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Case Study Carinthia / Slovenia – Productive Forests Affected by Climate Change

Robert Jandl, Andrej Breznikar, Marko Lekše,
Christian Tomiczek, Silvio Schüller,
Klaus Dolschak and Hans Zöscher

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1. Introduction

1.1. The present condition

The test area Ossiach Tauern is located in the province of Carinthia (Figure 1). The landscape of the test site is dominated by gently sloped hills. The Ossiacher Tauern is a W-E mountain ridge at the southern side of Lake Ossiach. It ranges from 500 to 1000 m a.s.l. The steep and moderately steep slopes are covered with forests and are north-facing. The upper part of the Ossiacher Tauern forms a plateau. The bedrock is formed of mica schists which are overlain by glacial moraines [1]. The soils are moderately acidic Cambisols (Brown Earths). The nutrient storage and the water-holding capacity of the soils are high.

The Slovenian test area Solčava - Luče lies in the mountain area of the Kamniško Savinjske Alpe on the border with Austria (Figure 1). High slopes and deep, narrow vales are predominant types of landscape. The lowest point of the area lies at an altitude of 455 m a.s.l., the highest peaks rise over 2000 m a.s.l.. From a geological point of view the area is characterized by very diverse bedrocks. The Western part is dominated by a variety of carbonate rocks (limestones, dolomites, marbly limestones). The Eastern part consists of silicate bedrock.

The region of the Ossiacher Tauern is by far dominated by forest land. Figure 2 shows the highly developed area close to the southeastern side of the lake with numerous hotels and guest houses. Grassland and cropland is dominant at the northeastern side of the lake and also interspersed in the main tourism area. Forests are located on the slopes of the Ossiacher Tauern. In lower elevation, mixed deciduous forests are dominant, in higher elevation coniferous



Figure 1. The test area Ossiach is located on the southern side of Lake Ossiach; the test area Solčava - Luče is located about 50 km to the SE just across the Austrian/Slovenian border.

forests are taking over. The lower part of Figure 2 shows grassland embedded in the forest in southeast of the test region. This area is located on the plateau of the Ossiacher Tauern and has been traditionally used as pasture land. The Ossiacher Tauern is basically public forest that is managed by the Österreichische Bundesforste AG (<http://www.bundesforste.at>). The local forest interventions are implemented by the unit in Millstadt/Carinthia.

The region Solčava/Lučé makes considerable efforts as a hiking tourist resort. The landscape is indeed spectacular and includes U-shaped glacier valleys. (Logarska dolina, Robanov Kot), high waterfalls (Rinka at the end of Logarska valley) and several forest reserves (Figure 3). The total area of Solcava/Luce comprises 21 367 ha. Forests cover 76% (16 191 ha) of that area. Agricultural land is confined to the immediate surroundings of farms and to the bottom of the valleys. The settlements are dispersed. The local community centres are the villages Solčava and Luče.

The present climate conditions for the village of Ossiach are shown in Figure 4. The mean annual air temperature is 8.4 °C and the annual precipitation exceeds 1000 mm. The growing season is presently humid. Typical for the area is a secondary autumnal precipitation peak. The forested test area ranges to an altitude of more than 1000 m and due to the elevational lapse the temperatures are lower. The Ossiacher Tauern is only in exceptional years affected by storms.

The climate in the Solčava/Lučé area is characterized by a combination of the mountain climate, the continental influence from the flatlands towards the east, and even the Mediterranean influence from the south. At the main mountain range of the test area the annual precipitation exceeds 2,000 mm. In the village Solčava the annual rainfall is approximately 1600 mm.

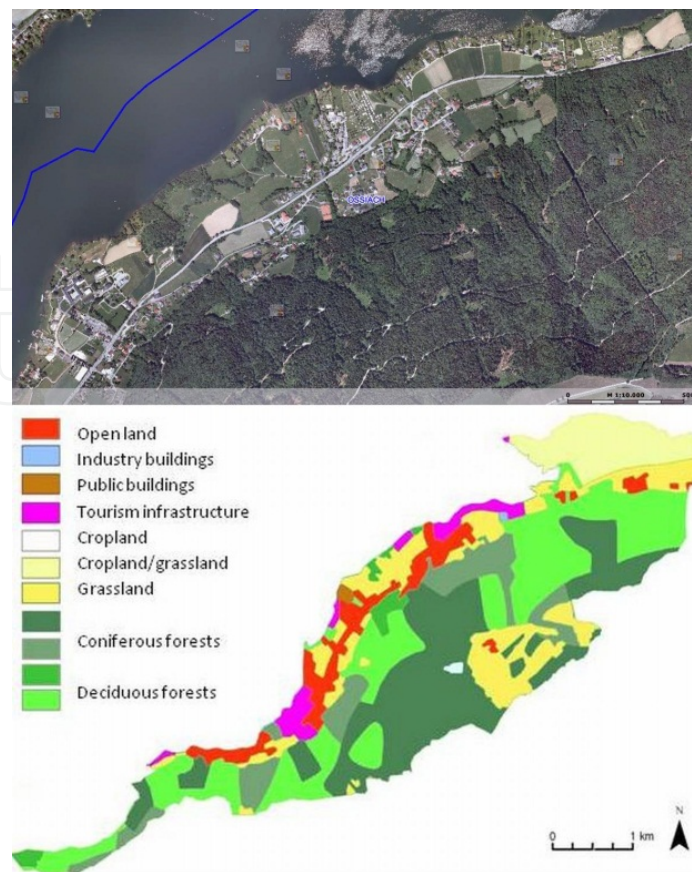


Figure 2. Orthophoto of the village of Ossiach (upper part) and land use categories on the southern side of Lake Ossiach (lower part).

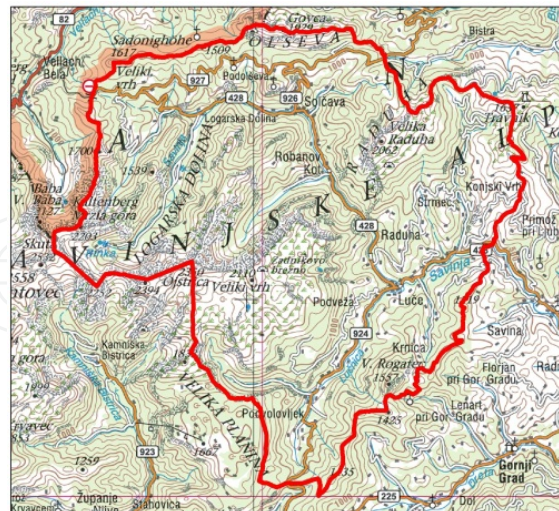


Figure 3. Map of the Solčava/Luče region.

Comparably to the climate in Ossiach, the main precipitation peaks are in June, July and in November. Local observers report recent stronger rainfall peaks in autumn.

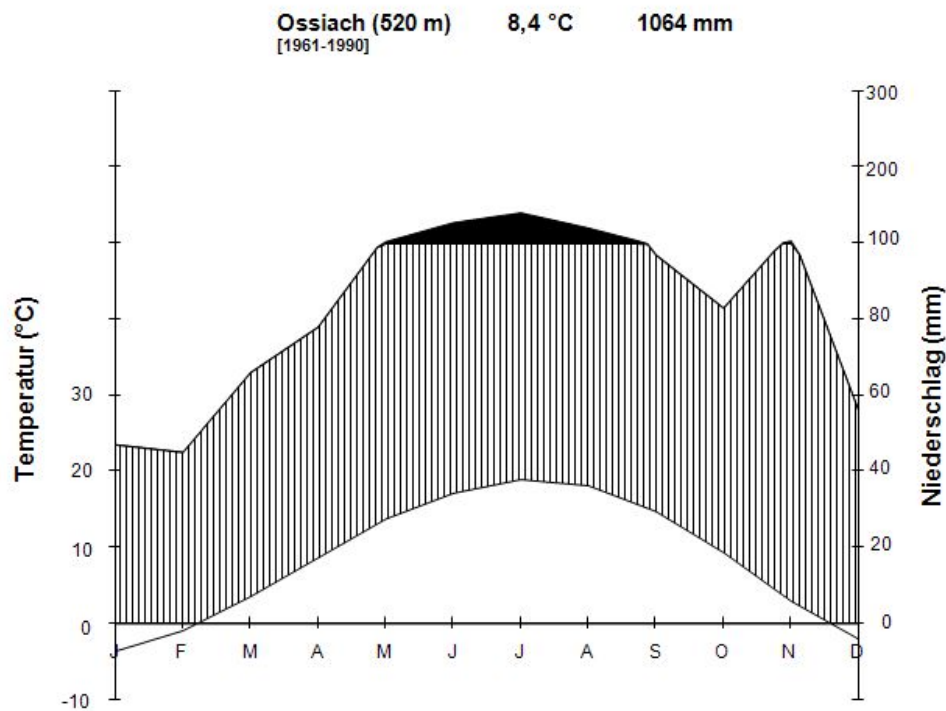


Figure 4. Walter Lieth diagramme for Ossiach based on climate data from 1961-1990.

The average annual temperature in Solčava is 6.4 °C and already 8.2 °C in the nearby town of Luče. In the valleys there are very frequent thermal inversions. Heavy snow and sleet usually occur in the altitudinal range of 700 to 900 m, and in mild winters also up to 1200 m. These events cause breakages in the forest canopy. A typical phenomenon of the region are the storms in the Savinja valley and in higher altitudes.

2. Forestry in the area

The potential natural forests of the Ossiacher Tauern would be dominated by beech [2]. This situation is evident in a small natural reserve where no active management of forests in historic times is on the records. In the larger part of the Ossiacher Tauern beech was actively suppressed from the 1950s onward, in order to make room for Norway spruce (*Picea abies*) and fir (*Abies alba*) that were demanded by the market. Presently, the forest stands are dominated by spruce with substantial proportions of beech and fir. On moist sites in low elevation and on the plateau alder is playing a local role. Further tree species such as oak, maple and larch are rare. Presently, no major obstacles are presented to timber production. The soils are fertile, the water supply is rich, and the pressure from biotic threats is well under control. The area is not particularly exposed to storms.

Presently, the main forest function is timber production. The Ossiacher Tauern has few designated protection forest and water conservation stands. The region of the Ossiacher

Tauern is an important recreation resort due to its location at Lake Ossiach and the proximity of the provincial capital Villach. In order to honor the expectations of tourists towards the scenery and in order to keep the region suitable for hiking activities a close-to-nature form of management is practiced. Thereby, large openings in the canopy are avoided and natural regeneration is the preferred strategy for the establishment of new forest stands.

The natural regeneration includes spruce, beech and fir with little differentiation in the growth dynamics. Larch only establishes on bare soils and is not abundant. Practical forestry is challenged by the vigor of beech. In natural stand dynamics especially the western part of the region would be dominated by beech at the expense of spruce. The species regenerates vividly and would out-compete spruce and fir. In order to achieve mixed-species stands with a dominance of coniferous trees, an early reduction of beech by cleaning (Läuterung) is advised [3]. -- In the upper parts of the Ossiacher Tauern natural regeneration is working very well. In the lower ranges the vital expansion of the herbaceous vegetation calls for small-scale clear-cuts that are later afforested. The plantlets are produced in a central forest garden and the use of autochthonous planting material is ensured. The plantation needs frequent weeding in the first years. - Selective cuttings and group selection are made on a small-scale, preferably where natural regeneration already had established. The low inclination of the slopes allows the use of tractors and does not require setting up cable systems.

The potential threats to the forests are quite limited. Root rot infestation of Norway spruce caused by *Heterobasidium annosum* is not a problem. Beech can be affected by the formation of red heartwood that economically devalues the stems. The remedy is the early harvesting of beech. A common biotic threat is deer browsing. The population density is rather high. The dense herbaceous vegetation and the abundance of seedlings offer plentiful fodder and allow maintaining a high deer density. However, the damages due to deer browsing are actively monitored and the population density is quickly adjusted when needed. - The pressure from bark beetle is generally low because the trees are vital and as such rather resistant to insect attacks. The forest practitioners have observed an increase in the population density of bark beetle in recent years. Additional counter-measures such as the exposure of catch trees and the installation of pheromone traps are already implemented.

The forest management conditions in the Solčava/Luče area are similar. The major part of the area is located in the montane and subalpine zone, and a substantial part of the area extends above the treeline. The forest stands are mostly coniferous (76%). As a consequence of the thermal inversions conifers also dominate in the valleys. Thermophilic tree species such as oak are rare and are confined to only a few places. The most common forest stands are fir-beech forests (Abieti-Fagetum praealpinum and Luzulo-Abieti-Fagetum). Spruce naturally occurs in the montane and subalpine zone forests and has been actively introduced to the entire region.

The average standing biomass stock of the forests in the Solčava – Luče case study area is 329 m³/ha. Spruce contributes 59%, an additional 10% are contributed by larch (*Larix decidua*), 5% by fir (*Abies alba*), and 2% by pine (*Pinus silvestris*). Among the deciduous tree species beech has the most important role and contributes 19% to the standing stock. Noble hardwoods such as maple, mountain ash, mountain elm, walnut, cherry and lime together represent 3% of stock. Larch is present in mixed forests together with spruce and beech and in pure stands at higher

elevations. Fir used to be an important tree in the past, but has strongly declined [4]. Pine occurs mainly in the warmer locations.

The forest surface in the area has been continuously increased in past decades due to reforestation and encroachment of abandoned agricultural land. The consequence was an increase in the standing biomass stock. In addition, the growth rates of the forests increased in the wake of the general trend in Europe [5]. The forests in the Solčava Luče area are mostly private owned (97%). Most common are farm forest estates. These are forests that are an element of an agricultural enterprise.

The main functions of the forests are timber production and protection against natural hazards. Timber is sold mostly as a roundwood, and some is locally further processed to furniture and used as construction wood. In a marketing effort the brand of 'Solčava Larch' has been developed during the last decade in order to raise the commercial value of the timber in recognition of its very high quality. On 12.341 ha or 76% of the area the forests fulfill the purpose of protection. Over 5000 ha are designated protection forests. Their status is declared by a legal act and these forests need to be managed according to special guidelines (Figure 5).



Figure 5. Protection forests in the Solčava Luče area.

The forests are the habitat of a large population of wild-living animals such as deer, roe deer, chamois, and wild boar. Hunting tourism is an important part of a local economy. The high animal density causes frequent damages due to browsing. The efforts of promoting and utilizing natural ecosystem dynamics such as the regeneration of a variety of tree species are therefore compromised.

Practical silviculture engages in a group selection system (Femelhieb) and in the case of mixed stand of beech and silver fir sites also in a selection system. Almost all forests are regenerated naturally. Only in exceptional cases autochthonous seedlings are planted in order to establish high-quality forest stands with a predefined tree-species mixture. Enrichment planting is used

to modify the spontaneously developing tree species composition towards an economically desirable tree species mixture.

Tending measures in forest stands are carried out in all age classes. Most common are tendings in young stands. Presently, only 50% of the planned tendings are implemented. It is well understood that this shortcoming has an adverse effect on the quality and stability of future forests.

3. The expected climate

According to the used climate scenarios of the IPCC A1B and B1 the annual precipitation is going to remain unchanged in the next 50 years and is going to decline thereafter. The unambiguous effect provided by climate scenarios is the increase in temperature and the elongation of summer droughts [6,7]. Even the optimistic IPCC scenario B1 shows an increase by more than 2°C in the next 100 years. A consequence is the increase in drought periods during the growing season, both with respect to frequency and duration (Figure 6). Particularly the change in the precipitation regime is controversially discussed among climatologists because the southern part of the Alps poses a considerable challenge to climate modelers [8]. The models used in the described research project predict less precipitation during the summer months especially in the second half of the century. The increase in the air temperature may be around 4°C in the next century. Besides the mere warming effect such an increase in air temperature may lead to more extreme events [9]. A form of extreme events are heat-waves. From presently approx 30 heat days per year an increase to annually more than 70 heat days is predicted. According to the used models the length of heat waves is expected to increase steadily. The heat waves will not be critical in the high mountain regions, but will have adverse effects on the forests in the foothill areas and in the valleys. For the forests in the region of Carinthia and Slovenia it is expected that droughts are going to be more frequent during the growing season, thereby affecting the vigor and the productivity of the forests. The number of dry days during the productive period is expected to increase by 15 % (Figures 7, 8) [7].

4. Climate change impacts

The expected climate change in the transnational case study area will in the long run affect the dominance of tree species. A valuable tool for foresters is given by the climate envelopes where presence/absence data on tree species can be translated into geo-referenced information [10]. In Figure 8 the climate envelopes for three highly relevant tree species within the experimental area are shown. The left yellow arrow indicates the experimental site in Carinthia, the right yellow arrow points to the Solčava Luče area. Green shades indicate an agreement of the used models that the respective species is present, red shades indicate the absence of a tree species according to the models.

Figure 9 suggests that the Ossiacher Tauern will lose the site conditions that are ideally suited for Norway spruce from 2050 onwards. Even beech that is in its optimum range in the region

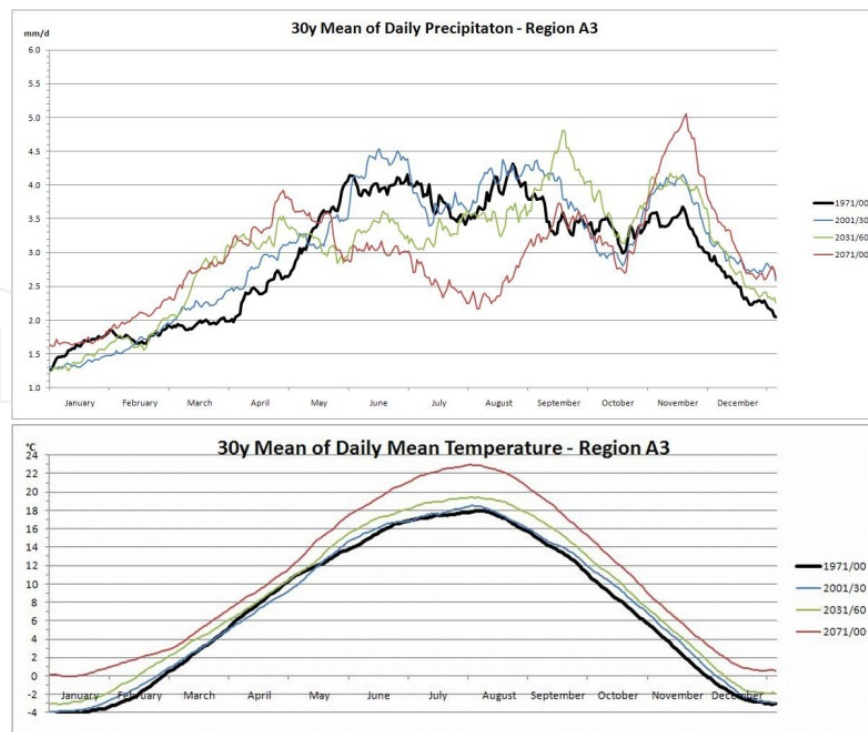


Figure 6. Scenarios for the future precipitation, air temperature, and duration of heat waves for the transnational case study area Carinthia / Slovenia. Upper panel: precipitation, central panel: air temperature; lower panel: duration of heatwaves.

will lose ground and will be only marginally useful for forestry in 100 years. The climate envelope model suggests that oak species will increase their competitiveness. It is quite important to interpret these simulations with hindsight to the capabilities and limitations of climate envelope models [10]. These models may not fully capture the local conditions and may not satisfyingly account for the frost situation. Especially late autumn frost events are problematic for oak forests. Valleys with a frequent temperature conversion may prove to be only marginally suitable for oak forests.

Also in the Solčava/Luče area the main climate change impact will also be a change in the tree species composition. Norway spruce is a natural part of forest communities, but in some cases its share is higher than in potential natural tree communities. Most models predict that the share of spruce and beech on the standing stock will decrease. Thermophilic tree such as oak species that are presently still rare will gain ground in the future.

An immediate foreseeable pressure on the forests is exerted by the expected summer droughts. Prolonged dry periods may severely limit the growth rates of trees and the different species cope quite differently with drought. Oaks and pines tend to recover well, whereas beech and spruce carry a legacy of reduced growth rates into the year after a severe summer drought [11].

The prediction of the future pressure from pests and pathogens is subject to very high uncertainties [12]. Quarantine pests will become more important as consequence of the global exchange of trading goods. Newly arriving pests and pathogens are potentially encountering

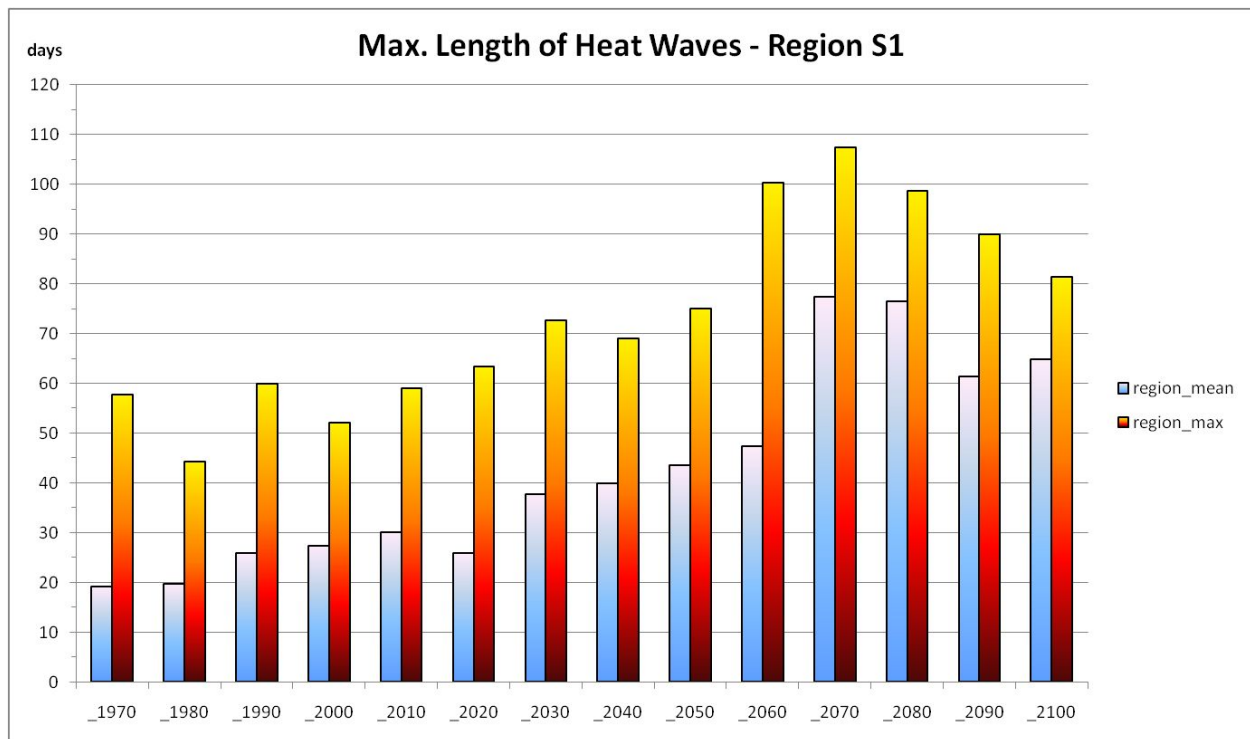


Figure 7. The length of heatwaves is expected to increase.

habitats that would be inaccessible to them. Climate change is opening windows of opportunities for pests and pathogens in areas that may presently be unsuitable for them. Despite these uncertainties foresters need to make evaluations on the risk of biotic forest damages. An attempt to evaluate the biotic risks has been made for the political districts of Austria [13]. Figure 10 shows that the southern part of the country carries, according to experts judgment, a low to moderate risk. Such a mapping needs to integrate numerous factors. Climate change is an important factor, but other influencing factors are of great importance. It has been shown that the increase in forest damages in Europe is by far not only triggered by climate change but that forest management has a strong impact as well [14]. The exposure of forests to biotic risks consists of several climatic factors but also on the tree species composition and its deviation from the potential natural vegetation, the forest road density (accessibility), the workforce available for forestry, and the protective functions of the forests. Assessments like the one presented in Figure 10 also reflect the presently known or anticipated pests and pathogens. The invasion of new species may alter the risk.

Storm is presently on the Ossiach Tauern not a particular problem and there is no indication that it develop into a more pronounced risk in the future. The geographic location of the area does not imply a major storm risk. In the Slovenian part of the area the risk is higher. The area has already experienced several extreme events in the recent past. Examples are a severe flood in Luče in 1990 with an estimated time of recurrence of more than 100 years, a large-scale windthrow on the Črnivec pass in 2008 and frequent snowbreaks in the canopies in the middle

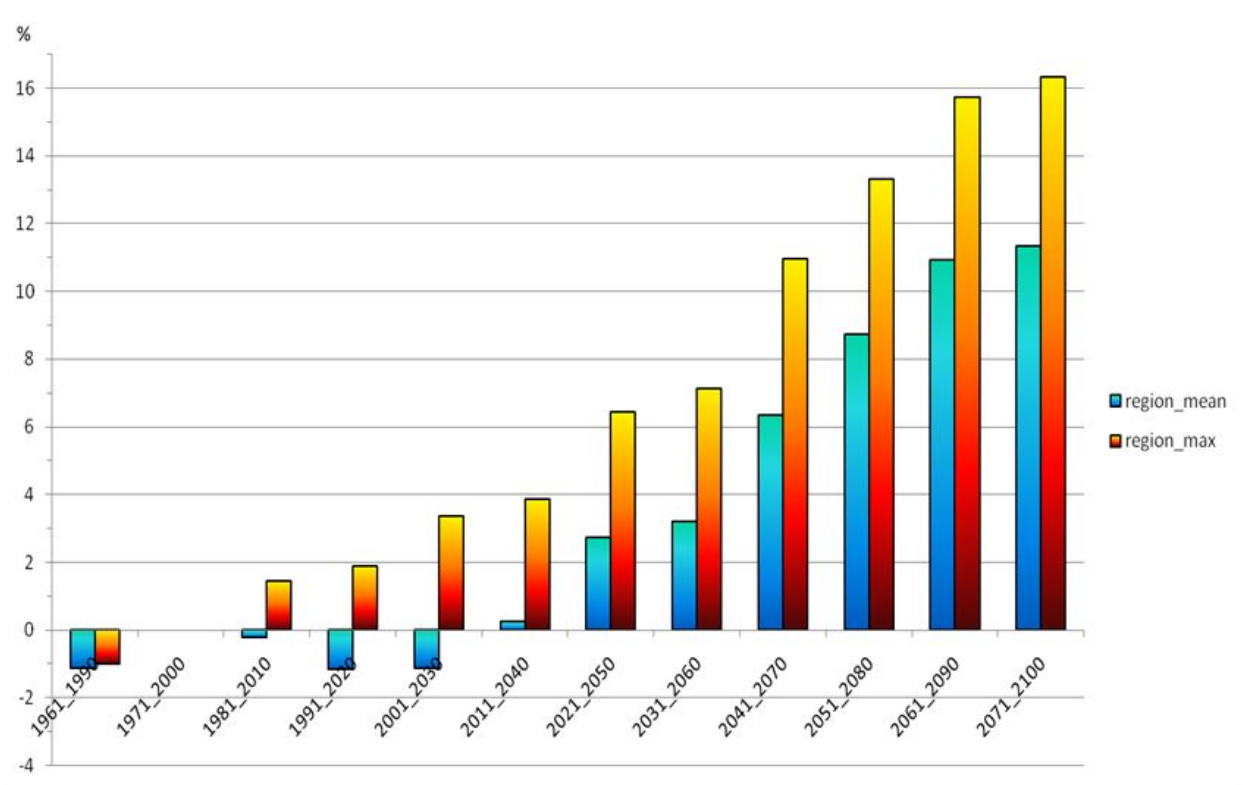


Figure 8. Increase in droughts, expressed as the percentage of the increase in dry days during the growing season. The reference period is 1971/2000.

altitudinal range of the area. In the storm event around 790 hectares of forests were damaged, and 390 hectares were completely destroyed.

By means of a forest productivity model the future development of forests in the Carinthian part of the case study area was assessed. The used models Caldis and Yasso07 are described in [15]. The modeling exercise included the growth assessment of different tree species under the two climate scenarios A1B and B1 as provided by the IPCC [6]. The data for reference stands were taken from the local stand inventory of the forestry enterprise. For simplicity several static assumptions were made:

- The simulation starts with the present tree species composition
- The forest management takes out trees of diameters larger than 45 cm in 2030 and 2090.
- The ingrowth of oak is either favored or suppressed.
- The stand grows under the climate scenario A1B or B1.

Figure 11 shows that the forests are generally growing better under the IPCC scenario B1 than under A1B. This indicates that the limiting factor for forest is not necessarily the temperature and climate change will not necessarily alleviate a thermal constraint. The climate effect is much stronger than the chosen forest management effect. The simulation contains several probabilistic elements such as the mortality due to storms and the regeneration of trees.

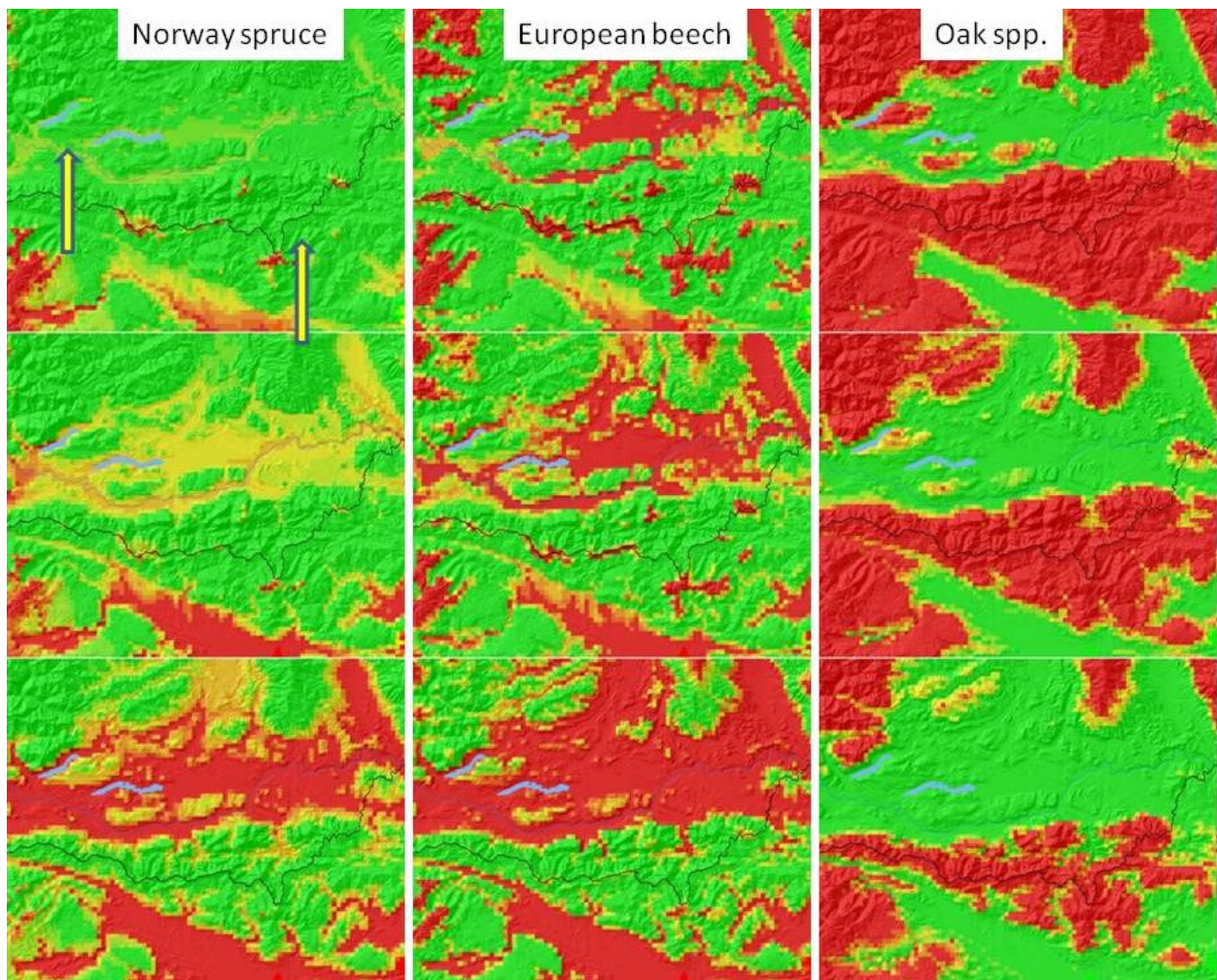


Figure 9. Climate envelopes for spruce (left panel), beech (central panel) and oak (right panel). The upper three maps represent the present conditions, the middle maps represent 2020/50, and the lower maps represent 2051/80. See text for explanation.

Therefore, no clear picture emerges from a single run of the simulation programme. There are several kinks in the temporal trend the stem volume.

Taking the output of the model into a soil carbon simulation model as described in [15] shows again a strong climate effect. The dotted lines representing the B1 scenario with less warming is in several cases the scenario that enables the soils to build up a larger carbon stock. The overarching impact of the forest management strategy on the soil carbon pool is clearly shown. A hypothetical forest without harvesting leads to an accumulation of the soil carbon pool by 10%. However, the effect is only temporary because overly mature stands are experiencing a higher risk of biotic and abiotic damages [16]. In a managed forest a strong peak of carbon is introduced in the assumption that harvesting residues are left behind and the root system of the harvested trees starts to decay. However, due to the reduced aboveground and belowground litterfall after the harvesting and the effect of the increasingly warm climate the soil carbon pool is gradually declining (Figure 12).

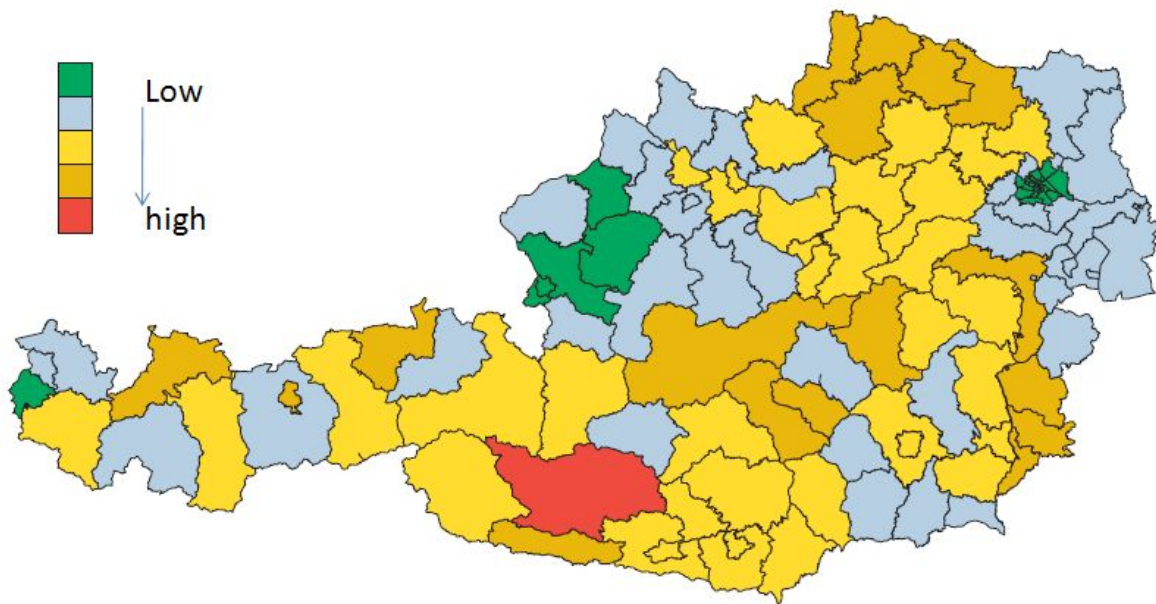


Figure 10. Forest health risk for Austria based on experts opinions.

Several model runs with the same set of input data were averaged in order to obtain a representative result of the simulations. Again, a simplified management regime was chosen:

- Three pure-species stands were compared dominated by Norway spruce, European beech, or oak spp.
- The climate scenarios were IPCC A1B and B1
- All stands were thinned only once and at the same time.

The harvesting was a removal of the thickest trees and no scenarios for the challenges of harvesting and protecting the remaining forest were developed. Furtheron, it was not included whether different timber market situations for spruce, beech, and oak may call for the selection of different diameters of the cut trees and different silvicultural intervention cycles. The effect of the management and the climate is expressed in the deviation from the reference time at the beginning of the simulation.

Figure 13 shows that at the beginning of the simulation period European beech grows better than spruce and oak. The differences are small. The interpretation of the result with respect to beech needs to be made cautiously because the competitiveness of the species is extremely high. This property of beech emerges from the underlying data set of the Austrian Forest Inventory and may overestimate the vigor of beech. The graph also shows that in the early phase of the model run the differences between the two climate scenarios are small. After the harvesting intervention beech and oak are recovering and are quickly gaining stem volume again. The growth of spruce is much poorer. Under the warmer climate scenario A1B the growth of spruce starts to decline. The effect is particularly obvious from 2060 on. But even the climate scenario B1 suggests a productivity decline for Norway spruce setting in around the year 2080.

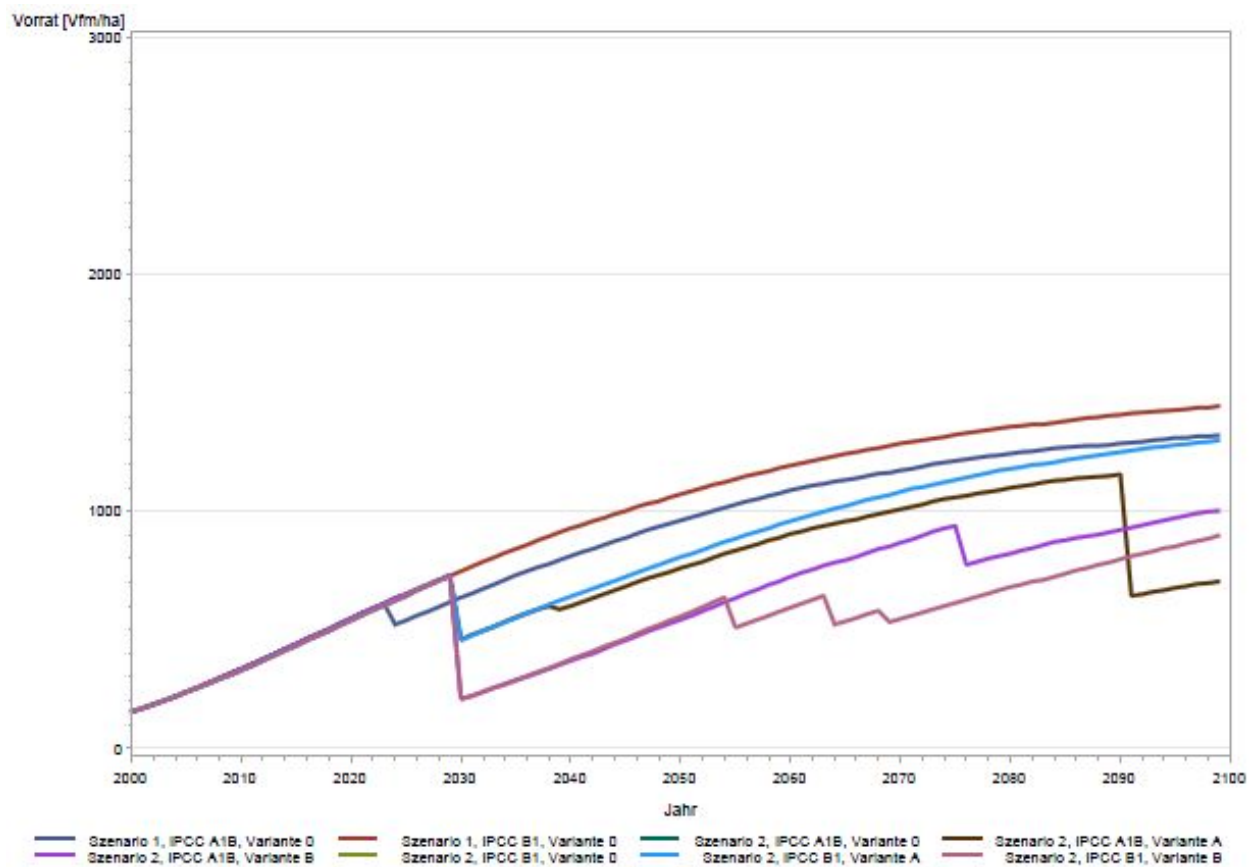


Figure 11. Standing stock of the stem volume of a forest in the Ossiacher Tauern according to different climate and management scenarios.

The simulated development of the forest does not include eventual biotic and abiotic risks arising from pests and pathogens and forest fires. It is assumed that biotic damages are remaining at the present level and that are encoded in the simulation model because data from the Austrian Forest Inventory of the last 30 years were used. An increasing risk of biotic damages is likely [12]. The higher risk needs to be absorbed by an increase in the management intensity, comprising the monitoring of pests and pathogens and the often required small-scale harvesting intervention in order to minimize the propagation of a biotic problem from single trees or small groups of trees to the entire forest stand. The management of forests may become more expensive. A further increase of timber prices and additional markets for the wood sector can alleviate the economic pressure.

Climate change also increases the risk of forest fires. In the entire case study area forest fires are presently rare events and an active strategy of fire suppression pursued. The increase in heat waves and drought periods (Figures 7, 8) can lead to situations that are also not reflected in the parameter selection of the forest growth simulation programme. For practical foresters an alerting system for fire danger may be useful in the future.

The soil carbon pool also responds to climate change and to the forest management decisions as shown in Figure 13. Figure 14 shows that in the first 30 years of the simulation neither the

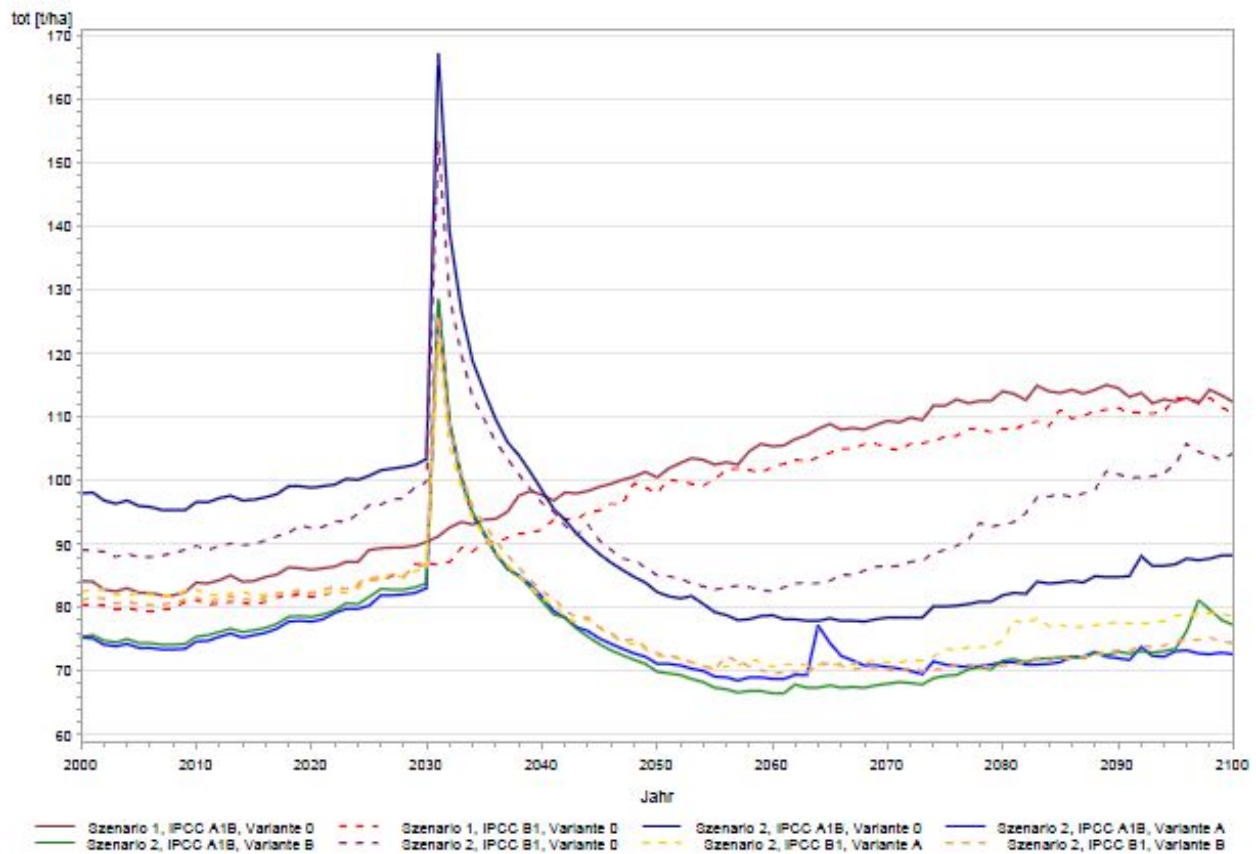


Figure 12. Soil carbon stock of the forest under different climate scenarios and management regimes.

climate scenario nor the selection of tree species leads to a pronounced change in the soil carbon pool. The harvesting operation in the year 2030 leads to different enrichments of the soils with organic matter because the amount of residues differs. Under the assumption of the warmer A1B scenario all soils release carbon into the atmosphere, because the temperature effect stimulates the mineralization of soil organic matter more than the productivity of the forests. In the less warmer B1 scenario beech and oak forests are maintaining their soil carbon pool. The Norway spruce forests loses slightly because the stand is more affected by disturbances thereby reducing the litter input to the soil. Over the course of the simulation period the soils are losing less than 20 tons carbon per hectare. This is a minor carbon loss that may not even be detectable in terrestrial soil surveys.

5. Forestry towards the climate change scenario

Secondary spruce forests on silicatic bedrock represent a known hotspot of biotic risks and have been severely affected by storms and bark beetle attacks in the recent past [17,18]. Rather fast climatic changes will influence the stability of these forests and can compromise their protective functions. In the Solčava Luče area forests are an important part of the economy. On average, forest properties have an area of 26 ha and are parts of agricultural enterprises.

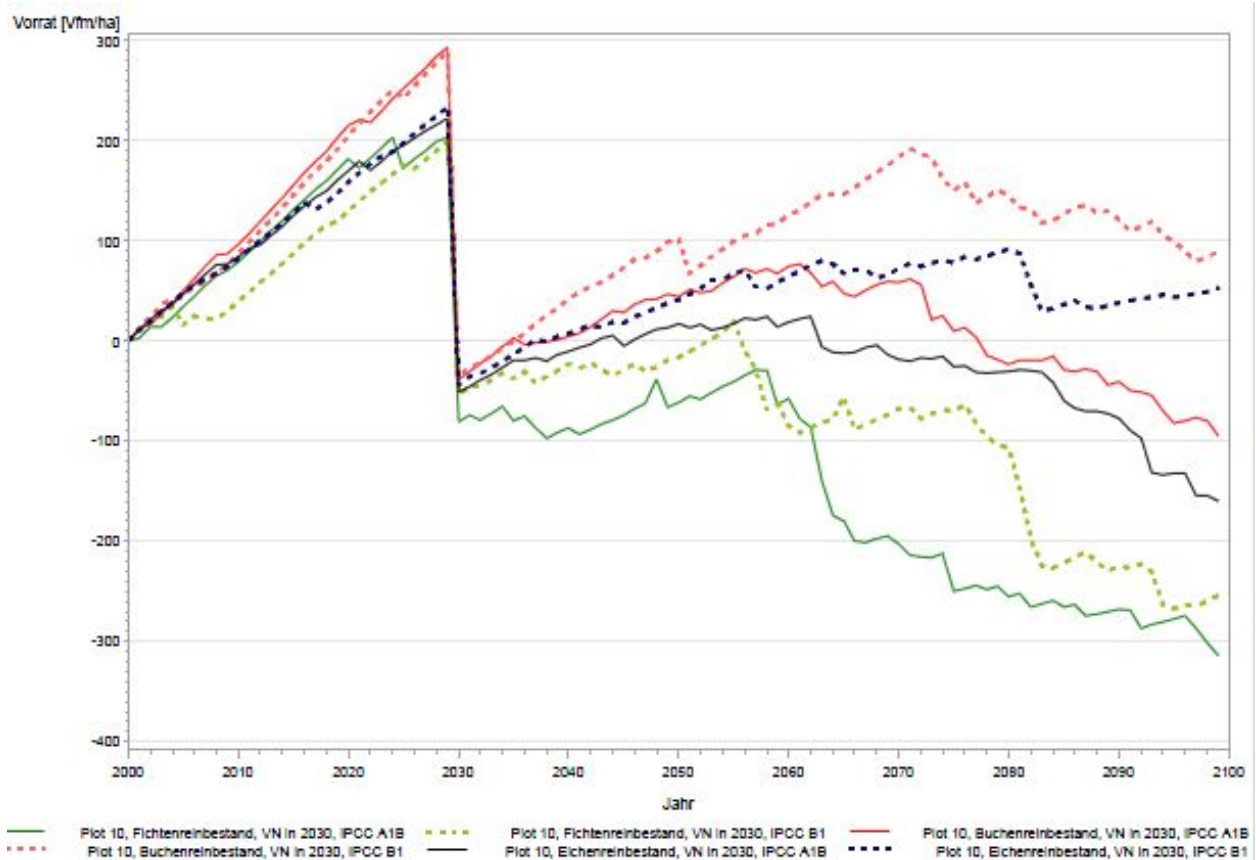


Figure 13. Comparison of the growth performance of Norway spruce (green), European beech (red), and oak (blue) at the Ossiacher Tauern for two climate scenarios (full line: IPCC A1B, dotted line: IPCC B1).

The economic success of these farms relies on the income from forest products. Forestry and wood processing are main economic activities in the area. Practical foresters and forest owners are not yet provided with stringent guidelines as an aid how to deal with climate change. However, comprehensive forest management plans are including advice on forest management based on site and silvicultural classes.

The economic setting in Ossiach is somewhat different. In Figure 15 the distribution of the workforce in the entire province Carinthia and in the community of Ossiach are shown. Although forestry is a highly important part of the regional economy the sector employs not many persons as their primary profession. In the community of Ossiach most people are working in the tertiary sector of the economy.

The main approach in practical forest management in the Solčava/Luče area is the stimulation of a change in the tree species composition. This is achieved by enrichment planting in cases where the natural regeneration of the desired tree species is not happening. The strategy is the introduction of tree species with a wide ecological amplitude. Emphasis is placed on using the most appropriate provenances within a tree species assuming that they can adapt to the future conditions. It also is widely accepted that spruce monocultures will not have the expected flexibility for coping with climate change. A promising method is underplanting pure spruce

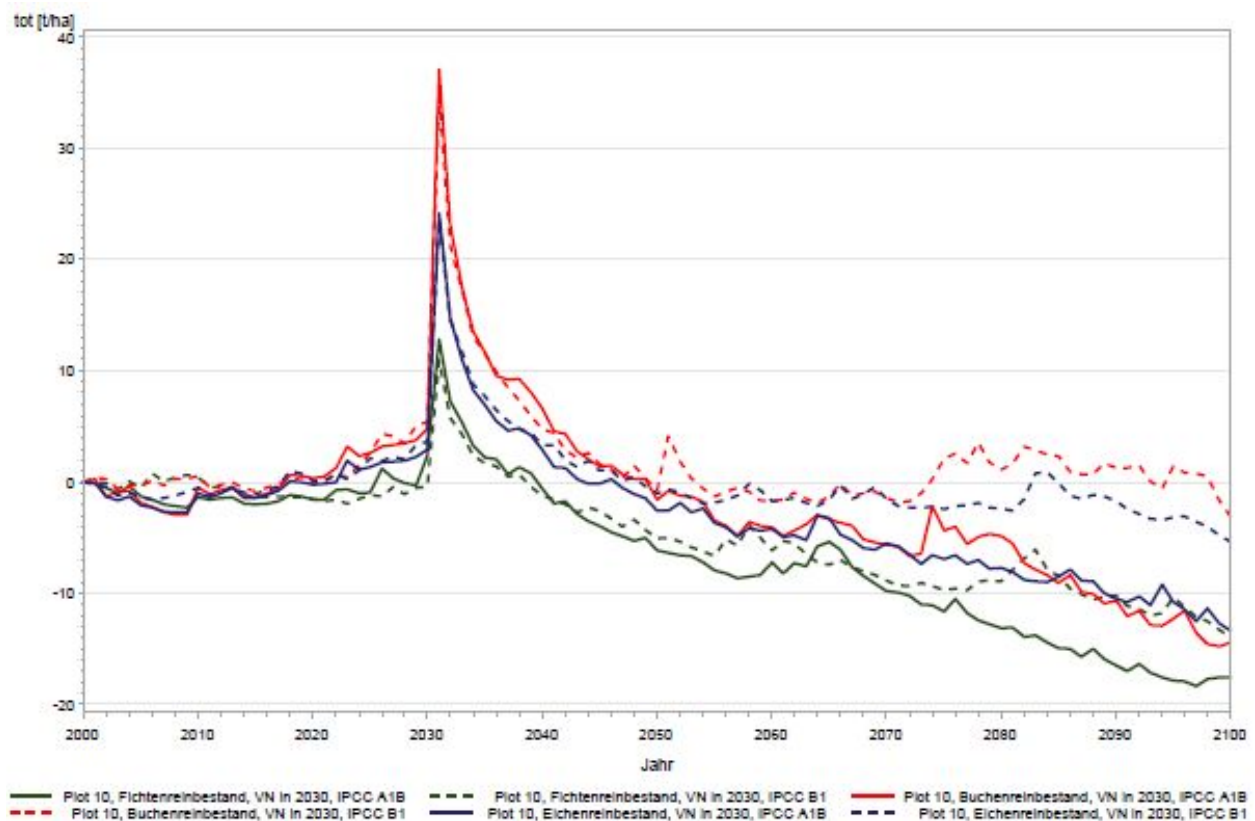


Figure 14. Temporal trend of the soil carbon pool for two climate scenarios (full line: IPCC A1B, dotted line: IPCC B1) for stands of Norway spruce (green), European beech (red), and oak (blue) at the Ossiacher Tauern. The reference soil carbon pool is the status at the beginning of the simulation period.

forests with beech and other broadleaved trees. Even a low proportion of deciduous tree can significantly increase the biological and mechanical stability of those stands [2,3]. The aim of the underplanting is the establishment of a network of tree clusters or stands with a rich tree species composition, based on site conditions and in line with climate change predictions. These clusters are the backbone of forests with a high stability and a low vulnerability towards negative effects of climate change.

In the Ossiach region a change of the tree species composition is achieved by stimulating the natural regeneration of existing species. Given that beech is very competitive, the natural dynamics are in favour of mixed-species stands. Despite the indication of the increasing pressure on Norway spruce as shown in Figure 9 it is assumed that Norway spruce will play an important role in the forestry of the future. The need for an increase in the silvicultural activities is already understood. However, the call for an increased use of deciduous forests by forest ecologists is not yet reconciled with the expected future demand on the timber market. So far, no convincing economical concept for a forest industry based on timber from deciduous trees has been presented. In recognition that climate change is a slow process forest owners are hesitant to adopt a silvicultural strategy that is yet in its infancy.

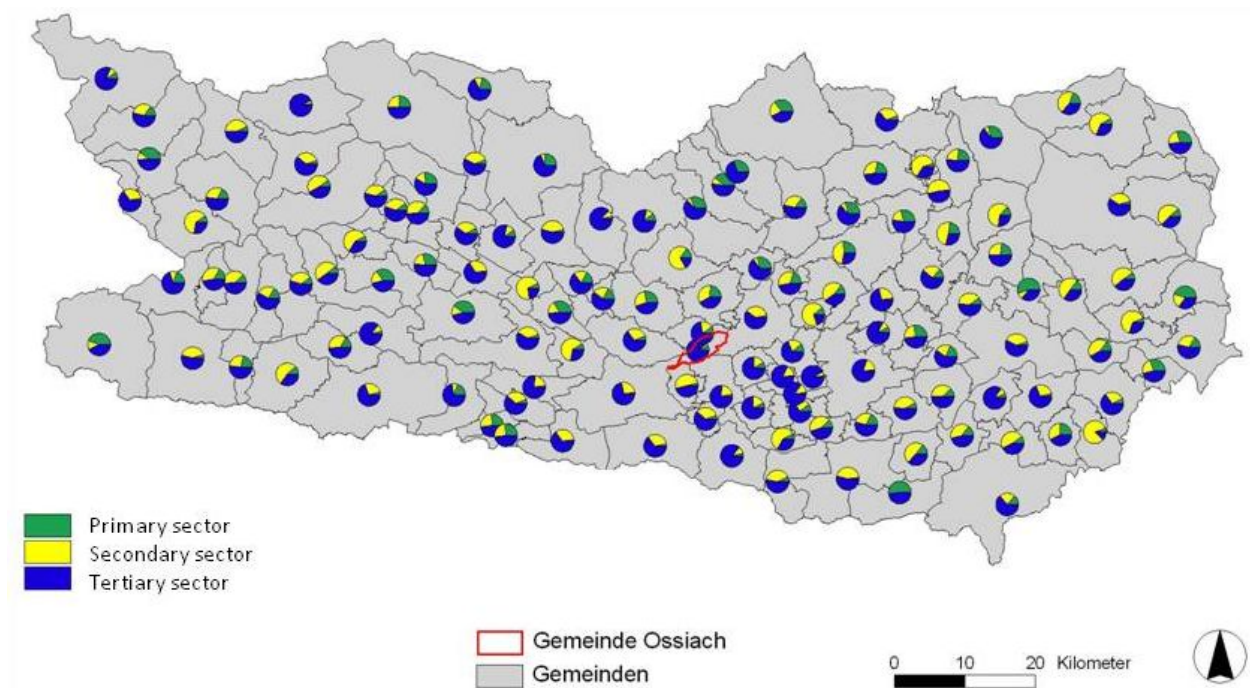


Figure 15. Distribution of work places according to economic sectors. The community Ossiach is indicated by red borders.

The technologies of timber harvesting have been developing at a rapid pace in the past decades. However, dealing with large scale forest damages is still a challenge. Forest access roads are an important element of silviculture. The long-term planning in the Solčava/Luče area includes the increase of the density of forest roads and the introduction of cable line technologies in difficult terrain. Effective risk prevention is based on protocols for pests monitoring, and precise action plans for recommended activities of intervention. There are still many opportunities both in Carinthia and in the Solčava/Luče area to establish protocols for the identification of risk hotspots for presently encountered and emerging problems with pests and pathogens. Promising attempts are databases that are populated with information by an international network of scientists and that are made available as web applications [12,19]. Concepts for the management and silvicultural treatment of protection forests are of crucial importance for the Solčava/Luče area. The specific education of practical foresters has already been recognized and capacity building is among the main tasks of the forestry service.

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Author details

Robert Jandl^{1*}, Andrej Breznikar², Marko Lekše², Christian Tomiczek¹, Silvio Schüler¹, Klaus Dolschak³ and Hans Zöscher⁴

*Address all correspondence to: robert.jandl@bfw.gv.at

1 Forest Research Center (BFW), Vienna, Austria

2 Zavod za Gozdove Slovenije/Slovenia Forest Service, Ljubljana, Slovenia

3 Institute of Forest Ecology, University of Applied Life Sciences (BOKU), Vienna, Austria

4 Forest Training Center - Forstliche Ausbildungsstätte (FAST) Ossiach, Ossiach, Austria

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