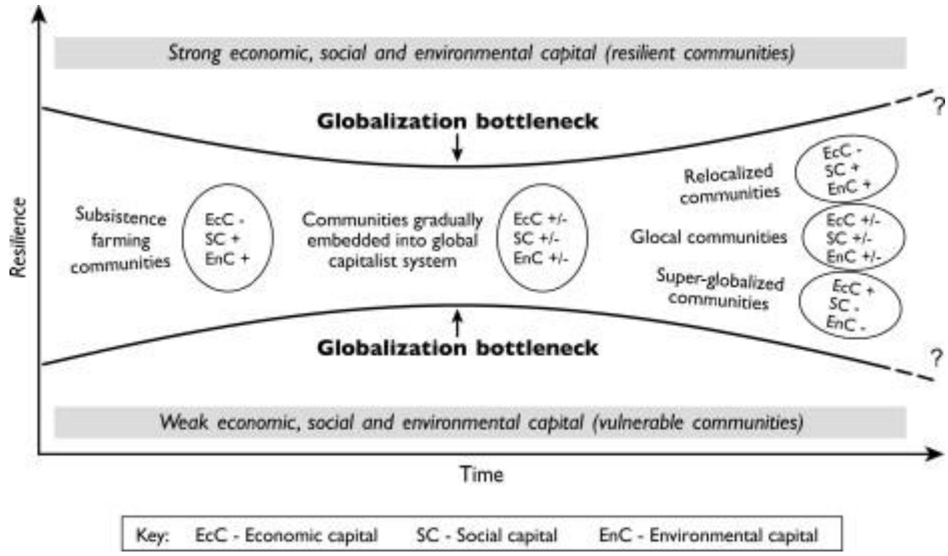

Figure 3. Types of communities and changing community resilience over time. Source: (Wilson 2012, p. 1224)

Starting from these basic considerations, we integrated the results of the preceding qualitative expert interviews and quantitative surveys. We therefore first identified several influencing factors on the forest management and grouped them in four categories, namely policies, economy, social aspects and temporal issues. According to the response to globalization processes (see Figure 3), we distinguish (i) relocalized, (ii) glocal and (iii) super-globalized development strategies. Describing a resilient and a vulnerable version for each for these three (i, ii and iii) strategies, we elaborated six socio-economic scenarios. These were combined with the two locally downscaled climate scenarios (A1B and RCP 8.5). This resulted finally in 12 scenarios for possible futures as well as one for the trend scenario (see Table 1; Figure 4 yellow boxes). The two climate scenarios represented one moderate (A1B) with an increase of temperature of 2-3 degrees until the end of the century and one extreme (RCP 8.5) scenario with an increase of about 8 degrees, considering the worst case for Alpine regions.

The A1B scenario expects an increase of temperature of around 1.1 °C until the year 2030 with a balanced warming of summer and winter season. Temperature rise will go up until 2050 to 2.2 °C in winter and for 1.9 °C in summer. Precipitation shows in the first half of the 21st century no clear trend, and annual rainfall tends to remain the same in the long-term. However, the seasonal rainfall will shift from summer to winter. Small-scale heavy rainfall will increase in intensity of 7-10 % per degree of temperature rise. Generally, effects of the climate change in this moderate scenario remain manageable. The increase of temperature results in a prolongation of the growing period up to three weeks in 2030 and water availability is sufficient. Farming and forestry in the Brixental benefits from the CO_2 fertilization effect. Single dry and hot summers could cause problems, such as declining harvest in grassland farming, a shorter mountain pasture period and bark beetle calamity in forestry. Further, the risk of forest fire rises which remain however rare. Tourism in summer as well as in spring and autumn benefits from the warmer and partly steadier weather conditions. However, the winter tourism suffers from a reduction of natural snow cover and the efforts of artificial snowmaking increases.

The RCP 8.5 scenario expects an increase of temperature of 1.3 °C in winter and 1.9 °C in summer until 2030, and a warming of 2.3 °C in winter and 3.7 °C in summer until 2050. The anticipated precipitation has no clear trend until 2030 and only little changes. However, rainfall will shift from summer (-5 %) to winter (+5 %). Nevertheless, consequences of this scenario remain manageable until 2030. Effects of climate change will accentuate until 2050, which especially affects farming and forestry. Even if droughts in some years reduce the harvest, farming generally benefits from higher temperatures, especially in the lower parts of the Alps. For forestry this conditions cause problems, as the current forest composition (high share of spruce) is not suitable. Also in this scenario, winter tourism suffers from a lack of natural and superficial snow. With the general warming traditional holiday destinations become too warm, so that higher Alpine areas benefit with agreeable climate conditions.

Table 1. Description of the 12 coupled scenarios (reduced here on their implications for forest management)

Relocalized region A relocalized region is based on regional small-scale value chains. Therefore, tourism, agriculture and forestry are focused on internal circular flows. Personal connections and traditional forms of economy are of importance.	**A1B**	In the **resilient** scenario, the forest is mainly dominated by an ecological mixed cultivation with a harmonious age structure, and it fulfils its different functions. In a **vulnerable** scenario, the forest is mainly dominated by a monoculture and the age structure of the trees is in disharmony.
	RCP8.5	In a **resilient** scenario, the forest is ecologically mixed and trees species are adapted to warmer temperatures. Thereupon it fulfils its different functions. In a **vulnerable** scenario, the mixed cultivation is not enhanced and not adapted to warmer temperatures.
Glocal region A glocal region tempts to combine positive aspects of local and global development attributes. Therefore, local value chains are merged with the global marked.	**A1B**	In a **resilient** version of the scenario, the forest is economically used, but even with partly monoculture, an ecological mixed cultivation dominates. In a **vulnerable** scenario, the forest is dominated by a monoculture and its cultivation and economic function is abandoned.
	RCP8.5	In a **resilient** scenario, the forest is economically used and an ecologically mixed, adapted cultivation is dominant. The forest area extends towards higher altitudes. In a **vulnerable** scenario, a monoculture in the forest is not adapted to the warmer and drier climate.
Super-globalized region A super-globalized region is economically completely focusing on the global commodity marked and forestry reacts on international demand.	**A1B**	In a **resilient** scenario, the economic function of the forest is in focus, however ecological standards are fulfilled. Therefore, the cultivation is mixed and the age structure is in harmony. In a **vulnerable** scenario, the forest is first overexploited and consequently abandoned.
	RCP8.5	In a **resilient** scenario, the warmer temperature is seen as an engine of growth and the cultivation of species is adapted. Even if the economic use of the forest is dominating, it fulfils minimum standards of its other functions. In a **vulnerable** scenario, the forest is overexploited and a young monoculture is dominating the forest.

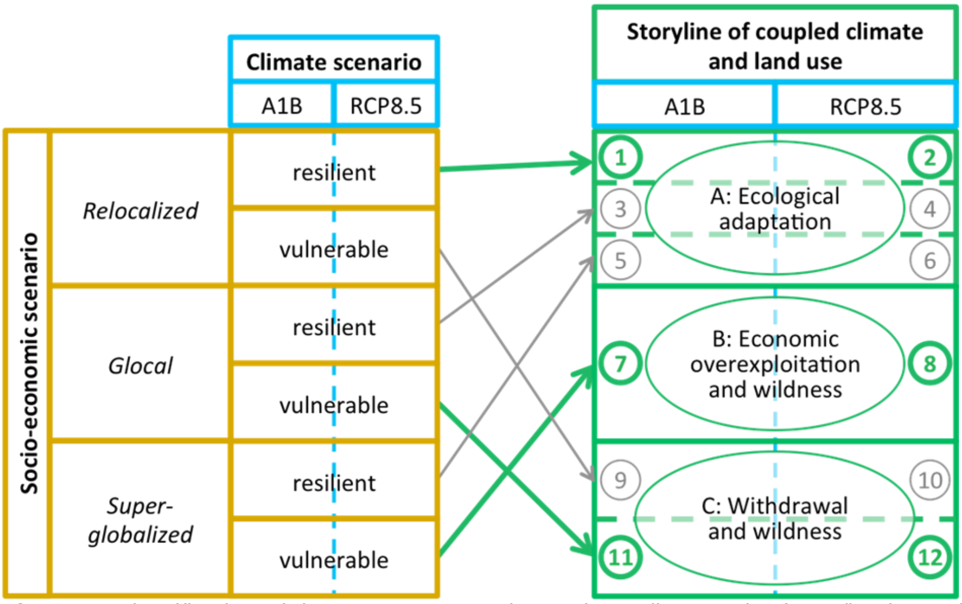

Figure 4. Classification of the STELLA scenarios and storylines to the forest/land use developments. The bold lines indicate the storylines chosen for hydrological modelling.

The elaboration of the scenarios by the researchers was followed by a participatory and transdisciplinary phase to include tacit local knowledge. First, we presented the scenarios to local stakeholders in a workshop, which took place the 25th of November 2015 in Kirchbichl (Tyrol) and was organized and moderated by the Service Centre of the Climate Change Centre Austria (CCCA), a project contractor specialized in communication who was not involved in the scenario development. Fifteen stakeholders and experts, consisting of female and male, local and regional representatives from policy, agriculture and forestry, regional development and spatial planning, hydrology and tourism discussed the socio-economic and climate scenarios on consistency and plausibility. Additionally, they had the possibility, to reject, to complement or to refine the scenarios. Participants were divided into two groups, one focused on the socio-economic scenarios based on the moderate (A1B) climate scenario and the other one examined the extreme (RCP 8.5) climate scenario. In order to facilitate the discussions, the moderate climate scenario was referred to as 'Meran' and the extreme as 'Bologna', as these two Italian cities feature similar recent temperature conditions compared to the applied climate scenarios in 2050 in Brixental. It was a conscious decision that the participants did not have the task to select the scenarios for further investigation, as they would tend to select the most likely scenario. Instead, they were asked to discuss the plausibility and consistency of the scenarios presented. The workshop ended in a shared lunch, which facilitated informal exchange among all participants.

Overall participants considered most features of the socio-economic scenarios as plausible and consistent. They added inputs according to the influence of European, national and regional support systems, the issue of security, natural forces and the issue of hunting and wildlife management. After the workshop, these additional inputs of the participants were integrated into the socio-economic scenarios by the researcher. For the hydrological modelling, we reduced the 12 scenarios to six storylines (see figure 4 green points 4, 1,2,7,8,11,12) according to their underlying effects on land use and forest management strategies. Thus, we finally condensed them to three general strategies allocated a guiding illustrative storyline to each of them (see A, B, C in Figure 4). The researchers discussed the effects on forest management with two official regional representative forest experts during another meeting. Therefore, two forest experts provided figures to translate the qualitative information of the storylines into rules to quantify the effects and to enable the production of transient land use maps with aid of Geographical Information System (GIS) operations (see Figure 5).

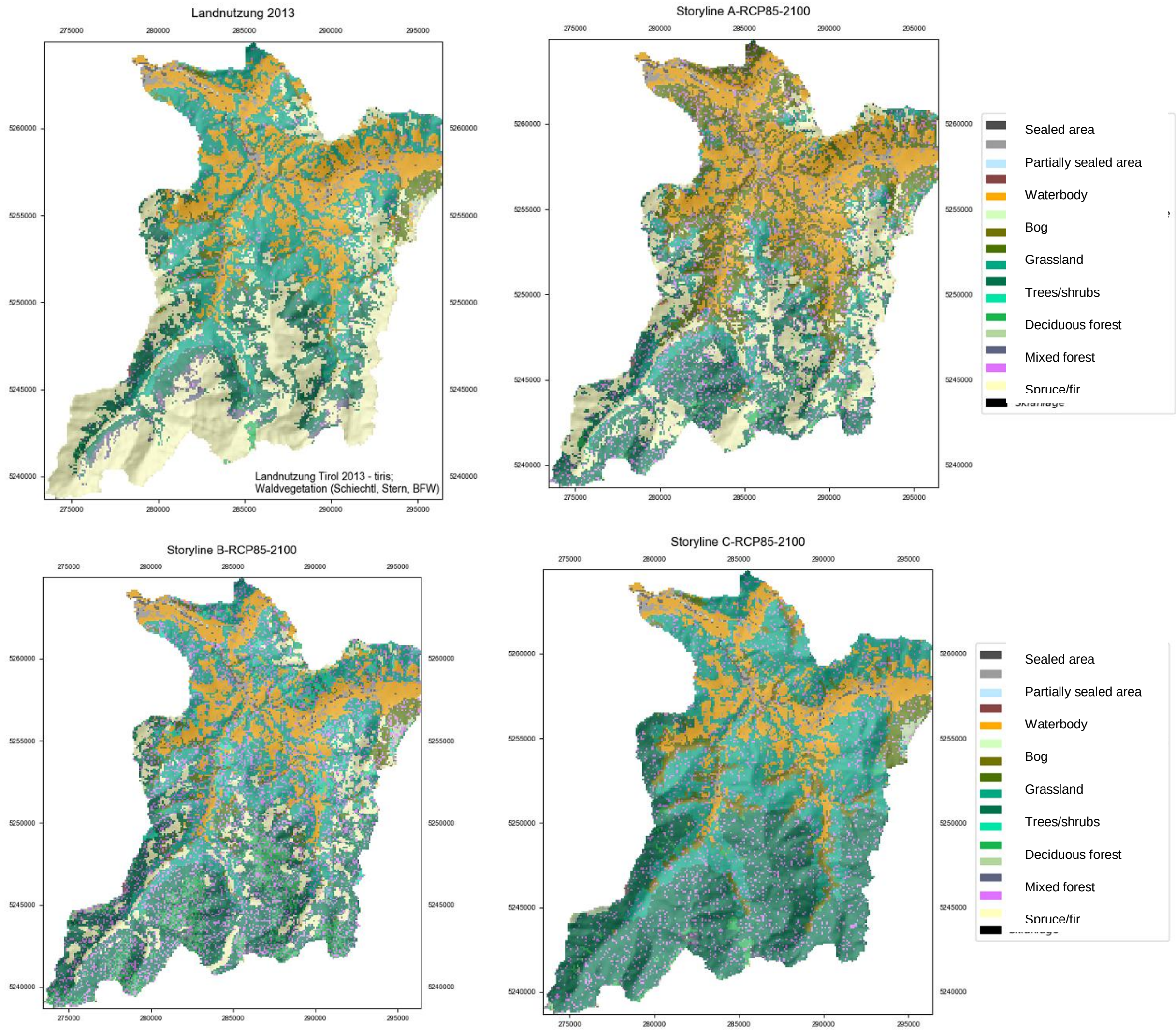

Figure 5. Land use maps: current situation and situation 2100 for the storylines A-RCP8.5, B-RCP8.5, C-RCP8.5

Integration of the storylines and modelling

After running the model calculations, a second stakeholder workshop was held on 30th of May 2017, again in Kirchbichl (Tyrol), once more organized and moderated by the Service Centre of the CCCA. The same 15 stakeholders as in the first workshop were invited, however, only six of them participated. The first aim was the presentation of the project results, including the elaborated holistic storylines with the socio-economic scenarios, climate scenarios and the deprived land use and its consequences for the hydrology. Further, the workshop enabled the researchers to gain another feedback on their work, to possibly integrate the results of discussions into further hydrological modelling. Furthermore, it was discussed how stakeholders perceived their integration into the research process as well as the use of the results for their professional activities and for local/regional development strategies.

Participants of the workshop suggested only minor changes for the storylines. Generally, participants evaluated their participation in the two workshops as enriching. They further suggested disseminating the project results in a non-scientific way to a broad audience, but specifically to agricultural, spatial planning and tourism institutions as well as to majors of the region. Here, especially representatives from regional development expressed a responsibility for further distribution of the information within their region. A press release was published in November 2017 to disseminate results to a broad audience. Further, a concluding factsheet was send to all involved stakeholders for further distribution.

Results of hydrological modelling

Modelling results revealed that, while the forest cover protects against weather extremes and has important features for climate change mitigation as carbon sink, with increased forest cover the run off measured at the river gauge decreases. The run off as measured in the gauges of the river draining the watershed is negatively correlated to the extension of forest cover. While increasing forest cover may prevent or mitigate extreme events of flooding, forests intercept and evaporate further certain amounts of precipitation, which may decrease water availability in the valley in times of minimal rainfall. Therefore, local, regional and national policy measures are proposed to prevent further intensification of farming in more advantaged flat areas at the expense of large-scale abandonment of alpine pastures.

Reflexion on the Methodological Approach

As mentioned above, we used expert knowledge to translate narrative scenarios into quantitative data of land use change. Although Mallampalli et al. (2016) show several methods for this step, we applied another method, which suited best to our approach of scenario development. As presented in detail above, we created our socio-economic scenarios and their resulting storylines on the basis of a mixed methods approach, including qualitative expert interviews and a quantitative survey. During a participative workshop with local stakeholders, they critically examined the consistency and plausibility of the developed socio-economic scenarios. Further on, their local knowledge has been integrated into the scenarios. Thereupon, we confronted experts with the adjusted coupled storylines of land use management, who then provided figures to map the changes of forest cover as a basis to an actual hydrological model. On this basis, hydrologists modelled the changes in runoff water. Therewith, the method served on the one hand side to enrich and deepen the research results with local tacit knowledge. On the other hand side the methodological process and the developed storylines served as an illustration of possible futures for local stakeholders as an impetus to adapt their local action in rural development processes. Therefore, the professional mediation through both stakeholder workshops was a crucial mean to bridge the scientific sphere to the practitioners sphere in this approach.

The press release resulted in considerable resonance on scientific, governmental and regional level. Thus, project results were perceived by regional actors and provoked a discussion among affected stakeholders. The local stakeholders involved in the process, especially the agricultural representatives, will discuss the results further in their regional committees. Therefore, we affirm that our applied approach resulted in a process of mutual learning, with benefits for researchers, practitioners and decision makers (see Kröger and Schäfer, 2016). Even if we cannot yet evaluate whether our way of working encouraged adaption to future change among stakeholders, we deem the debate launched by their participation in the process and the press release of the research results as a positive signal for consideration in future action.

Conclusion

We presented a holistic approach of participatory scenario development and its further elaboration into storylines, which encompasses transdisciplinary values. It proved to be a useful method to include not only the tacit knowledge of local stakeholders, but also to foster the dialogue between scientists, practitioners and policy makers. The combination of different sources of knowledge was a precondition to reduce uncertainties on a regional level and allowed deeper identification of stakeholders with the results. We demonstrated that the approach presented is a mean to transdisciplinary research, as it contributes to bridge the gap between problem solving and scientific research (Lang et al., 2012). Our example on forestry systems presented here can serve to investigate other social-ecological systems with small-scale scenarios, such as on land use changes related to grassland farming systems (see Kohler et al., 2017).

Whereas project budget often limits stakeholder participation (Bohunovsky et al., 2011), the project presented here included this extensive participative approach. Thus, the holistic approach demanded financial resources, but resulted in detailed benefits for the scientific as well as non-scientific communities of this project. Therefore, we recommend comprehensive participative approaches for future research.

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