Structure and composition of forest stands at regional and national levels in the last five decades

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Introduction

Temperate forests in Europe cover a large bioclimatological range and play a prominent role in timber production, nature protection, water conservation, erosion control and recreation (Spiecker, 2003). For centuries temperate forests in Europe have been affected by human activities. Forest management has caused large-scale changes in the spatial distribution, tree species composition, and structure of forest stands (Johann, 2007). In the 18th and 19th centuries, even-aged forestry created large areas of uniform, mainly conifer-dominated forest stands. In the past few decades, as nature-based forestry has become widely accepted, several phenomena associated with changes in the forest structure and species distribution have occurred (Spiecker, 2003; Gold et al., 2000).

These phenomena are easier to recognize and explain if long-term changes have been precisely documented. Archival data such as forest management plans with inventory data, forest maps, land registers and felling records, which are often neglected sources of information, enable us to quantify the long-term changes and study the impacts of different factors on changes in forest structure and composition over the past decades or centuries (Chapman et al., 2006; Klopčič et al., 2009).

Forest management in Slovenia has a rich tradition. For some forest areas the first inventories and forest management plans were elaborated in the second half of the 18th century (Bončina and Kozorog, 2014). Due to diverse environmental conditions (the Alps, Mediterranean, Dinaric Mountains, and Pannonian Basin), different past forest management practices and available archival data on forest stand structure and composition, Slovenia is an appropriate case to study changes in the structure and composition of forest stands at the landscape and regional levels. The aim of this study was thus: 1) to analyse the spatiotemporal changes in forest area as well as forest stand structure and tree species composition in the period 1970-2018 at the regional and national levels; and 2) to assess the impact of environmental, natural and social factors on changes in forest structure and species composition.

In Slovenia forests cover 11 400 km^2, which represents 58% of the total land area. The underlying characteristic of the study area is a considerable variation of relief and climatic conditions (Poljanec et al., 2010). The zonality of forest vegetation in Slovenia is quite clearly defined due to distinctive orographic factors, different soil substrata and well-preserved forest stands. Forest vegetation is classified in eight forest types according to the terminology of the Ministerial Conference on the Protection of Forests in Europe (MCPFE) (European forest types, categories and types for sustainable forest management reporting and policy, 2006), and reflects the distinctive and unique patterns of human impacts, modification of species composition, latitudinal/altitudinal zonation of vegetation, climatic and edaphic variability, silvicultural systems applied and forest management intensity:

- Alpine coniferous forests (EFC 3; 225 km^2),
- acidophilous oakwood forests (EFC 4.1; 241 km^2),
- sessile oak–hornbeam forests (EFC 5.2; 577 km^2),
- Central European sub mountainous beech forests (EFC 6.4; 1 901 km^2),
- Illyrian sub mountainous beech forests (EFC 6.6; 1 505 km^2),
- Illyrian mountainous beech forests (EFC 7.4; 2 612 km^2),
- thermophilus deciduous forests (EFC 8; 77 km^2),
- floodplain forests (EFC 12; 45 km^2).

In the spatial analysis (Poljanec, 2008) of the entire Slovenian forest area (32 597 compartments = 11 400 km^2), spatiotemporal changes in forest area as well as forest stand structure and tree species composition over the last four decades were documented at regional and national levels, along with the impacts of different environmental, natural and social factors on changes of forest cover, forest strand structure and tree species composition.

Changes of forest stand structure and composition in the period 1970-2018 were described by differences in the total growing stock, annual increment, growing stock of small, medium and large diameter trees, and differences in the proportion of European beech (*Fagus sylvatica* L.), silver fir (*Abies alba Mill.*) and Norway spruce (*Picea abies* (L) H. Karst.) in the growing stock of forest stands.

Changes in forest area

The first reliable data on forest area in Slovenia is from the first half of the 19th century (Blaznik, 1970). The forest area for the period before the first forest inventory of forests (1947) can be assessed from different historical databases. For the area of the former Drava Banovina there are both the Josephian (Rajšp et al., 1998; Kušar and Hočevar, 2005) and the Franziscean Cadastre (Blaznik, 1970; Žumer, 1976), and for the Primorska region, the Landscape Map of Primorska is particularly important, showing the land use for the year 1830 (Šebenik and Bončina, 2004). As estimated by Žumer (1976), there were 783 646 hectares of forests in Slovenia in 1875, and this increased to 846 151 ha by 1910. In 1947, the first national forest inventory including the entire Slovenian forest area was carried out. According to the estimates from that period, the forested area amounted 832 920 ha (NFI, 1947). After World War II, the area of forests in Slovenia steadily increased. According to data from the regional forest management plans in 1971, forests occupied 50% (Remic, 1975) of the total land area in Slovenia (1 004 700 ha forests). This increased to 56% by the year 2000 (Veselič and Matijašić, 2002), and according to the findings of Hočevar (2003) even up to 60.5%. In 2018 the total forest area in Slovenia amounted to 1 177 244 ha, or 58% of the total land area (Slovenia Forest Service report, 2018).

Changes in the forest cover varied in different parts of Slovenia. According to the estimates of Šebenik and Bončina (2004), the proportion of forest land in the Karst region changed from 19% in 1830 to 55% in 2000 (Figure 1). Great changes in the proportion of forests also occurred in the Alpine region (Ferreira, 2005).

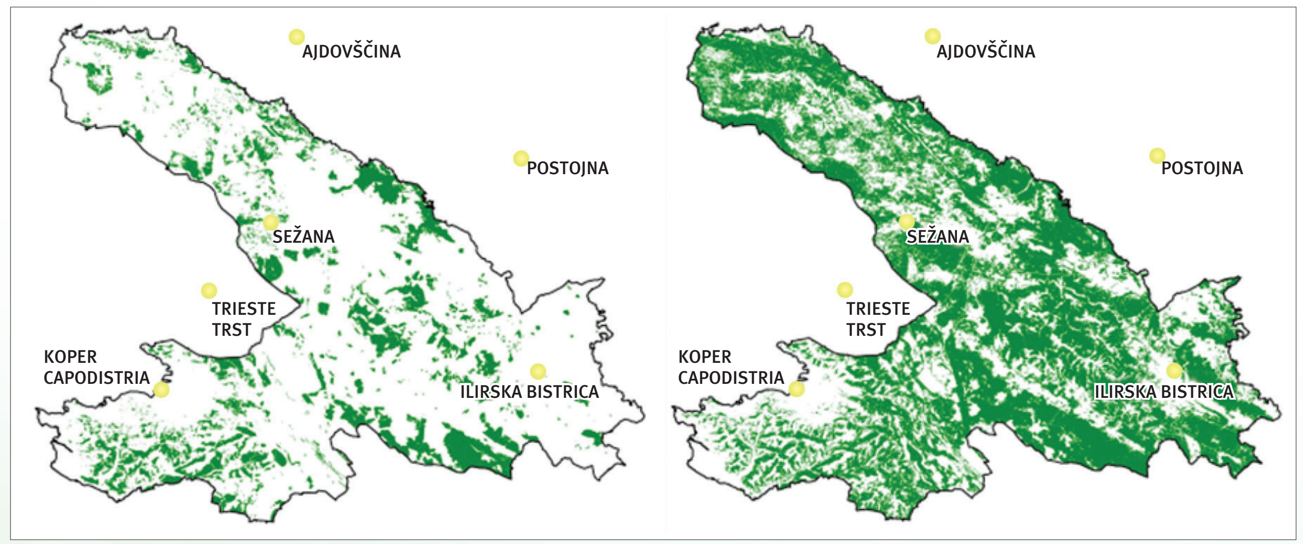

Figure 3: The successful Karst afforestation that received a "Grand prix" at the Paris World Exhibition in 1900. In 1830 forests covered 19% of total land in the Karst region, today forest covers about 55% of the Slovenian Karst area (Šebenik and Bončina, 2004).

Forest area has increased mainly due to the abandonment of agricultural land (Kobler, 1996; Ferreira, 2005) and much less due to planned afforestation (Miklavžič, 1954; Perko, 2002). Land abandonment is interrelated with the prevailing demographic and socio-economic changes (Ferreira, 2005; Hočevar et al., 2004), and partly influenced by natural conditions, especially elevation and inclination (Hočevar et al., 2004). In the period after WWII, the creation of new forest areas was primarily the result of the direct conversion of shrubs and other abandoned agricultural land, where Norway spruce monocultures were planted (Miklavžič, 1954). The increase in the forest area of the Karst was initially the result of the Karst afforestation process, a pan-European campaign of the forestry profession, and the result of significant social changes, as reflected mainly in the abandonment of intensive grazing (Šebenik and Bončina, 2004).

Estimates of the increase in forest cover in Slovenia differ slightly in the literature due to different methodologies in data gathering and changes in the criteria for defining forest land, as well as in different interpretations of the defined criteria (Hočevar et al., 2006).

Changes in forest stand structure and composition

The first estimations of the growing stock and increment at the national level go back to 1947, when the first inventory of all Slovenian forests was produced (1947). According to this, the average growing stock in Slovenia amounted to 137 m^3/ha and the annual increment 3.25 m^3/ha (NFI, 1947). Both growing stock and increment decreased from 1947 to 1951 because of intensive harvesting; the cut at that time was almost twice the total volume increment of forest stands (Turk, 1955; Perko, 2005; Bončina, 2008). The second national forest inventory, implemented in the years 1950 and 1951, showed the critical state of the forests (Zemljič, 1961; Perko, 2005). In 1953, the growing stock was estimated at 112 m^3/ha, and the increment at 2.76 m^3/ha (Statistični letopis, 1975). The inventory contributed significantly to the change in forest management (Perko, 2005), as reflected in the lower amount of harvesting. The growing stock in 1957 again reached the value of the growing stock from 1947, 137 m^3/ha (Osnutek perspektivnega plana razvoja gozdarstva v LR Slovenija v razdobju od 1957–1961, 1958). The regional forest management plans, elaborated for the period 1971 to 1980, showed a further increase in the growing stock, up to 174 m^3/ha (Remic, 1975). In the period 1970 to 2018, the average growing stock increased from 174 m^3/ha to 302 m^3/ha.

From 1970 to 2005 an increase in the total growing stock was registered in most of the compartments (N=28 685). In 2% of compartments, however, no change was observed, while in 11% of compartments the growing stock actually decreased. Changes in the growing stock differed to a statistically significant degree among the forest types. The increase in the growing stock was highest in the Central European sub-mountainous beech forest (EFC 6.4) and Illyrian sub-mountainous beech forest (EFC 6.6), and lowest in the Alpine coniferous forest (EFC 3) and Thermophilus deciduous forest (EFC 8) (Poljanec, 2008).

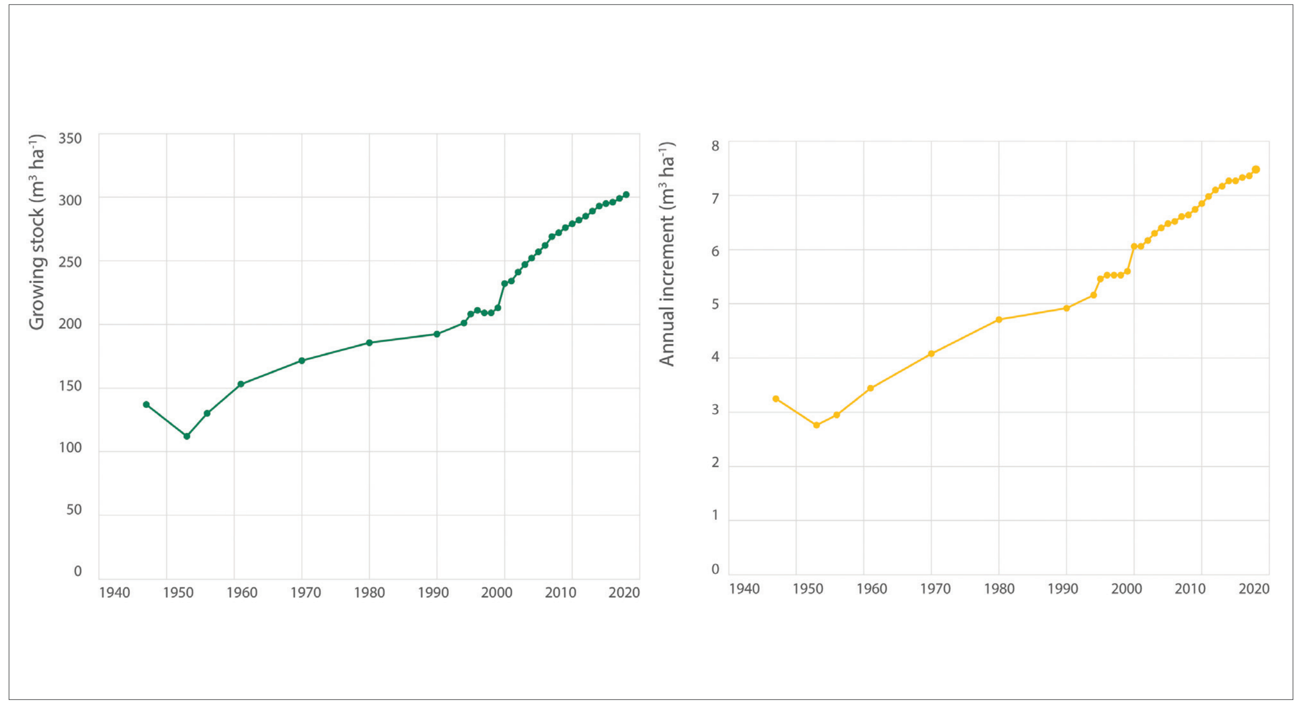

Figure 4: Changes in the growing stock and increment of Slovenian forests in the period 1947-2018.

Changes in the diameter distribution indicate the gradual ageing of stands, as the share of small-diameter trees decreased (from 49% of total growing stock in 1970 to 30% in 2018), while the shares of medium-diameter (30 cm ≤ dbh < 50 cm) and large-diameter trees (dbh ≥ 50 cm) increased substantially (from 44 % to 46 % and from 9 % to 24 % of the total growing stock, respectively). The changes in conifers and broadleaves are different. A considerable increase in the growing stock of small- and medium-diameter trees was recorded for most broadleaved species, whereas for conifers an increase in the growing stock of large-diameter trees and decrease in the growing stock of small-diameter trees were evident. There are several reasons for the decrease in the amount of small-diameter conifers trees: 1) affirmation of close-to-nature management based on natural tree species composition (Diaci, 2006), which resulted in the promotion of deciduous trees; 2) in the period 1970-2005 regeneration of conifer forests was poor; 3) regeneration of silver fir as one of the dominant tree species was significantly hindered by large ungulates (Bončina et al. 2009, Klopčič et al. 2010; Simončič et al. 2019); 4) creating Norway spruce plantations was stopped; and 5) conversion of existing Norway spruce plantations into mixed forests (Miklavžič, 1954; Diaci, 2006b).

In the period 1970 to 2018 the tree species composition of the forests changed substantially. The share of broadleaves increased from 40% of the total growing stock in 1970 to 55% in 2018. The growing stock of European beech doubled, whereas the share of silver fir decreased from 17.5% to 7.4% of total growing stock. Changes were less evident for Norway spruce, and its share decreased from 34% to 31% of the total growing stock.

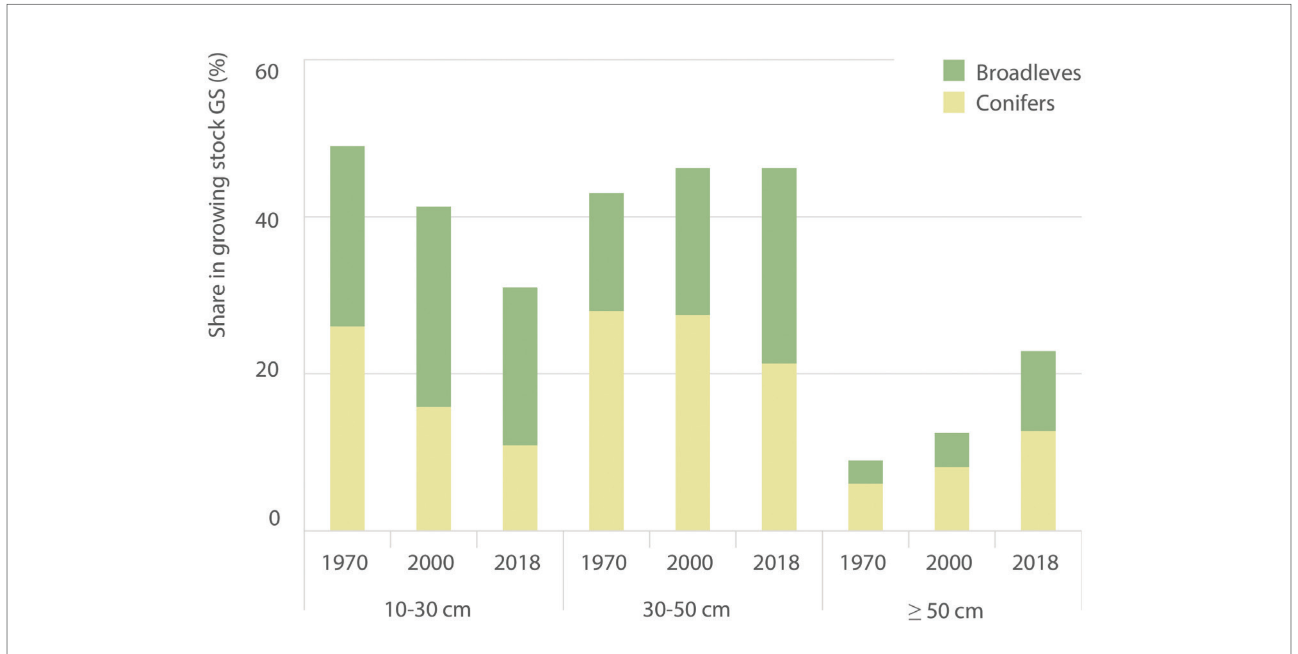

Figure 5: Changes in the diameter distribution of forest stands in the period 1970-2018 indicated the gradual ageing of stands.

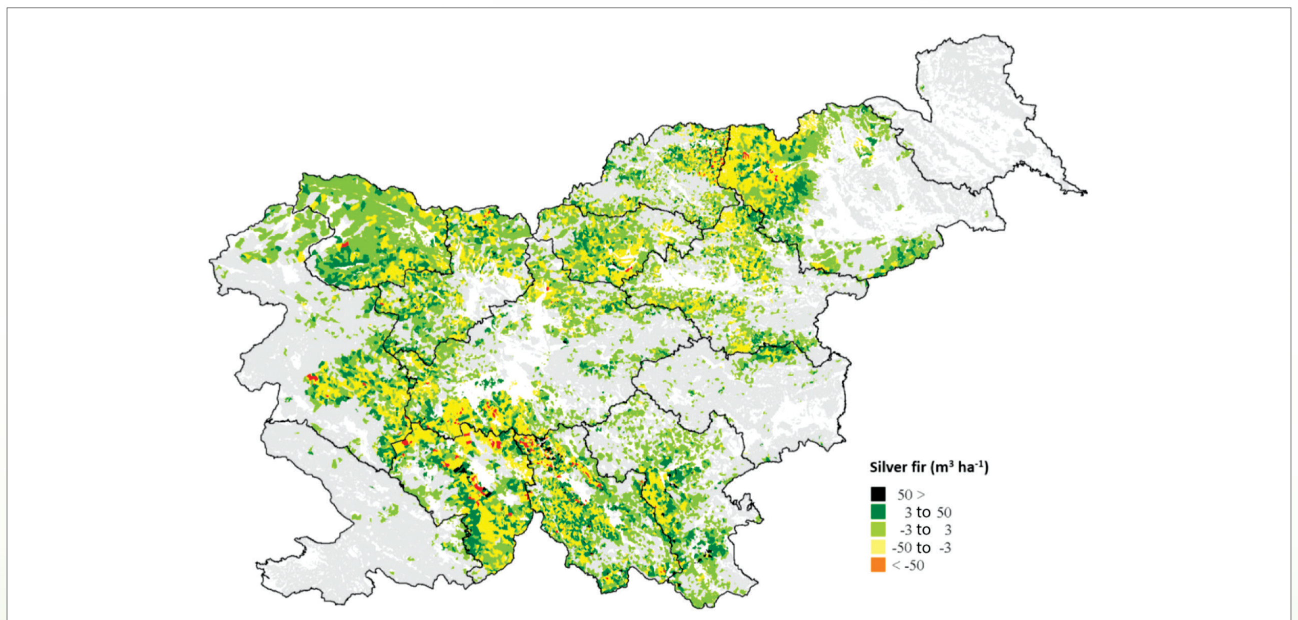

Figure 6: Average ten-year changes in the growing stock (m^3/ha) for silver fir in the period 1970–2005 (Poljanec 2008)

Changes in the proportion of Norway spruce, European silver fir and European beech were significantly different among forest types. The proportion of spruce decreased in forest types where spruce is not present in the potential natural vegetation, and increased the most in the mountainous vegetation belt, especially in the Alpine coniferous forest type (EFC 3).

The proportion of beech in the growing stock of forest stands increased on 54% of the total forest area, remained almost unchanged on 7% and dropped on 39% (Poljanec et al., 2010). However, these changes differed significantly among forest types. Additionally, in the period 1970-2005, beech expanded its area by more than 1,200 ha per year on average, i.e. the annual expansion rate amounted to 0.24% (Poljanec et al., 2010). Beech expansion was more pronounced at lower altitudes, on sites with steep topography, and on sites with a higher proportion of beech in potential natural vegetation (ibid).

The proportion of silver fir in the total growing stock decreased in all forest types, but significant differences in spatiotemporal dynamics and changes in fir abundance were found between forest types, representing a complex interplay of site conditions and past forest management (Ficko et al., 2011). Furthermore, analyses show a significant redistribution of fir. Disappearance of fir was registered on 5.1% of the total forest area in the analysed period, and expansion on 5.5%. Areas where fir disappeared are warmer and drier on average than areas where it has remained present, and it expanded to areas with higher annual precipitation and lower mean temperature, which could indirectly indicate the impact of climate change (Ficko et al., 2011).

Factors of structural changes of Slovenian forests

Structural changes of forest stands in the observed period are dependent on the initial state of forest stands, site conditions and several other factors, which can be roughly classified into

1) environmental factors,
2) forest management and
3) socio-economic factors (Poljanec, 2008).

Environmental factors

Among the environmental factors, altitude, temperature, precipitation and site productivity have the strongest impacts on structural changes. Their influence, however, is small and mostly indirect. They explain changes in the growing stock of Norway spruce, European silver fir, European beech, and partly also in the amount of large diameter trees. A small influence of environmental factors on changes in total growing stock and increment is also observed in forest reserves. Long-term studies of primeval forest remnants in Dinaric fir-beech forests show that the total growing stock in natural forests varies little, whereas changes in the tree species composition, diameter distribution and horizontal structure of forest stands are much more intensive (Bončina and Diaci, 1998; Roženbergar and Diaci, 2002).

Changes in the growing stock, increment and diameter distribution of forest stands are significantly driven by natural disturbances. Natural disturbances decreased the growing stock and increment of forest stands, and increased the proportion of small diameter trees in the total growing stock. In Slovenia large-scale disturbances occur quite regularly (Klopčič et al., 2009), and result in a high amount of sanitary felling. For instance, in 1996 and 1997 the level of sanitary felling was high due to snow and ice storm disturbances, while in the period 2005-2008 due to windthrow (Jelovica plateau and Gornji Grad), snowbreak (Zgornje Jezersko), forest fire (Karst region), and bark beetle outbreaks (Poljanec et al., 2014). The last large-scale disturbances that damaged Slovenian forests were sleet, which significantly impacted vast areas of forests between January 30th and February 10th 2014, windthrow in December 2017 and again in 2018 that mainly damaged forests in Koroška region, and the gradation of bark beetles that has been continuously present to a great extent as a secondary disturbance ever since 2015. Such disturbances are difficult to predict, since they depend on a variety of factors (Poljanec et al., 2004). However, they all are undesirable in terms of forest management. While natural disturbances in forest management cannot be eliminated, their effects can nevertheless be significantly mitigated by adequate care of forest stands (Klopčič et al., 2009).

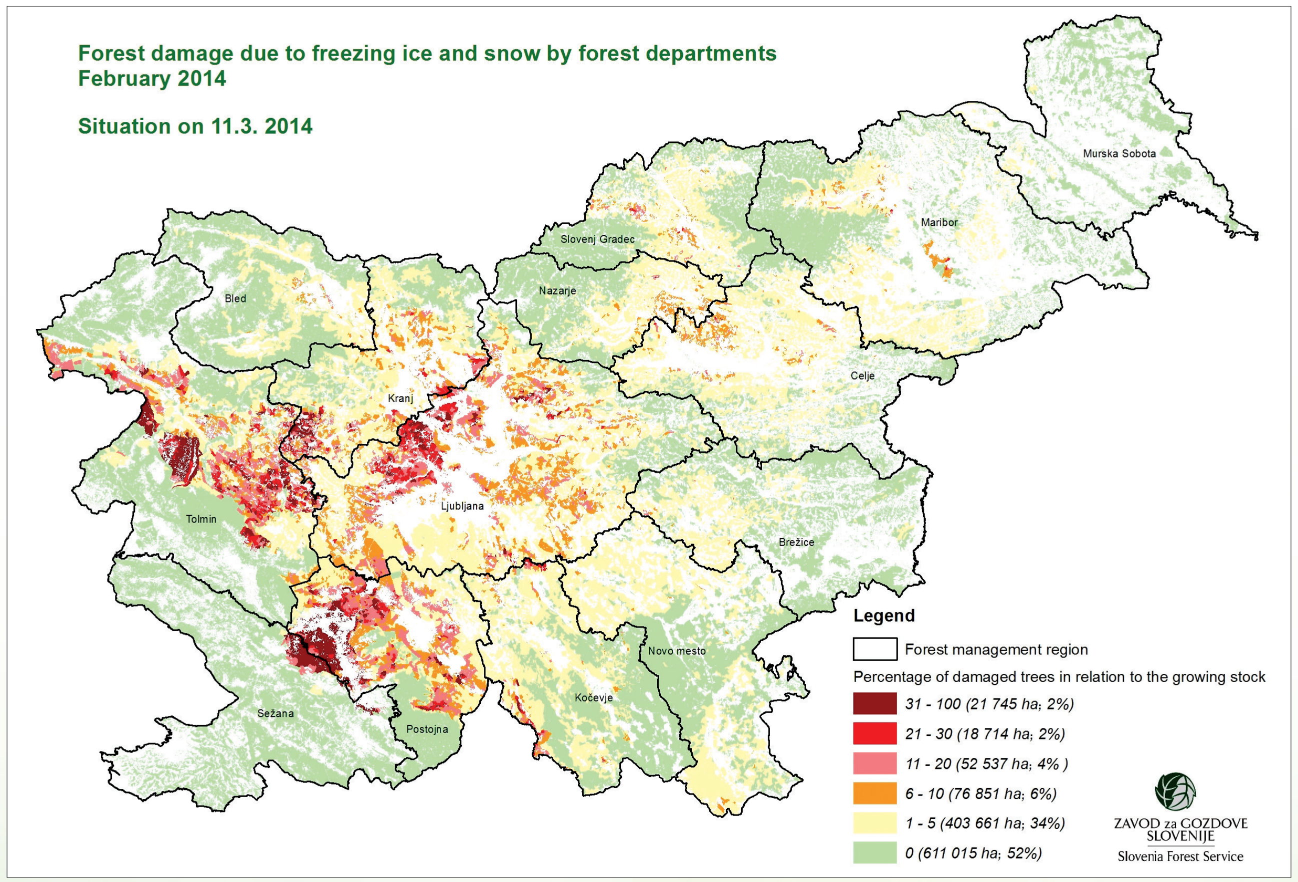

Figure 7: An important driving factor of forest changes are natural disturbances. The forest stands in the last decade suffered due to an extensive ice-storm in 2014, windstorms in 2017 and 2018 and bark beetle outbreaks in the period 2015-2018.

Forest management

In managed forests, the forest structure is mainly influenced by directed measures. On the stand level, the forest structure is impacted by harvesting. Thinning impacts the growing stock and annual increment, diameter distribution of forest stands, the proportions of tree species and distribution of trees in a stand (Kotar, 2005). The dynamics of forest regeneration at a stand level significantly impact the tree species composition in young development phases (e.g. Diaci et al., 2005). The area and method of regeneration on the higher spatial levels (e.g. management class, forest management unit) have significant impacts on the dynamics of changes in the forest structure. Besides the maximum allowable cut, the regeneration techniques are also of high importance. They impact the horizontal structure of forest stands, which is reflected in their size and shape (Poljanec and Bončina, 2006), changes in diameter distribution and tree species composition.

In addition, ungulate management is an important factor which significantly impacts the dynamics of forest stands, especially tree species composition (Klopčič et al., 2010; Simončič et al., 2019).

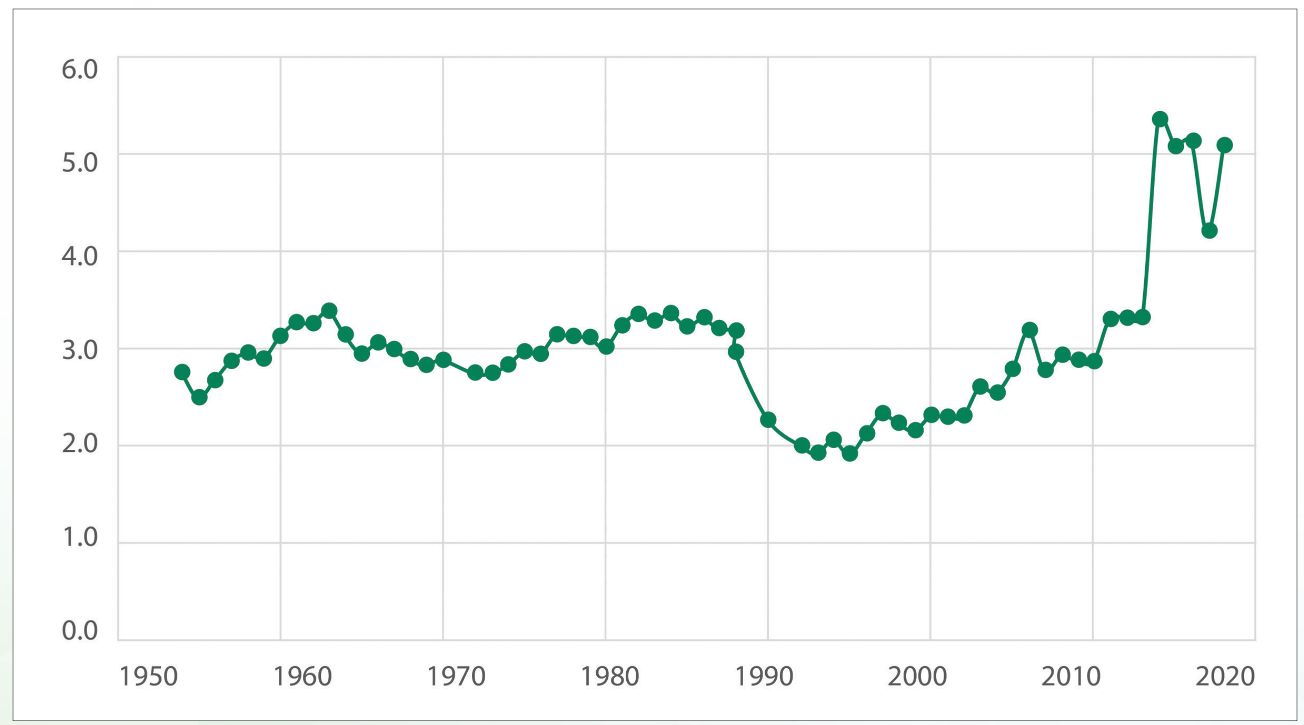

Figure 8: Dynamics of annual cut (m^3/ha) in Slovenia from 1955 to 2018.

Socio-economic factors

Among the socio-economic factors that impact forest stands, the ownership and size of private forest property are important.

There are huge differences in the past development of forest stands between state and private forests. Approximately 80% of the total forest land is now privately owned. Before World War II private forests were overused, and the average growing stock amounted to approximately 120 m^3/ha (Turk, 1955; Winkler, 1970; Perko, 2005; Bončina, 2008). After World War II, and until today, the amount of cutting has been much smaller than the volume increment of forest stands, and this is especially evident in the period after 1990.

Furthermore, the intensity of forest management in the privately owned forests, as described by annual harvest per hectare, depends on the size of the private property (Češarek et al., 2018). The harvest intensity per hectare in small forest properties is significantly lower than in larger forest estates. In addition, the number of co-owners negatively influences harvesting intensity.

In the period 1970-2018 forest area increased from 1 004 700 ha to 1 177 244 ha, due to forest succession on abundant agricultural land. Therefore, past land use influenced the development of forest stands. In forest compartments in previously agricultural land, changes in the growing stock of forest stands and diameter distribution were greater compared to those compartments that were initially covered by forest, as expected.

Conclusions

Forest stands in Slovenia, as well in Central Europe, have changed significantly over the previous centuries (Klopčič et al., 2009; Spiecker, 2003). In the observed period, the changes are reflected in the increase in growing stock, general ageing of forest stands and shifting tree species composition, moving closer to the current climatic and edaphic conditions. Despite the general trends of the changing composition and structure of forest stands, research results (e.g. Poljanec et al., 2010) indicate that the changes varied between forest types and regions. Forest resources in extreme site conditions were less affected, in particular in the mountains where forest changes are slow due to harsh growing conditions, while in other forests types changes in the structure and composition can take on different forms. Varying magnitudes and orientations of changes in stand parameters can be linked to the impacts of different site conditions, initial state of forest stands and different natural and anthropogenic disturbances, as well as the selection of indicators and scale on which changes are observed.

The initial state of forest stands in 1970 and forest management are the most important factors explaining the changes in forest stand structure and composition over the last four decades, while the impacts of natural and social factors are indirect, as they point to differing conditions for forest management. The initial state of the forest stands in 1970 was a result of the interplay between different site conditions (Oliver and Larson, 1996) and different past forest management and land use histories (Spiecker, 2003; Johann, 2007). In the majority of the study area, intensive harvesting and even-aged forestry promoting spruce significantly changed the stand structure and composition, while the application of uneven-aged systems in the 19th and beginning of the 20th centuries, particularly in the Dinaric region, resulted in more preserved forest stand structures and compositions. In the past 70 years, nature-based forestry (Diaci, 2006) has been applied through intensive forest management planning over the entire study area. The harvest intensity decreased and only in exceptions reached the net annual increment, while natural tree species and a more diverse, site-oriented forest structure were promoted through silvicultural measures.

The structure and composition of forest stands show significant improvements over the period under research. In fact, some stand parameter values such as average growing stock, current annual increment and diameter distribution are close to the target values. The development of species composition is generally favourable, since alteration of the natural tree species composition has decreased. However, despite the overall improved conservation status of forests, the status and future development of the silver fir population remains unfavourable (Bončina et al., 2009).

According to the present state of the forests, expected social conditions and environmental changes, ageing of forest stands may be expected, along with a further increase in standing volume and a shift in tree species towards the potential vegetation. Regardless of the general changes different developments of forest types are expected. The expected climatic change and general ageing of forest stands will probably reduce the resistance, especially in older coniferous dominated stands. The occurrence and severity of storms, snow-breaks and insect attacks is also expected to increase, which might influence forest management and the timber market.

In the future, regeneration and tending of appropriately structured growing stock will be given priority over growing stock accumulation (NFP, 2007, Poljanec et al., 2012). On account of significant differences inside the study area, a differentiated approach adapted to local forest conditions will be required. Forest management in the coming years should be focused on the increase of the resistance of forest stands and thus the reduction of management risks due to environmental change.

Literature

Blaznik P. 1970. Gospodarska in družbena zgodovina Slovencev: zgodovina agrarnih panog I. Ljubljana, DZS: 650 p.

Bončina A. 2008. Načrtovanje donosov pri mnogonamenskem gospodarjenju z gozdovi. Gozdarski vestnik, 66, 1: 15–27.

Bončina A., Diaci J. 1998. Contemporary research on regeneration patterns of Central European virgin forests with recommendations for future research. Zbornik gozdarstva in lesarstva, 56: 33–53.

Bončina A., Ficko A., Klopčič M., Matijašić D., Poljanec A. 2009. Management of silver fir (Abies alba Mill.) in Slovenia. Research Reports Forestry and Wood Science and Technology, 90: 43–56.

Chapman R. A., Heitzman E., Shelton M. G. 2006. Long-term changes in forest structure and species composition of an upland oak forest in Arkansas. Forest Ecology and Management, 236: 85–92.

Češarek D., Ficko A., Bončina A. 2018. Influencing timber harvesting in private forests in Slovenia within the 1995-2014 period. Acta Silvae et Ligni, 115: p. 29-42

Diaci J. 2006. Nature-based silviculture in Slovenia: origins, development and future trends. In: Nature-based forestry in Central Europe: alternatives to industrial forestry and strict preservation. Diaci J. (ed.). Studia forestalia Slovenica, 126: 119-131

Diaci J., Pisek R., Bončina A. 2005. Regeneration in experimental gaps of subalpine Picea abies forest in Slovenian Alps. European Journal of Forest Research, 124, 1: 29–36.

European forest types, categories and types for sustainable forest management reporting and policy, 2006. European Environmental Agency Technical Report No. 9.

Ferreira A. 2005. Vloga gozda v trajnostno-sonaravnem razvoju Zgornje Gorenjske. Doctoral dissertation. Ljubljana [A. Ferreira]: 271 str.

Ficko A., Poljanec A., Bončina A., 2011. Do changes in spatial distribution, structure and abundance of silver fir (Abies alba Mill.) indicate its decline? Forest Ecology and Management 261: 844–854 s.

Gold. S., Korotkov A.V., Sasse V. 2000. The development of European forest resources, 1950 to 2000. Forest Policy and Economics, 8: 183–192

Hočevar M. 2003. Stanje in simulacija trajnostnega razvoja gozdnih fondov v Sloveniji = The state and simulation of sustainable development of forest resources in Slovenia's Forests. In: Območni gozdnogospodarski načrti in razvojne perspektive slovenskega gozdarstva : zbornik referatov = Regional forest management plans and developmental perspectives of Slovenian forestry : conference proceedings, 21. gozdarski študijski dnevi. Bončina A. (Ed.). Ljubljana, Biotehniška fakulteta, Oddelek za gozdarstvo in obnovljive gozdne vire: 103–122.

Hočevar M., Kušar G., Cunder T. 2004. Monitoring in analiza zaraščanja kraške krajine v GIS okolju = Monitoring and analysis of spontaneous afforestation of Karst landscape in GIS environment. Zbornik gozdarstva in lesarstva = Research reports : forest and wood science & technology, 75: 21–52.

Hočevar M., Kušar G., Japelj A. 2006. Integralni monitoring gozdnih virov v Sloveniji - stanje in potrebe v luči vseevropskih meril = Integral monitoring of forest resources in Slovenia - state and needs in a view of Pan-European's criteria. In: Monitoring gospodarjenja z gozdom in gozdnato krajino = Monitoring the management of forests and forested landscapes. Hladnik D. (Ed.). (Studia forestalia Slovenica, 127). Ljubljana, Biotehniška fakulteta, Oddelek za gozdarstvo in obnovljive gozdne vire: 27–51.

Kotar M. 2005. Zgradba, rast in donos gozda na ekoloških in fizioloških osnovah. Ljubljana, Zveza gozdarskih društev Slovenije in Zavod za gozdove Slovenije: 500 p.

National forest inventory (NFI) in 1946 and 1947. 1947. Ljubljana: 73 s.

NFP. Resolution on the National Forest Programme. 2007. Official Gazette of RS, No. 111/07.

Johann, E., 2007. Traditional forest management under the influence of science and industry: the story of the alpine cultural landscapes. Forest Ecology and Management 249:54–62.

Klopčič, M., Poljanec, A., Gartner, A., Boncina, A. 2009. Factors related to nature disturbances in mountain Norway spruce (Picea abies) forests in the Julian Alps. Écoscience, 16, 1:48-57.

Klopčič M., Jerina K., Boncina A. 2009. Long-term changes of structure and tree species composition in Dinaric uneven-aged forests: are red deer an important factor? European journal of forest research, DOI: 10.1007/s10342-009-0325-z.

Kobler A. 1996. Primer analize zaraščanja kulturne krajine s pomočjo GIS-a. V: Geografski informacijski sistemi v Sloveniji 1995–1996, Černe A. (Ur.). Ljubljana, Zveza geografskih društev Slovenije, Zveza geodetov Slovenije: 110–114.

Kušar G., Hočevar M., 2005. Jožefinski (avstroogrski) vojaški zemljevid - „nov" vir informaciji o gozdu = Austro-Hungarian military map made under the Emperor Joseph II - a „new" information source about the forest. Gozdarski vestnik, 63, 10: 419–429.

Medved M., Košir B. Robek R., Veselič Ž., 2005. Spremljanje gospodarjenja z zasebnimi družinskimi gozdovi v Sloveniji = Forest management on family farms and the management of other small private forests in Slovenia. In: Prihodnost gospodarjenja z zasebnimi gozdovi v Sloveniji = Future of private forest management in Slovenia.. Adamič M., Winkler I. (Ed.). (Studia forestalia Slovenica, 123). Ljubljana, Biotehniška fakulteta, Oddelek za gozdarstvo in obnovljive gozdne vire: 61–86.

Oliver C. D., Larson B. C. 1996. Forest stand dynamics. Updated ed. New York, John Wiley & Sons: 520 p.

Osnutek perspektivnega plana razvoja gozdarstva v LR Slovenija v razdobju od 1957–1961. 1958. Ljubljana, Društvo inženirjev in tehnikov gozdarstva in lesarstva LR Slovenije: 149 str.

Perko M., 2002. Kronologija pojavljanja ter vpliv najpomembnejših abiotskih in biotskih dejavnikov na umetno osnovane smrekove sestoje v GE Planina. Gozdarski vestnik, 60, 2: 77–95.

Perko F. 2005. Trpeli so naši gozdovi – slovenski gozd in gozdarstvo v prvem desetletju po drugi svetovni vojni. Ljubljana, Jutro: 327 str.

Poljanec A., 2008. Changes in forest stand structure in Slovenia in period 1970–2005. Doctoral dissertation, Ljubljana: 169 s.

Poljanec A., Bončina A. 2006. Obravnavanje gozdnih sestojev v gozdarskem načrtovanju na primeru gozdnih območij Bohinj in Pohorje = Treatment of forest stands in the forest planning on the case of Bohinj and Pohorje forest areas. Zbornik gozdarstva in lesarstva, 79: 53–66.

Poljanec A., Ficko A., Bončina A. 2010. Spatiotemporal dynamic of European beech (Fagus sylvatica L.) in Slovenia, 1970-2005. Forest Ecology and Management, 259: 2183–2190.

Poljanec A., Jonozovič M., Marenče M., Matijašić D., Pisek R., Veselič Ž. 2012. Regional forest and wildlife management plans; compendium. Slovenia Forest Service, Ljubljana: 111 p.

Poljanec, A., Ščap, Š., Bončina, A. 2014. Volume, structure and distribution of salvage logging in Slovenia in the period 1995 2012. Gozdarski vestnik,72, 3:131-147.

Annual report on the state of forests 2018. Ljubljana, Zavod za gozdove Slovenije (Slovenian Forestry Service), www.zgs.gov.si (18.9.2019)

Rajšp B., Serše A., Trpin D., 1998. Slovenija na vojaškem zemljevidu 1763–1787. Ljubljana, Znanstvenoraziskovalni center SAZU, Arhiv Republike Slovenije.

Remic C., 1975. Gozdovi na Slovenskem. Ljubljani, Borec, Poslovno združenje Gozdonogospodarskih organizacij: 309 str.

Roženbergar D., Diaci J., 2002. Long term stand structure changes in virgin forest remnant Pečka - Slovenia.

Simončič, T., Bončina, A., Jarni, K., Klopčič, M. 2019. Assessment of the long-term impact of deer on understory vegetation in mixed temperate forests. Journal of vegetation science, 30, iss. 1:108-120.Spiecker, H., 2003. Silvicultural management in maintaining biodiversity and resistance of forests in Europe-temperate zone. Journal of Environmental Management, 67: 55–65.

Statistični letopis SR Slovenije. 1975. SRS, Zavod RS Slovenije za statistiko, XIV. Letnik, Ljubljana.

Šebenik D., Bončina A. 2004. Spreminjanje gozdnatosti kraškega gozdnogospodarskega območja v obdobju 1830-2000 = Changes in the forest cover of the Karst forest management region in the period 1830-2000. Gozdarski vestnik, 62, 9: 355–366.

Veselič Ž., Matijašić D. 2002. Gozdnogospodarski načrti gozdnogospodarskih območij za obdobje 2001-2010 = Regional forest management plans for the 2001-2010 period. Gozdarski vestnik, 60, 10: 461–489.

Turk Z., 1955. Izkoriščanje gozdov v desetletju 1945–1954. Gozdarski vestnik: 296–321.

Zemljič M., 1961. Naš gozdni fond 1947–1958. V: Prikazi in študije, VII, 9. Ljubljana, Zavod LR Slovenije za statistiko: 11–30.

Žumer L., 1976. Delež gozdov v slovenskem prostoru. Ljubljana, Studia Forestalia Slovenica = Strokovna in znanstvena dela, 50: 259 p.