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FORESTS AND FORESTRY IN SLOVENIA

GOZDARSKI INŠTITUT SLOVENIJE
SLOVENIAN FORESTRY INSTITUTE

Preface

The foundations of the close-to-nature concept have deep roots in Slovenian forests and forestry, and are gaining in importance worldwide in times of environmental change.

The publication presented here has its origin in a bilateral collaboration involving Sweden and Slovenia in exchanging knowledge and experience to improve sustainable forest management.

Experts from the Slovenia Forest Service, the Department of Forestry and Renewable Forest Resources at the Biotechnical Faculty - University of Ljubljana, the Slovenian State Forests Company and Slovenian Forestry Institute, all contributed to the complex and detailed description of the current conditions in our country.

Matjaž Čater
Peter Železnik

Ljubljana, July 2021

Slovenian forests

Matjaž Čater, *Slovenian Forestry Institute*

Slovenian forests cover more half of the country (58.07%) and represent an essential landscape element. Forests take up 1 177 244 hectares and predominate on as much as three quarters of Slovenian territory; Slovenia is a mountainous country, where more than one third of its territory lies above 600m and two thirds of this is forest.

Half of the land in Slovenia has an incline greater than 20% and a good fifth more than 35%. Three quarters of the areas with an incline greater than 20% are forested, while forests cover up to 90% of land with an incline of 35% or more. Forests have mainly been preserved in higher and steeper locations, which are less suitable for agriculture and where their protective role is reflected in the protection of settlements, infrastructure and agricultural land against natural disasters. The present situation, enabling stable agricultural production, can only be maintained in Slovenia through high forest cover. Forests are thus an essential feature and constituent part of the environment, and their protective and social importance is steadily increasing.

The macroclimates in Slovenia are influenced by the Mediterranean Sea, the Alps, and the Pannonian Plain. Most of Slovenia's forests are located within the natural environment of beech, which, together with the beech-oak and fir-beech forests, cover about 70% of the nation's forestland. Seventy-one tree species can be found in total in Slovenian forests, of which 10 are coniferous and 61 are deciduous species.

The heterogeneous ecological conditions result in diverse forest vegetation patterns. Based on studies of the phyto-geographic regions and on different geographic features such as geology, soil, relief, precipitation, temperature, potential vegetation, climate, and phenology, the country can be divided into seven eco-regions and sub-regions (Kutnar et al., 2002).

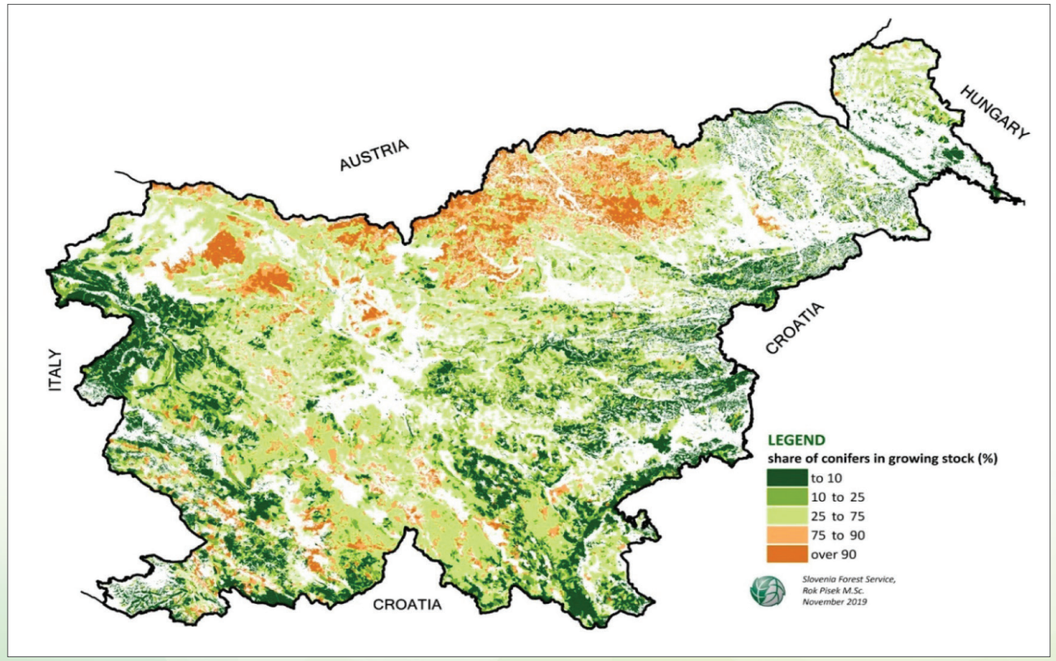

Figure 1: Slovenian forests (SFS, 2019)

The Alpine eco-region (1) consists of the Julian Alps, the Kamnik-Savinja Alps, and the Karavanke mountain chain. In the western part of this region, at altitudes of 900 m.a.s.l. up to the upper forest line at approximately 1 500 m.a.s.l., beech and silver fir-beach forests of different associations grow (*Anemone trifoliae-Fagetum*, *Homogyno sylvestris-Fagetum*, *Ranunculo platanifoliae-Fagetum*). Many beech and silver fir-beech forests have been converted to essentially pure monoculture of Norway spruce. Some potentially natural sites of primary Norway spruce forest can be found above 1 000 m.a.s.l. Secondary spruce forests of *Avenello flexuosae-Piceetum* extend over a large area, on non-calcareous parent material of potentially natural sites of acidophilic beech forests at Pohorje mountains. At lower altitudes, acidophilic beech forests of *Castaneo sativae-Fagetum* grow. In the Alps and Karavanke, the upper tree line reaches 1 700 m.a.s.l. The woody vegetation that can be found above timber line is dwarf-mountain-pine shrubbery (*Rhodothamno-Rhododendretum hirsuti* association), mixed with single larch (*Larix decidua* Mill.) trees.

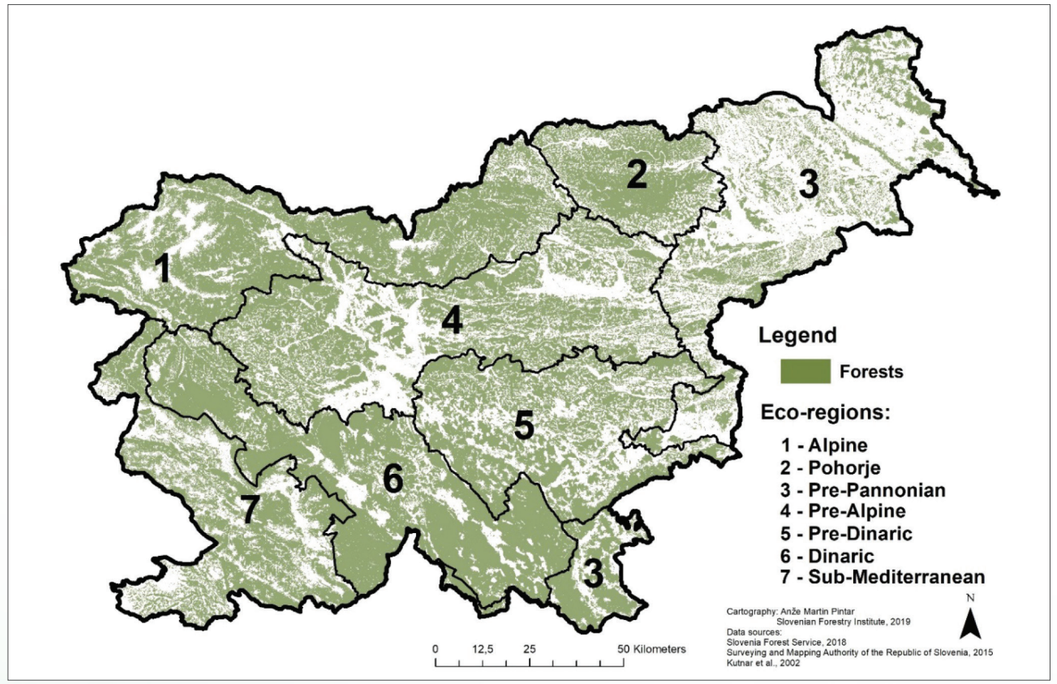

Figure 2: Slovenian eco-regions (Cartography by Anže Martin Pintar).

The Pohorje eco-region (2) includes the crystalline Pohorje massif and Kozjak Mountains. In the lowland and hilly areas, mixed forests of beech, sweet chestnut, and sessile oak (*Castaneo sativae-Fagetum*) grow. In the northern part of this region, on shady and very steep slopes at altitudes from 400 to 1 000 m.a.s.l., *Galio rotundifolii-Abietetum* forests predominate. The parent materials consist of non-carbonate tonalite, gneiss, mica schist, amphibolite, and others. Predominantly at altitudes between 900 to 1 300 m.a.s.l., the so-called 'acidophilic alti-mountain' beech of the *Luzulo albidae-Fagetum* association occurs. The geological bedrock consists of moderately acidic non-calcareous stones. These forests have always been subject to significant human impact, such as clearing for meadows and livestock grazing. Beech was locally exterminated at the Pohorje massif range in the period when glassworks were active in the area. All these activities resulted in the complete predominance of Norway spruce (*Picea abies* (L.) Karst.), which has an evident influence on the sites. The secondary spruce forests were classified as the *Luzulo sylvaticae-Piceetum* association. The *Cardamini savensi-Fagetum* is a zonal beech association of the upper parts of the Pohorje mountain range. It grows on silicate metamorphic and igneous rocks between 800 and 1 300 m.a.s.l. In these forests, European silver fir (*Abies alba* Mill.) and Norway spruce are mixed with beech.

The Pre-Pannonian eco-region (3) extends from the south-east to the north-east of Slovenia. Forests cover only a small part of this region. Forests of hornbeam (*Carpinus betulus* L.) and oaks (*Quercus* sp.), which would be characteristic of lowlands and the hilly parts of Slovenia, were mainly cleared and the land has primarily been used for agriculture. On small areas along watercourses, associations of white willow (*Salicetum albae*), forests of black alder (*Alnetum glutinosae*), and pedunculate oak-ash forests (*Querco roboris-Ulmetum laevis*) occur. On the plains, which are influenced by high underground water and temporary flooding, oak-hornbeam forests (*Querco roboris-Carpinetum*) can also be found. These riparian forests are threatened since in the past the marshes and wetlands were intensively drained. In many places, they have been converted to wet meadows. In the northern part of this region, on the lower altitudes of hills, *Pruno padi-Carpinetum betuli* occur, while at higher altitudes zonal beech forests (*Vicio oroboidi-Fagetum*) grow. On slopes from 300 to 700 m.a.s.l., moderately acidophilic beech forests with admixed sweet chestnut and sessile oak (*Castaneo sativae-Fagetum*) grow. They thrive on very different non-calcareous parent material. On Luvisols and degraded soils, forests of *Galio rotundifoli-Pinetum sylvestris* prevail.

The Pre-Alpine eco-region (4) is located between the Alpine region (1) in the north, and the Dinaric (6) and Pre-Dinaric regions (5) in the south. On these plain areas and gentle slopes, azonal forest associations of *Vaccinio-Pinetum sylvestris* grow. This is a pioneer association occurring mostly on poor sites. Much more common in this area are acidophilic beech forests of *Blechno-Fagetum* associations and *Castaneo sativae-Fagetum* associations, which are growing on Dystric Cambisol on various non-calcareous geological formations. In many cases, forests of *Castaneo sativae-Fagetum* have been changed either to Norway spruce monoculture forests or to coppiced forests with a mix of sweet chestnut (*Castanea sativa* Mill.), Scots pine (*Pinus sylvestris* L.), and sessile oak (*Quercus petraea* (Matt.) Liebl.). In this region, thermophilous beech forests (*Ostryo carpinifoliae-Fagetum*) cover large areas of the southern exposed sites from lowlands to an altitude of around 1 000 m.a.s.l. with a relatively high amount of precipitation. In the mountain belt, on dolomite and limestone of various geological formations, beech forests of *Hacquetio epipactis-Fagetum* and *Lamio orvalae-Fagetum* are also very common.

The Pre-Dinaric eco-region (5) extends from the central to the south-western part of the country. Here, beech forest of *Hacquetio epipactis-Fagetum* and *Lamio orvalae-Fagetum* associations are very common, along with a variety of other forest associations. On gently configured hills and flatlands, at altitudes from 150 to 350 m.a.s.l. there are some remnants of hornbeam forests (*Abio albae-Carpinetum betuli*). However they have mostly been converted into agricultural and urban areas. *Castaneo sativae-Fagetum* forests grow on non-calcareous parent material. A major part of these moderately acidophilic beech forests have been changed either to monoculture spruce or to coppiced forest. On Dystric Cambisol, acidophilic hornbeam forests of *Vaccinio myrtilli-Carpinetum betuli* occur. Like most forests in this hilly region, they have been intensively utilized due to their location close to settlements and easy access, as well as favourable land configuration.

In the Dinaric eco-region (6) the Dinaric ridge separates the littoral and continental regions. It is characterized by a mixed silver fir-beech forest (*Omphalodo-Fagetum*). It covers parts of the high Karst plateaus of southern Slovenia and extends to Croatia. It grows mostly at altitudes from 700 to 1 200 m.a.s.l. The parent material is limestone with sporadic dolomite. In the lower part of the mountain belt, between 600 and 900 m.a.s.l., beech forests of *Lamio orvalae-Fagetum* occur. From lowlands up to altitudes of around 600 m.a.s.l., sub-montane beech forests of *Hacquetio epipactis-Fagetum* can be found.

In the Sub-Mediterranean eco-region (7) limestone and flysch are the characteristic parent materials. The most common type of forest vegetation is *Ostryo carpinifoliae-Quercetum* pubescentis. In the past, many sites of these forests were converted to pastures. In the second half of the 19th and at the beginning of the 20th centuries, many of them were planted with Austrian pine (*Pinus nigra* Arnold). After World War II, many pastures were abandoned and have now been gradually overgrown by forests of *Ostryo carpinifoliae-Quercetum pubescentis* associations. The mountainous parts of the Sub-Mediterranean region are covered by beech forests of *Seslerio autumnalis-Fagetum*. This occurs up to 1 100 m.a.s.l. in the littoral mountain region and grows on the coldest sites of the Sub-Mediterranean region. On the edge of its area, many of these forests have been changed into secondary forests of *Seslerio autumnalis-Ostryetum carpinifolia* associations. The *Castaneo sativae-Fagetum* association is very common on medium deep to deep Dystric Cambisol on acidic flysch formations in the Brkini sub-region.

In the initial period of colonization, forests were cleared in the lowlands and on hillsides, and these areas are still the basis of agricultural production. In primarily forest regions, traces of the last colonization between the 12th and 15th centuries are still clearly visible. Today, the actual tree species composition deviates greatly from the potential vegetation. The high share of Norway spruce is the result of spruce planting during 18th and 19th centuries following the model of the German forest management school. Pine was also planted in the region of the Slovenian Karst during the second half of the 19th century to alleviate the effects of the strong north-eastern "bora" wind and regenerate the barren, rocky karstic landscape.

The high diversity of habitats and biotic communities that have developed through the millennia have created a great many different ecosystems in the relatively small Slovenian area. Numerous animal species have found their niches; above all, many amphibians and mammals are linked to the forest. Preservation of the forests has certainly contributed to Slovenia being one of the few European countries where brown bears, lynxes and wolves can be found.

Forest regulation in Slovenia has a long tradition: the first known regulation, the Ortenburg Forest Regulation, was written in 1406. Empress Maria Theresa's "Forest regulation in Carniola" in 1771 established sustainability in forest management, securing a permanent wood supply. Almost two centuries later it was prescribed by the Forestry Act in 1953, by obligatory forest management plans that had to be elaborated for all forests irrespective of ownership and size of the property. With the independence of Slovenia, a new Forestry Act was adopted in 1993.

The tradition of planned forest use is several centuries old. The recognition of the economically valuable forests emerged in the dry and warm sub-Mediterranean climate, where sustaining the existence and regeneration of forests is difficult. The first shortage of wood occurred in the Karst, from where wood was transported to Trieste and Istrian littoral cities. It was there where the first economic measures were passed by which some municipal communities were ensured a permanent supply of wood from the neighbouring forests.

The beginnings of forest management on Slovenian territory are related to forests belonging to the Idrija mine, where mercury was discovered in 1493, the Trnovo Forest and forests in the vicinity of Tolmin and Bovec. The first timber yield regulation for the Idrija forests dates to 1742, the next to 1759. The first plan for the Trnovo Forest was produced in 1771. In the second half of the 19th century, large forest estates on the Slovenian territory started to develop forest management plans on their own initiative. In the large forest estates of the high karst of Kočevsko and Notranjska, an original method was developed of forest regulation and management, different from the German school which was established in Europe at that time. It represents an autochthonous contribution to the development of forestry and forest regulation in Slovenia. With the plan elaborated in 1892 for the Kočevje forests owned by the Count Auersperg, Leopold Hufnagl developed his own system of selection forest management. He consistently opposed and fought against the established clear-felling system to prevent the spread of karst in the context of which a simultaneous, well-organized afforestation action was carried out in the Slovenian Karst, which gained worldwide recognition. Hufnagl was also a pioneer of nature conservation, as he placed under protection some virgin forest remnants in the Kočevje region. In the area of Notranjski Snežnik, on large Schönburg-Waldenburg estates, Heinrich Schollmayer-Lichtenberg adopted Hufnagl's concept of selection forest management and introduced an original concept of a control method in forest regulation and management. The concept was immediately put into practice in the neighbouring Windischgraetz forest estates in the forests of Javorniki, Nanos and Hrušica. The Postojna forest management region represents a unique example in Slovenia, where the concept of a control method in a forest area of more than 20 000 ha was been practiced since 1890. In the 1950's a management system for the entire Slovenian forest area was introduced, irrespective of ownership, and by 1968 the first regulation of all forests in Slovenia had been performed with considerable revisions for number of management units. Based on this knowledge, Slovenian forestry began the elaboration of regional forest management plans in 14 regions, with four rounds of such plans being developed for all regions (1971-1980, 1981-1990, 1991-2000, 2001-2010). According to the provisions of the Forestry Act from 1993, the National Assembly of the Republic of Slovenia adopted the National Forest Development Programme in 1996.

Table 1: **Changes in the forest area in Slovenia in the period 1875-2019**

Year	Forest area (x 1000 ha)	Forest cover (%)
1875	737	36
1947	897	43
1961	961	48
1970	1 026	51
1980	1 045	52
1990	1 077	53
2000	1 134	56
2006	1 174	58
2019	1 177	58

The fundamental principles of forest treatment and management are:

- **sustainability** - the sustained preservation of forests, sustained use of their goods and non-material functions,
- **close-to-nature management** - the exploitation of forests to such a degree and in such a way as to ensure the preservation of all their natural constituents, and
- **multi-purpose management** – an approach respecting the balanced significance of the ecological, productional, and social roles of forests.

In accordance with the professional foundations provided by the Slovenia Forest Service, forests are managed by forest owners: private owners (natural and legal persons), local communities and the state.

A total of 71% of forests in Slovenia are private and 29% of forests are public, owned by the state or communes. Larger and undivided forest estates of state-owned forests enable good professional management. Private forest estates are small, with an average area of only 3 ha and even these are further fragmented into several separate plots. For the great majority of these estates, forests are not of economic interest. Private forest property is becoming even more fragmented as the number of forest owners is increasing. According to the latest data there are already some 314 000 (with co-owners even 489 000) forest owners in Slovenia. The major fragmentation of forest property, the number of forest owners and co-owners, present a serious obstacle to professional work in private forests, to optimal timber production and utilization of forest potential.

Slovenian forests in numbers (2018)

Source: National Forest Inventory NFI, Slovenian Forestry Institute (SFI) 2018, Slovenian Forest Service

Table 2: **Forest area** (source: Land use map MKGP, SFS)

Forest area	1 177 240 ha
Forest reserves	9 508 ha
Protective forests	98 762 ha

Table 3: **Living stock** (source: NFI, SFI 2018) and increment (*ingrowth period 2007-2012, NFI 2012)

	unit	conifers	broadleaves	Σ
Living stock	m^3	168 346 000	217 790 000	386 136 000
	m^3/ha	143	186	329
Increment*	m^3/year	4 226 000	5 262 000	9 488 000
	m^3/ha, year	3.42	4.44	7.86

Table 4: **Diameter class-structure** (source: NFI 2018, SFI)

class	≤20cm	20-40cm	40-60cm	≥60cm	Σ
%	9.7	42.0	37.0	11.3	100

Table 5: **Planned** (source: report on Slovenian forests 2018) and realized cut (NFI, SFI 2018)

	unit	conifers	broadleaves	Σ
planned	m^3	3 070 000	3 767 000	6 837 000
realized	m^3	4 661 886	2 330 943	6 992 829

Table 6: **Regeneration and tending** (data source: Report on Slovenian forests (SFS))

Tending measures	3 782 ha
Regeneration with planting	477 ha
Natural regeneration	95%

Table 7: **Tree species in the living stock** (source: NFI, SFI 2018)

Species		[m^3/ha]	%
Fagus sylvatica L.	European beech	109.7	33.4
Picea abies(L.) Karst.	Norway spruce	94.3	28.7
Abies alba Mill.	European silver fir	25.9	7.9
Quercus petraea (Matt.) Liebl.	sessile oak	17.5	5.3
Pinus sylvestris L.	Scots pine	13.0	3.9
Acer pseudoplatanus L.	Sycamore maple	12.0	3.7
Carpinus betulus L.	common hornbeam	7.8	2.4
Castanea sativa Mill.	sweet chestnut	5.3	1.6
Pinus nigra Arnold	Austrian pine	5.2	1.6
Ostrya carpinifolia Scop.	hop hornbeam	4.7	1.3
other		33.3	10.2
Σ		328.7	100.0

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Slovenian Forest Service web page, 2019 (www.zgs.si)

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

Aleš Poljanec, *Slovenia Forest Service,*
Andrej Bončina, *University of Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Forest Resources*

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).

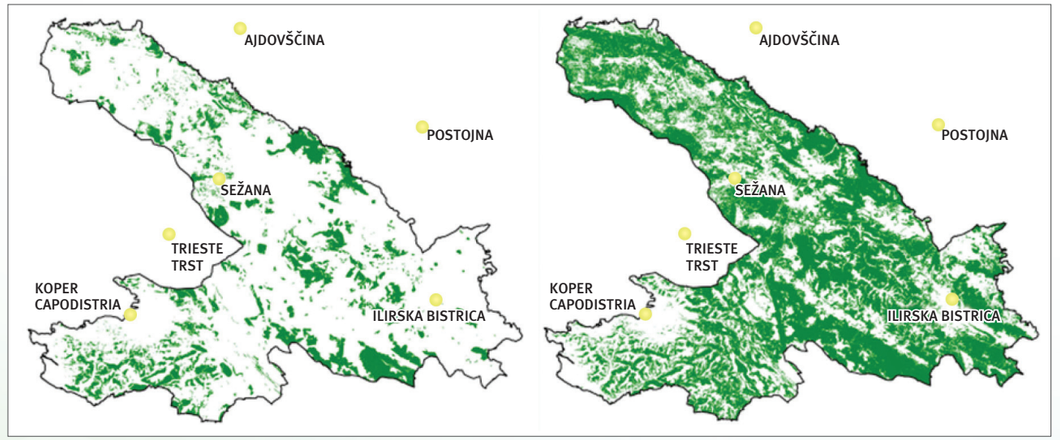

Figure 3: The successful Karst afforestation that received a "Grand prix" at the Paris World Exhibition in 1900. In 1830 forests covered 19% of total land in the Karst region, today forest covers about 55% of the Slovenian Karst area (Šebenik and Bončina, 2004).

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).

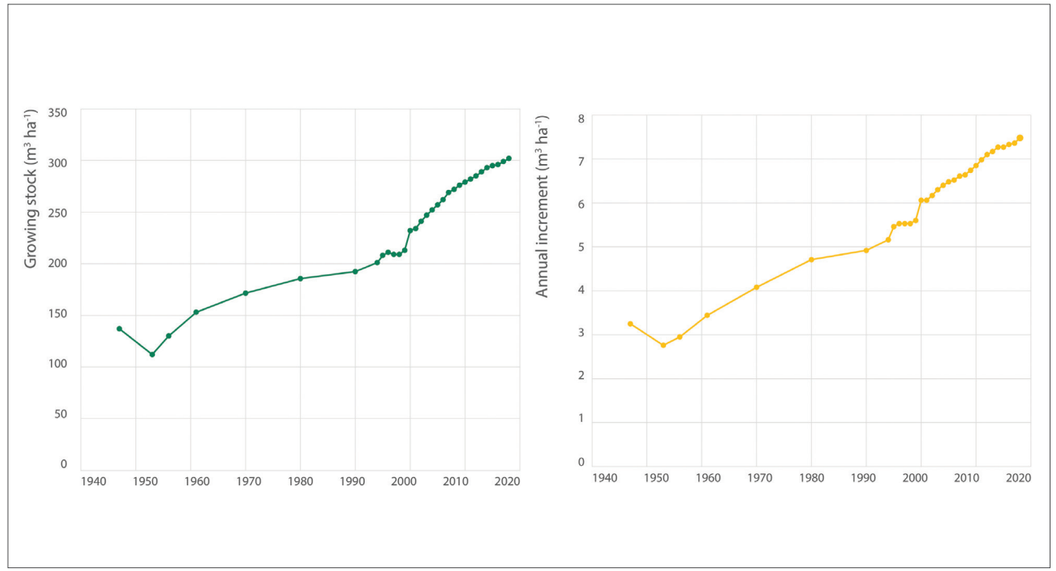

Figure 4: Changes in the growing stock and increment of Slovenian forests in the period 1947-2018.

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.

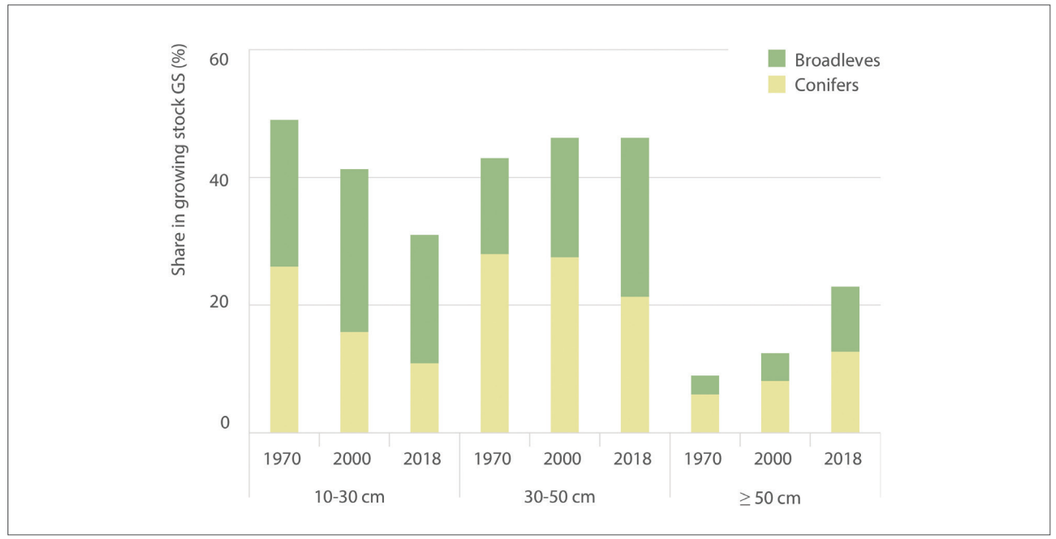

Figure 5: Changes in the diameter distribution of forest stands in the period 1970-2018 indicated the gradual ageing of stands.

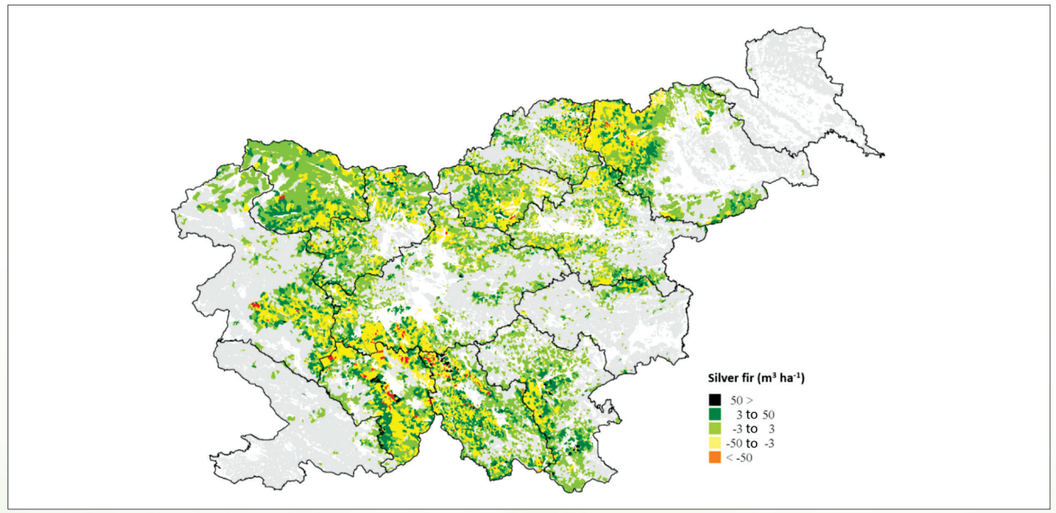

Figure 6: Average ten-year changes in the growing stock (m^3/ha) for silver fir in the period 1970–2005 (Poljanec 2008)

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).

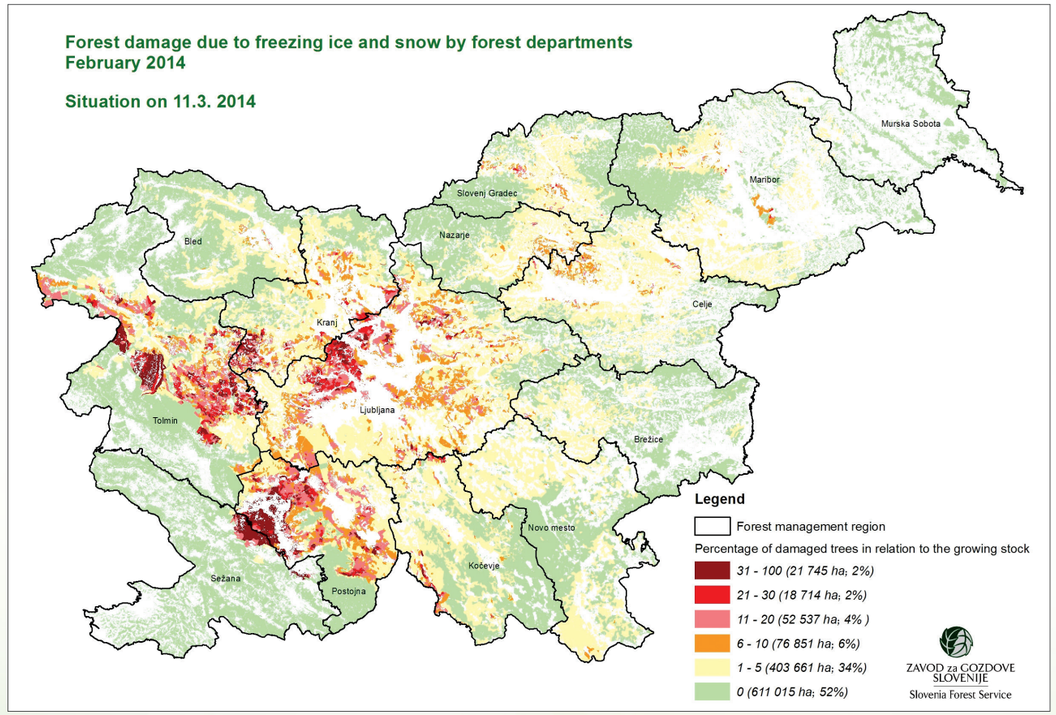

Figure 7: An important driving factor of forest changes are natural disturbances. The forest stands in the last decade suffered due to an extensive ice-storm in 2014, windstorms in 2017 and 2018 and bark beetle outbreaks in the period 2015-2018.

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).

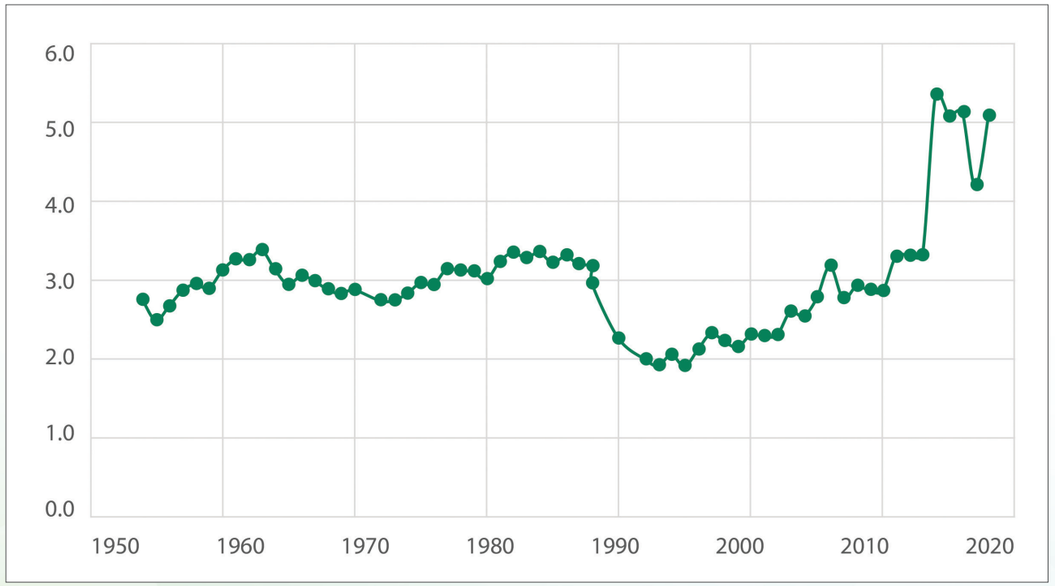

Figure 8: Dynamics of annual cut (m^3/ha) in Slovenia from 1955 to 2018.

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.

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Forest management - silvicultural systems

Matjaž Čater, *Slovenian Forestry Institute*,
Jurij Diaci, *University of Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Forest Resources*

The crisis of the human natural environment, and particularly the change and exploitation of forests with increasing need for the provision of goods caused the development of silviculture (Eng.: silviculture, Ger.: Waldbau, It.: selvicoltura, Fr.: sylviculture). Forestry shifted during its development from deforestation and shifting agriculture in prehistoric times, through exploitation and mechanistic management towards the current sustainable, close-to-nature approach. The latter provides, along with the permanent and optimal yield, a number of ecological, social, nature-protection and other important forest functions, which are in harmony with the related requirements and environmental constraints.

Most of the world exploits forests, and due to pasturing, intensive agriculture and urbanization, the share of forests in tropical and developing countries is significantly decreasing, although in European countries the share is rising. Nevertheless, European forests are among the most changed ones due to the long-term prolonged cultivation of conifers at the expense of deciduous tree species, and promotion of fast-growing tree plantations with short-term benefits. Moreover, the economic importance of forests has recently started weakening in Europe, while the ecological and numerous intangible benefits are becoming more and more pronounced. This view of forests as a renewable source of raw materials and energy, a carbon sink and provider of ecological and social functions (Diaci 2006) is counterbalanced against increased wood consumption (UNECE - European Commission 2007), global scale deforestation and human population growth, as the differences in the silvicultural principles applied around the world are becoming greater than ever (Diaci and Golob, 2009). The situation is worsened by the increases in water and air pollution, and the increasing frequency and intensity of extreme weather events.

Planning represents silviculture's starting point. The basic purpose of planning – the determination of current conditions and defining practices to provide successful forest development – is divided into long-term, regulatory-forest management planning, and implementation, silvicultural planning. The regulatory plan outlines the framework guidelines and restrictions on forest intervention, while a detailed plan defines direct guidelines for the practical implementation of the regulatory plan.

Planning is crucial for sustainable forestry, and is based on a control method and the continuous verification of the forest's current state, and its responses and adaptation to the applied silvicultural measures (Diaci 2006).

Nearly 300 years ago the principle of sustainability was introduced in Central Europe and Slovenia, for which forest management planning was essential. Early examples are the Slovenian Idrija mining forests (the first established plan in 1724) and the Trnovo forest plan (the first plan of 1771), which supplied Trieste and Gorizia with wood – the first plan-regulated forest in the Austro-Hungarian empire was the Vienna Forest from 1720 (Gašperšič 2009). Forests were managed in the manner of old German clearcutting approach, applied in the Alpine and Pre-alpine region of Slovenia. The first deviation from this conservative approach was made during second half of the 19th century to avoid degradation of the sites in the high karst region of Kočevska by introducing plentering (Hufnagel) and a unique control method (Schollmayer) in the Notranjska region (Mlinšek, 1992). After World War II a widespread development programme was adopted due to the poor state of the forests and clear-felling was prohibited by law.

Today the development of forests is carried out in accordance with the natural site conditions by the measures of regeneration and tending. Tending represents all measures which aim to regulate the growth of individual trees and entire forest stands, provide the highest economic return and improve stand quality and stability (Leibundgut 1984). All development processes in forests are regulated and triggered by varying light conditions, which influence interspecific and intra specific competition, especially in low light environments. By eliminating competitors and helping quality trees, with tending measures for young stands and thinnings, we increase the share of quality assortments and provide a better quality of emerging stands, strengthening their mechanical and biotic stability and ensuring optimal quality yield.

In the north European countries clearcutting is the main silvicultural system, justified by the special ecological conditions and predominating tree species. Lower temperatures and a raw humus layer limit development of natural regeneration (Lafleur et al., 2018). The consequences of clearcutting may be reflected in many consequent forest generations in degraded sites, reduced production capacity, compromised mechanical and biotic stability of the stands, and consequently lower yield and reduced resilience (Diaci, 2006). The requirements for greater intensity and economic efficiency require an increasing mechanisation of work, the introduction of fast-growing species and the use of chemical preparations and fertilizers that are not allowed in Slovenia.

Forest management is now being abandoned on poor and less profitable sites, which do not meet the economic criteria. Governance follows the traditional concept, emphasizing the more natural tree species composition of altered forests (conversions) and preserving their healthy conditions. Around the wider world, but especially in Europe, there are growing efforts towards developing models of sustainable forest management.

Although Slovenia is known for its sustainable concept of management and a large share of preserved and protected forests compared to other European countries, the number of silvicultural problems is increasing; natural regeneration is hampered by overpopulated ungulates, there is an evident imbalance between developmental phases, forests are declining, and tending is performed insufficiently. Management costs are rising, as well as the pressure and demands for the increased protective and social functions of forests, while forestry as a field is being marginalized due to matters related to the state economy and political inconvenience. Noticeable deviations from planned and implemented silvicultural works compared to stable investments from the previous decades are increasingly evident. There are many challenges for the future, and one of the principal tasks is to preserve the active direction of sustainable forest development with an atmosphere of cooperation and the provision of adequate information to forest owners (Diaci and Golob, 2009).

Silvicultural systems

All measures for achieving the targeted goal of managed forests in a given time and space are defined by the silvicultural system. It represents the planning directions and all the required direct measures in the individual spatial forest units to permanently achieve the targeted/ final state, the defined goal with tending methods and information about the method of regeneration (forest restoration).

The first systems from the early ancient periods would be hard to characterize as silvicultural due to the lack of timber (the Mediterranean). They were designed for smaller areas than systems applied later in the 19th century. Lack of timber and increasing demands caused a crisis which encouraged the development of the sustainability principle – the permanent provision of timber and the definition of the smallest area that would provide such a concept. The first forms followed design from agriculture, where each year the same area of harvested forest was planted with young trees. The number of all such parcels represented the area of the forest, which consistently provided a permanent yield. The strict spatial order allowed control and the first such transparent management was established in Central Europe, which became later known as the German forestry school.

In the middle of the 19th century, the fragments of a different, selective silvicultural approach in France, Switzerland and Slovenia were established. Due to unregulated primitive plentering, which left behind depleted forests, the system gradually proved its efficiency and benefits, as developed in opposition to the former clearcutting system of the German forestry school, especially after World War II. Today this approach is acquiring international recognition for obtaining other, also protective and social forest functions.

Silvicultural systems can be classified according to their historical development and application, from the early cultivation types like clearcutting, the shelterwood system and edge-shelterwood system, to modern approaches based on tending that include the irregular shelterwood method, selection system and free silvicultural technique.

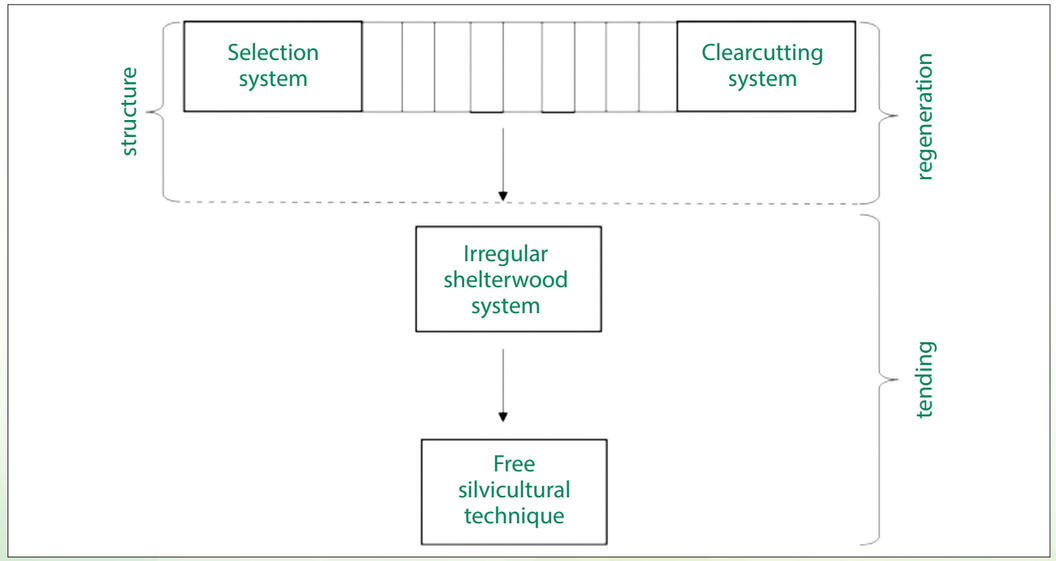

Figure 9: Silvicultural systems according to their leading or governing principles: regeneration, structure and tending (after Mlinšek 1968).

Clear-felling

Despite its rigidity, clear-felling is still present in most European countries: it prevails for example in Austria, Scandinavia and a large part of Russia due to specific environmental conditions, and as a form of exploitation in the tropical and subtropical belt on a global scale (Diaci, 2006). The remains of this type of management in Slovenia are still visible today in Pohorje and Alpine spruce forests, where ironworks or glassworks were set in the past. Trees grown under this system are more susceptible to mechanical damage (windthrows), insect attacks, and so on (Diaci, 2006). However, shifting from clear-felling to a different system represents long term and expensive process. The system in Slovenia is prohibited by the law: it is characterized by short-term advantages, such as large quantities of equal assortments, the possibility of machine-felling, low costs of tending and harvesting, simple planning and the possibility of mechanised tree planting. However, the long-term weaknesses outweigh these short-term benefits (Bormann and Likens, 1986), and these include depletion of site conditions, problematic natural regeneration and lower stand stability of larger areas, which are present for generations after their establishment, preventing the natural balance from being re-established. Moreover, the resulting increased risk of erosion, changes in energy flow and matter cycling due to increased solar radiation (Mayer, 1981; Flemming, 1968; Holstener-Joergensen, 1967) and increased exposure to temperature and precipitation extremes (Mitscherlisch et al., 1966; Hibbert, 1967) are processes that are far from natural. Accelerated mineralization of the soil and loss of nutrients also have negative effect on water quality, while the presence of pioneer species may inhibit the establishment of climax tree species for a longer time period due to altered site conditions (Irrgang, 1990; Diaci, 2006).

Despite criticism and numerous shortcomings, the clear-felling system may be applied on small surfaces in direct conversions – in cases of the compromised health of a certain stand which threatens the adjacent stands. After the conversion, intensive investment in the restoration and protection of such stands is required.

Figure 10: Clearcutting in Slovenia is prohibited by law since 1949 (Photo: M. Čater)

Shelterwood method

The shelterwood system is composed of various cutting forms of cutting – preparatory, regeneration, light and final or only light and final logging. By progressively loosening the mature canopy over time the intensive development of the ground vegetation is controlled, which would otherwise prevent successful regeneration. Light conditions allow the emergence of natural saplings under mature canopy stand, especially in the case of broadleaves. Preparatory logging stimulates floor activity due to less dense canopy cover and releases adult quality trees; regeneration logging allows the emergence of saplings in mast years. The measure intensity reaches up to 30% of the growing stock, but not more, otherwise emerging species would suppress sapling development. This is followed by one or several light cuts, which are carefully planned to cause as little damage and injuries to the remaining regeneration as possible. Light conditions are adapted to the regenerated species. With the last, final logging we remove the remaining trees of the mature stand, usually when the younger phase does not require further protection from the mature stand. The time from the beginning of the light cuts to the final cut is the regeneration period, and this mainly depends on the light requirements of the species and the size of the stand. For light demanding species the regeneration period is shorter than for shade tolerant species.

This system was created as a response to the clearcutting system in Central Europe and, has been established mainly in broadleaf and mixed forest stands. In Slovenia, it was present at the time of glassworks and ironworks in Carinthia, Pohorje, and Idrija, and represented a qualitative improvement in the direction of forest soil conservation and the protection of the newly emerging stands. The regeneration process was also more transparent and faster compared to the previous one. The main disadvantages of the system are the dependence on the mast years of the old stand, and the susceptibility of the young stand to later interventions. This system is still in use in some pure and mixed beech stands of Central Europe (Diaci 2006).

Strip-shelterwood system

The more favourable conditions at the forest edge and more successful regeneration compared to the conditions under shelter promoted development of the next system, known as the strip-shelterwood approach. The forest edge was shifted by harvesting, and by cutting belts the width of the tree height along the forest edge favourable conditions for the emergence of various types of young trees were established. The edges were initially straight and with development they adapted to the ground conditions (exposition, slope) or prevailing winds that influenced the microclimate. The distinction among cutting, harvesting and transporting areas was clearer than in shelterwood light logging. By determination of the bandwidth, the method allows the cultivation of species with different ecological light requirements. Like the shelterwood method, this system introduced a rigid and strictly defined spatial order to ensure an annual harvest and successful natural regeneration. Unfortunately, the system does not consider the forest as a whole system or does not respect individual trees and microsites that require an individual approach. Tending is not anticipated, the mechanical stability of the forest stands created in this way is questionable, and they are often damaged by the wind. Rapid regeneration leads to uniform forms or stand shapes that are unstable on large areas.

Figure 11: Strip-shelterwood system (Photo: M. Čater)

Irregular shelterwood system

Large-sized forest stands created by the clearcutting or shelterwood system did not provide sufficient stability against the natural disturbances. The search for better possibilities, with regeneration in the openings and gaps, led to the development of so-called regeneration cores, where young trees emerged under the shelter and protection of the mature canopy stand. Later, the cores were merged, and each forest stand acquired the new form with a multidimensional structure. The original form was limited only to the regeneration of the oldest parts of the stands with the smallest scale logging (Germany), while a later system relied heavily on the tending principle (Switzerland) and gained its present value. For the first time in history, the harvesting system adapted and followed the tending principles of the adult stand, to both the site conditions and the ecology of the entire forest. The new system required close cooperation with silvicultural planning, and no longer followed a strict spatial order.

Today's irregular shelterwood approach involves assessing the responses of adult stands and creating a favourable climate for successful regeneration by constant evaluation of the tree responses to the silvicultural measures applied (i.e., the control method). The resulting measures dynamically adjust to the goals. Both care and tending are used at the same time in all development phases, which are present on a small surface and provide with their diversity a greater stability of the stand. Cutting is adapted and more detailed and, more frequent than in the previously described systems, with a lower intensity. Regeneration is carefully planned on location, where other measures would not damage or compromise its emergence. Logging is carefully planned to provide minimal injuries.

Figure 12: Irregular shelterwood system (Photo: M. Čater)

Natural regeneration of tree species is constantly present in all older development phases of the forest. Depending on the ecological conditions, they can always be included for stand renewal or the admixture regulation of tree species, if necessary. If problems arise with regeneration, the vitality of the stand is compromised. Following all the tending measures, however, ensures sustainability. The rotation period introduced by the previous systems is defined individually and refers primarily to the dynamics of the rise in value, which indicates the economic suitability of the stand regeneration, and thus the cutting of adult trees, which is species and site specific. The share of development phases is balanced, towards the permanent provision of silvicultural and other objectives and functions of the stand on small surface areas. In Slovenia this is the predominating system.

Plenter / selection system

The original form of plentering had a different character from today's selection system, as the forests were extensively exploited in a way that enabled negative selection, leaving behind fewer valuable individuals. The forests were not tended, and the yield was modest. The selection structure may be presented as a natural reaction of forests, especially at extreme sites, and as a transient and short-term process in the old growth forests reserves.

The advanced system was first presented in France during the middle of the 19th century and in Switzerland at the end of the 20th. At the same time, on Slovenian territory, selective large-scale Kočevje forests were established, while in Postojna, in addition to the established selection system the control method was also applied, which included repeated forest inventories. The first approach was numerical and individual – all felling trees were chosen by measuring the threshold of the diameter at breast height. The forests of the high karst would soon be devastated by the clear-felling method, since the soil would not favour regeneration on larger areas, so the management consequently focused on plentering and natural regeneration under the cover of mature forest stands.

In the selection method forest trees of all dimensions are represented on a small surface area, ensuring sustainable production and conservation of the site's potential. Regeneration is continuous, and the growth and development of trees are more individualized compared to the previous systems. The canopy cover is not continuous, but variable, multi-layered and following a stepwise structure. A tree's status can only be determined by its social position in relation to the neighbouring trees.

In the social ascent of trees, the overgrowing of individual trees appears when the light conditions or the release of competitors allows the passage from one to the other layer. In the selection stands we may define the various stand positions of the forest trees as follows:

1 **the position of suppressed, waiting individuals** is characterized by shady microsites, where height growth is supressed, and only the most vigorous individuals survive. Shade tolerant species like silver fir (*Abies alba* Mill.) could dwell in this position for more than a hundred years. Growth is plagiotropic, due to modest light-intensity conditions.

2 **the position of runners** is indicated by smaller gaps and light shafts, where height growth is rapidly increased due to the increased light environment or release of the competitors. Mechanically, these trees are not very stable due to high slenderness ratio.

3 **the position of winners or carriers**; the social ascent is completed; despite slow initial radial growth a long period of stable, unsuppressed height and radial growth is followed.

The social ascent of trees is not strictly increasing, and the reverse path is also possible, from runners to the suppressed position of waiters. In plenter forest with the advanced selection technique, regeneration, regulating of competitors (waiters, runners, winners), tending and exploitation are performed with one single measure. This usually refers to clusters of an individual position rather than to individual trees (like in the case of numerical plentering), so the efficiency is greater. Objectives are defined by the equilibrium state (continuous production by preserving natural processes), where self-regulating mechanisms of care and tending are most emphasized and expressed. The measure of balance represents the size of the growing stock, the representation of tree species in the growing stock and their radial increment. The control method checks the forest response after silvicultural measures have been performed and adjusts them in the most favoured direction with regard to achieving a balanced state with total inventory or, if the costs of this are too great, using sampling methods.

The selection system is of course not suitable for all tree species and all sites; it is more adapted to shade tolerant species that can thrive in modest light conditions – especially for conifers (spruce and fir). The selection method is more demanding in the case of broadleaves (beech), especially due to unwanted forms of growth and, consequently, poor assortment quality if the light is not sufficient. Where regeneration is compromised due to overpopulation with herbivores, the preservation of the selection method is associated with high costs.

Of all the presented systems, the selection system is closest to natural processes, which can also be observed in virgin forests and old growth reserves (Diaci 2006, Schütz et al. 2016, Adamič et al. 2017). The cost of tending and regeneration is low compared to other systems; indirect care and tending prevail with self-regulating mechanisms performed by selection cutting. Due to individual tree growth, the stability of the stands is better and also better able to adapt to environmental changes. Assortment structure and yields are constant, focused primarily towards the quality of native, autochthonous species. The more even distribution of target trees – carriers – along the entire surface consequently means less accumulated harvesting intensities, dispersed throughout the whole stand. In the case of larger assortments, harvesting is more demanding due to the increased injuries of loggers or damage to regeneration and remaining stand. This is also true for the regeneration phase, which is less abundant, but spatially dispersed throughout the stands. Due to the complexity of the work, the planning is more difficult, aimed at combining stands with similar structure and silvicultural goals.

Free silvicultural method

Of all the techniques reviewed here, the free silvicultural approach is the youngest and includes principles of the plentering, selection and irregular shelterwood systems. It is characterized by the free choice of silvicultural measures but requires a lot of professional competence and consistency. It is suitable for all types of sites and stands, but most of all in cases where we can not only consider the principles of irregular shelterwood or plentering alone: it may be applied on degraded and changed stands, where there are problems associated with inappropriate former management (litter-gathering forests, coppice forests) or in degraded or declining forests, where site and stand conditions require great flexibility with regard to the silvicultural approaches adopted. Due to its adaptation to the specific site conditions and problems, the free silvicultural technique combines elements of various approaches on small surface areas. It requires careful and demanding planning according to the established management objectives.

The principles of the free silvicultural technique combine the preservation of natural site fertility, the nursing of young forests and tending of the adult stand, preserving and respecting individuality, attention being paid to function holders, natural regeneration, natural governance of the site factors, silvicultural planning and great alignment with natural processes (Mlinšek 1968). The measures should mimic natural conditions and cause as little disturbance to the forest as possible (Mlinšek 1968).

Figure 13: 95% of Slovenian forests are regenerated naturally (Photo: M. Čater)

Tending measures are applied in all stand development phases. Setting clear and realistic goals represents the most demanding part of the process; it is a prerequisite for determining the type and extent of the necessary tending measures to reach the defined goal (function). The goal of each development phase is its next stage, where their characteristics and properties are described in detail – the quality, the structure and the possible peculiarities of the site. Direct or indirect tending should provide protection against adverse conditions (weather, mechanical, biotic) and enable the selection of quality individuals and promote the desired positive properties.

- In the youngest development stage direct tending is performed to protect saplings in the herbal layer by regulating the species admixture (the relationship between tree species, taking into account their competitive power) and cleaning (removing herbs and shrubs that inhibit the growth of the young and the removal of diseased specimens). We exploit the influence of an adult stand, providing indirect care for protection against weather extremes and protection against wild animals. The stability design and quality of the next developmental stage depends on the proper timing of the performance and quality of the work, which should be strictly maintained.

- By cleaning of the dense young forest (with a height up to 2-3 m) a mass of quality individuals is selected and the conditions for social ascent are provided. Future quality is increased by removal of overgrown and branched trees, and by thus reducing the density greater mechanical stability is provided. The density of conifers may be smaller than in broadleaves but depends on the individual tree species. Large-scale tending with negative selection becomes positive in the later development stages, when individual positive qualities are recognized.

- After stratification in the former stage is finished and the economically interesting properties of individuals begin to appear, we start to perform selective thinning to stimulate growth, as the growing space is restricted. Resistance, mechanical stand stability and above all value all significantly increase at this stage. The former mass selection progressively transforms to selected groups and/or responsive individuals. Thinning is constantly present until the stands are introduced to the regeneration phase. The optimal growing conditions of the selected individuals provide better quality and yield of the stands. **Thinning intensity** indicates the time when tending begins and determines the amount of the harvested wood volume according to the living stock in the stand. The **frequency** of thinning is species and site specific: in younger stands and on good sites, interventions are more frequent due to faster stand response, while on more modest, depleted and older stands, where interactions between selected individuals/groups and their competitors is declining out because of their age, thinning becomes less and less frequent.

An important silvicultural tool is the filling layer – the remainder of the lower pole stand layer that disappears in time and is difficult to maintain in pure stands; usually it is composed of ecologically complementary tree species. It provides more favourable soil conditions and a stand microclimate even at its higher age, favourable natural regeneration and the possibility of regulating light in both stand layers. The value of the upper layer should not suffer from this, however, otherwise the nourishing role of the filling layer is missed. Measures within filling layer (light intensity, shaping) are separated from the thinning in the upper layer.

Silvicultural planning

Forest management could not be imagined without silvicultural planning due to the complexity of processes and constantly changing state of forest ecosystems. A silvicultural plan includes a set of all the necessary measures and actions in time and space to ensure optimal success by following the natural processes and at the same time considering the requirements for the permanent and multipurpose role of the forest stands. A silvicultural plan is a tool for finding optimal solutions, as well as a document for verifying the state and success of previous decision-making processes (Mlinšek 1968, Diaci 2006). It is crucial to closely integrate silvicultural planning and forest operations.

A forest management plan defines the main guidelines to ensure sustainability at the spatial and content level of forest management districts and units; it is more strategic and refers to general orientations and the coordination of interests. Silvicultural planning derives a more detailed set of direct, implementing measures with specific tasks in the content of completed works. Successful silvicultural planning requires key knowledge of the stands, sites and their origin, with clear, realistic and defined objectives (and measures) to achieve defined goals. All parts of the forest stand with the same long-term forest management goals on similar sites are classified into permanent silvicultural planning units. Smaller, tending units are defined by the short-term or stage silvicultural goals, and relate to the same developmental stages within the silvicultural-planning units.

Silvicultural goals

Silvicultural goals are defined by the prevailing ecological, economic and social conditions. With regard to the temporal scale, we define long-term goals as those affected predominantly by site fertility, and short-term goals as those defined by the growth characteristics of forest stands. Preservation of **site productivity** (site-production capacity) is only possible with a good understanding and proper selection of suitable tree species. The starting conditions listed in the forest management plans of forest units serve as a reference here. Long-term silvicultural goals define and characterize the forest management, and the final silvicultural image of the forest stand with its defined structure, tree species admixture, quality and targeted living stock (Mlinšek 1968). As a measure of site fertility we consider the maximal possible yield (of mass or value) achieved by the ideal silvicultural treatment (Kotar 2005), by the peak of the average volume or increase in value. Natural site fertility may be reduced (Karst) or preserved (Dinaric region).

Stand growth potential is defined by the development of stand value: if the growth potential and site productivity are consistent and optimally exploited, the peak of the average value increment achieves site fertility. The culmination itself is prolonged, giving the silviculturist wider space to manoeuvre for the final measures and regeneration of the stand. If the growth potential is large and the site productivity is small (e.g. in case of allochtonous species), current tree species deplete and degrade site conditions, as their nutritional demands are too great. The introduction of regeneration is appropriate when the average value increment begins to decline. Due to the incorrect selection of tree species, however, the situation could also occur when the average increment does not reach the level of site productivity, and thus it is reasonable to introduce the regeneration process without delay. This is because the loss of stand value increases over time.

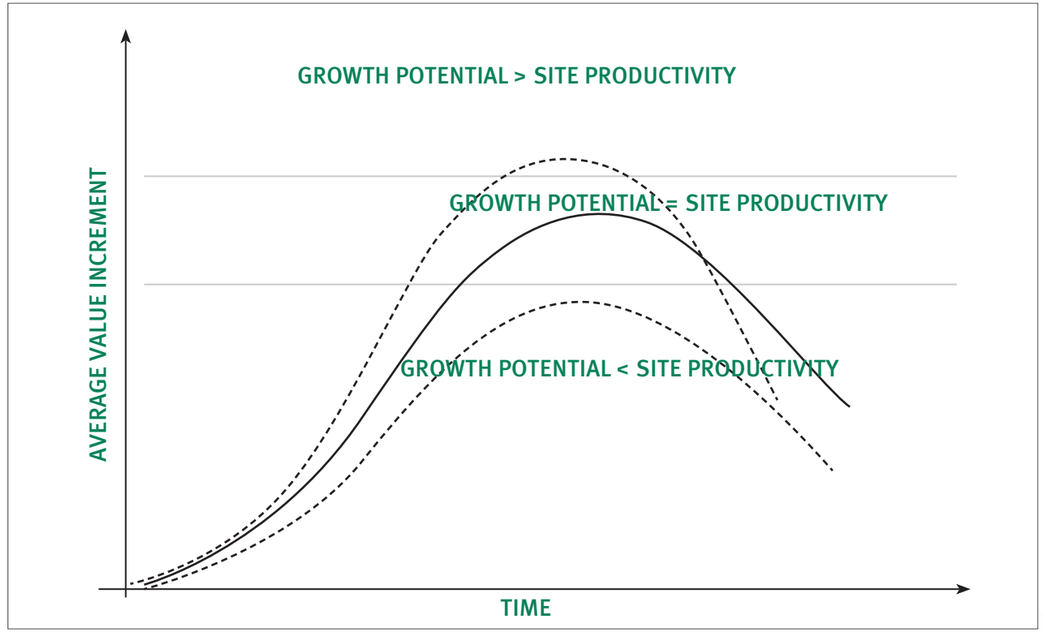

Figure 14: Growth potential and site productivity

Silvicultural measures

Silvicultural measures represent the best solution for achieving the goal of a certain final value of the stands, with many possible routes and given schedules. Targets can be achieved faster with more intensive measures or over a longer time period with lower intensity. We adapt measures to the condition of the forest, the available material resources and experience, such as the knowledge of the forest owner. The measures in tending units relate to the development stages of the stands, considering the overall image of the stand. The specific area and normative standards are also considered when planning and calculating costs.

Silvicultural plan

A silvicultural plan is needed to document various decisions in the process of reaching the final, targeted state of the forest. The initiation of a plan may be based on either a completed planning period with realized objectives, or different circumstances that require the adjustment of an existing plan by obtaining new, updated information for its actualization. For many factors that influence such decisions, it is sensible that the current and former planner are the same person, because valuable experience is transferred to the next planning period (lasting five to 15 years).

- The current forest management plan, the course of the current management (silvicultural plans) and maps represent starting points for the definition of the situation, which is verified in the field. The assessment of the measures required to achieve goals relates to individual development phases, where development trends should be identified (Diaci 2006). Special features are parts of stands, where no measures will be performed.

- The stage of gathering information is followed by drawing up and assembling a plan, defined by the objectives and multifunctional target forest image. Long-term goals are set for planning units, followed by the stage objectives and general orientations (tending, regeneration, logging). The general part of the plan defines the state of the forest, the long-term objectives and guidelines for the planned units, while the special part of the plan defines the current condition, stage goals and measures for each tending unit. An essential supplement is a map of sites showing the planning and tending units along with all the required details. Once the stage goals of tending units have been achieved, the plan is updated. It is complemented according to the stand development and management intensity, with preference given to more demanding interventions.

- Implementation is closely related to tree marking, logging and harvesting; the thoughtful spatial order and rational time sequence of such measures can reduce costs and increase the work quality. After performing the work and protection measures, the planner and forest owner compare the plan with what has been realized (Diaci 2006). Organization of the planning in Slovenia is separated from the implementation (logging, harvesting).

- The control of the forest response to tending measures triggers corrections and an assessment of the quality of the past planning period. Adjustment corrections could be performed with additional silvicultural measures or tending, which are reasonably combined with regular interventions or logging measures in order to lower costs.

Involving forest owners in the planning process is sensible for assessing the cost of tending measures. The plan should rely on the decisions and orientations of the owners, and less on detailed stand description. If developed with the participation of forest owners, such a plan is a good tool for finding the optimal solutions for the future forest conditions.

Regeneration

The first cultivation systems had difficulties with regeneration because of their strict spatial order, and therefore artificial regeneration was necessary. Professional observations recognized benefits of **natural regeneration**, which is today encouraged due to the lower costs, existing microsite adaptation of the young forest and free choice among numerous autochthonous species. Regeneration under adult stand canopy cover provides better protection and benefits with regard to future stand quality. In vital stands natural regeneration is constantly present, but only a few trees reach the final stage of an adult, dominant position in a constantly changing cycle of replacing generations. Physiological ageing, which dictates regeneration cycles, is accelerated by disease, while shading in younger stages of development causes a slowing down of the processes and indirectly prolongs lifespan. It also depends on the site and composition of tree species. Forest ecology and respecting economic frames are starting points which can help to determine the time and duration of the regeneration in an individual stand.

In cases of altered tree species composition (spruce, pine plantations), on degraded stands, in the extreme conditions or after large scale natural disturbances, regeneration with sowing or planting, known as **artificial regeneration**, is applied. The areas for regeneration are prepared by manual arrangement of residuals after harvesting. In limited quantities, these increase the circulation of soil nutrients and favourably affect soil conditions. The competitive ability of the introduced seedlings is also improved by the mechanical removal of ground vegetation.

Soil preparation (where required) represents a more demanding and expensive task and influences the structure and release of soil nutrients; it also includes preparation for mechanical sowing or planting. However, the value of this approach is questionable on sensitive soils, which could be easily damaged and compressed by heavy machinery. Species selection must be in line with site conditions and numerous ecological factors. Due to the many advantages, planting predominates before sowing. Seedlings are planted on average on 500 ha per year, while sowing is performed on average 10 ha. Seedlings and seed of up to 35 tree species are used for artificial regeneration although Norway spruce still predominates and is followed by European beech, noble hardwoods such as maple and cherry and oaks. Enrichment planting is needed if natural or artificial restoration is not successful and regeneration on larger scales is compromised. The success of planting decreases with the age of seedlings, as the demands of young trees progressively increase and consequently the transplant shock is also greater. Such enrichment planting also provides an opportunity for adaptation to climate change by utilising seedlings and seed from forest stands adapted to warmer and/or dryer conditions.

Based on ecological regions, Slovenia is divided into seven provenance regions with further sub-regions and four altitudinal belts. The legislation requires the use of seed and seedlings in the same altitudinal belt as the forest reproductive material was collected, while it encourages its use within the same provenance region. Unfortunately, there is only a limited number of forest nurseries in Slovenia and seedlings that would fit the planting site best are not always readily available. This is amplified as most seedlings used for artificial regeneration are bareroot seedlings.

Realization of silvicultural work is the responsibility of the owner. Among the most important activities of a district forester is thus co-operation with forest owners in the form of advising, educating, and training for carrying out the professional work of silviculture and forest protection. The most effective approach is through direct contacts with owners, and more than 100 seminars and workshops are organized by the Slovenia Forest Service annually to educate forest owners when this is not possible. Nature and administrative procedures are two different notions, but nevertheless for all activities of silviculture (including the selection of trees for possible felling) and forest protection, the Slovenia Forest Service issues administrative decrees for forest owners. The work and financial resources intended for the forest are an investment that they mostly will not benefit from themselves. Because of this, and also due to the public interest in the generally useful roles of the forest, a system of financing and co-financing investments in forests has been established from the budget of the Republic of Slovenia and European funds, which enables forest owners who manage their forests according to such plans to obtain some resources once their work is finished.

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Scientific support for close-to-nature forestry

Matjaž Čater, *Slovenian Forestry Institute*,
Jurij Diaci, *University of Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Forest Resources*

Contemporary close-to-nature (CTN) forestry in Slovenia combines different silvicultural tools that can be broadly classified into three silvicultural systems: selection, irregular shelterwood and free-style silviculture (Mlinšek, 1996). All three systems are based on the leading principle of forest tending, which represents gradual continuous improvement of individual crop trees, forest stands and sites; they also advocate a holistic approach to complex forest ecosystems (Schädelin, 1934). In strict compliance with the principle of tending, the free combination of different types of felling is permitted, so the silvicultural system is adjusted to a unique combination of the site's requirements, stand conditions and the silvicultural goals. Nevertheless, several guiding principles are applied: the use of natural regeneration and native tree species, following natural processes and mimicking historical disturbance regimes, favouring complex vertical and horizontal forest structures, as well as respecting tree individuality. Additional measures are needed for sustaining habitats and biotopes, such as planned non-intervention (forest reserve network), retention of special habitats (ancient trees, coarse woody debris), adapted management and special tending measures (Papež et al., 1997).

Despite the broad available spectrum of silvicultural tools, the focus remains on as small-scale management as possible to introduce the natural regeneration of all native tree species in an appropriate mixture and quality (Schütz et al., 2016). In such a way, the forest stand climate could be preserved with indirect tending provided for the young forest and a sustained natural process of tree differentiation. All this can enhance the vitality of the forest tree populations and reduce the direct costs of management and risks. Many tools of freestyle silviculture have been developed through observation and interaction with forests. However, a standardized scientific approach is required to verify the validity of observations, to control the management success and develop statistical or mechanistic models which would allow thoughtful generalization. With the development of CTN silvicultural systems, from single tree selection to the freestyle system, and with the development of scientific methods, the procedures of verifying the performance of CTN silviculture and the methods of scientific support for it have also improved.

Control method as a science-based evaluation of close-to-nature silviculture success

Three hundred years ago Central European forests were scarce, the remaining ones were heavily degraded, while forest resources, especially wood, were deficient. Erosion represented a serious threat to settlements, agricultural land and infrastructure. Conventional forestry based on rules of sustainability thus developed to improve the overall conditions of forests. Although von Carlowitz, the father of sustainability, proposed in his book Silvicultura Oeconomica from 1713 many silvicultural tools, conventional forestry relied largely on clearcutting and planting of conifers. In the following centuries, many new conifer plantations were established. Clearcutting and plantations initially played a positive role, but soon proved problematic regarding forest health and susceptibility to disturbances, as the Central European temperate region was naturally dominated by broadleaved tree species. Within the Alpine region a decline of forest protection functions became a serious threat, especially erosion, due to large-scale clearcutting. Apart from that, the appearance of monocultures was heavily debated (Johann, 2006). Moreover, in many farmer forests throughout Europe an alternative in single tree selection system emerged, while on the hand many farmer forests were heavily understocked, representing a so-called „green façade".

Selection silviculture led to spatially complex structures; consequently, adequate control instruments were required for efficient forest management and proper comparison with other approaches, especially with the newly developed science-based clear-felling system. At that time, the French forester Adolphe Gurnaud developed an ingenious idea for monitoring forest development (e.g. increment, growing stock, mixture) at regular intervals and adapting management accordingly – the so-called „control method". This represented a turning point in CTN silviculture; with the control method it became a serious science-based substitute for conventional forestry (Schütz, 2001a). Very likely a special kind of control method was also independently developed in Slovenia (Mlinšek, 1972). With various amendments and improvements, the control method still remains the basis for the forest management planning within the framework of CTN silviculture. The control method has many similarities with the later developed adaptive management of natural resources (Walters, 1986).

Old-growth forests, close-to-nature silviculture and scientific research

Old-growth forests represented one of the crucial early research areas for scientists interested in CTN silviculture. Both researchers and managers were aware of the importance of reference old-growth conditions. Raising awareness of this started with the early works of Rubner (1920) and Frölich (1954), which followed by the pioneers of the systematic study of old growth forests in Europe, such as Leibundgut (1982). Much of this early work is today forgotten or inaccessible due to language barriers. For example, Schütz (1969) researched the coexistence between Norway spruce and European silver fir in old-growth forests and Janj in Bosnia and Herzegovina (BiH) and two Swiss selection forests. He confirmed the long suppression periods for both species and the importance of this phenomenon for the longevity of trees. This important developmental feature of trees in old-growth forests was later confirmed many times (e.g. Bigler and Veblen, 2009). Another early example is a paper from Mlinšek (1967), who studied the demographic structure of old-growth forests in BiH and found that European beech attained ages of 500 years and more. This indicated that three competing species in mountain mixed forests, namely beech, Norway spruce and silver fir, are comparable with regard to longevity.

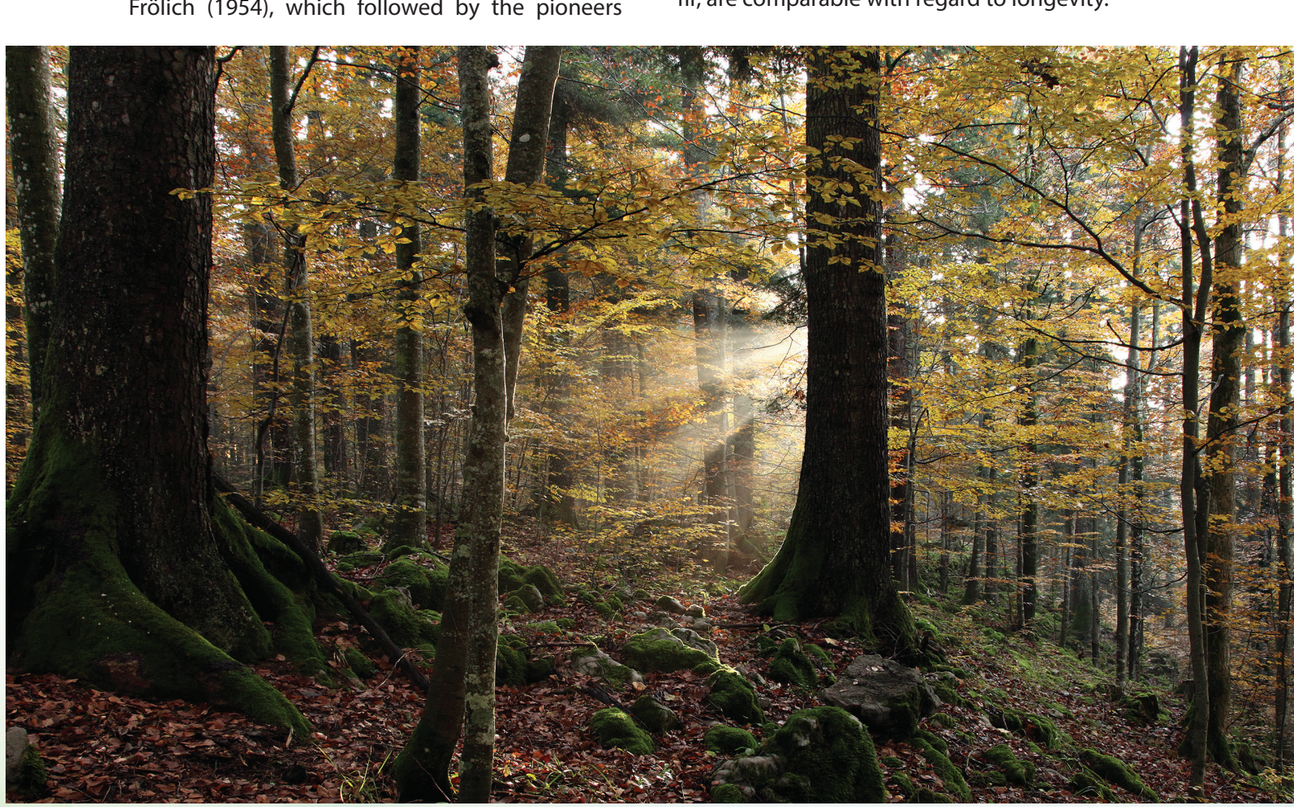

Figure 15: Old growth reserve Rajhenavski Rog (Photo: M. Čater)

Earlier researchers developed an extensive network of research plots and database of measurements, which have made it possible to continue old-growth research (Nagel et al., 2012). Knowledge on the range of variability of the disturbance regime is crucial for developing silvicultural tools and preserving habitats. This is because forest developmental dynamics are influenced by the interaction of site factors and natural disturbances; in other words, events such as fires, wind, ice damage and bark beetle outbreaks. Recent research indicates that, for example, south-east European beech and mixed mountain forests are driven by prevalent endogenous dynamics with sporadic intermediate disturbances, often in form of wind-throw or ice-damage (Nagel et al. 2017). While mountain conifer forests are probably driven by more frequent intermediate and even large-scale disturbances, like boreal forests (Zielonka and Malcher, 2009). Thus, single and group selection may well mimic the natural disturbance regime in the former, while larger gaps within the framework of irregular shelterwood may be closer to the developmental dynamics of high-altitude Norway spruce forests.

Another interesting body of research relates to the decline of conifers and effect of management. The beech progression in old-growth forests of south-east Europe was already observed in the early 20th century. Research into old-growth forests indicated that the main driver for these phenomena is interaction of natural and anthropogenic influences, namely climate change, atmospheric pollution and over browsing (Diaci et al., 2011). Comparative research of old-growth and managed forests can reveal the negative effects of management on the structure and function of these ecosystems. Several comparisons in Slovenia and neighbouring countries indicated the greater complexity of old-growth forest stands, but smaller diversity of flora, while the regeneration structures of both were similar (Bončina, 2000). A higher diversity of trees in managed forests is likely, as well as higher light levels at forest floor, partly due to the consistent favouring of minority tree species by local foresters (Adamič et al., 2016). This is different to the results from research on northern hardwood stands in America, which indicated that the recurring application of selection cutting leads to the homogenization of forest structure and composition (Miller and Kochenderfer, 1998). This difference may be attributed to different natural disturbances and management regimes between regions. There is an ongoing debate about possible lower genetic variation in forests that are managed with CTN silviculture. The persistent shadow on the forest floor of a larger area may reduce the proportion of species and genotypes adapted to climatic variability, and especially extremes. However, there are only few studies that have examined this, and they indicate minor or no differences. A recent study from Slovenia did not confirm any differences in the genetic structure of tree populations between old-growth and managed forests (Westergren et al., 2015).

Spatio-temporal gap dynamics and plant architecture

Plant architecture indicates the future commercial quality of stands. Broadleaves, and especially beech, may develop unwanted plagiotropic growth in low-light regimes. Sagheb-Talebi (1996) suggested that the best architecture of beech saplings is achieved in low-intermediate light levels. Research in Slovenia indicated that in the case of Dinaric mixed mountain forests, plagiotropic growth is associated with relatively low light levels, e.g. below 10-20% of relatively diffuse light, and may vary between CTN silvicultural systems (Čater and Levanič, 2013). Plagiotropic plants are often outcompeted with the further development of regeneration (Roženbergar and Diaci, 2014). Continuous cover silviculture does not necessarily increase the share of badly shaped trees, if management is carried out appropriately. With appropriate gap spatio-temporal dynamics (gap size, shape and within gap microsite variability) silviculturists influence the quality of the remaining mature stand and the mixture and quality of regeneration. Therefore, a considerable amount of silvicultural research has been devoted to this topic. The results indicated tree species gap niche partitioning in several forest types (mixed mountain forests, spruce and pine plantations). A method of explaining micro-site partitioning based on four combinations of diffuse and direct light levels was developed to describe this phenomenon and transfer the results into practice (Diaci, 2002). The eco-physiological response from beech and fir in various light microsites shows that beech is more efficient in exploiting direct radiation in sun-exposed parts

Figure 16: European beech forest (photo M. Čater)

of the gap when compared to silver fir (Čater et al., 2014). The abundance of the same microsite categories along the elevation gradient in two silvicultural systems clearly indicated the forest structure and its fragmentation. The separation of microsite areas between both silvicultural systems in lower elevation belts was evident, while in the highest elevation zones with the most expressed conflict between regeneration and browsing the shares of microsites were almost identical, indicating the same, small-scale irregular shelterwood system, known also as the freestyle silvicultural approach (Čater and Kobler, 2017).

Pedunculate oak forests are difficult to regenerate due to changed natural processes, fragmentation and environmental pollution. However, favourable microsites for the natural regeneration of pedunculated oak were defined by accounting for within-gap microsites according to light asymmetry. In floodplain forests these are microsites under canopies, receiving low levels of diffuse light and high levels of direct light (Diaci et al., 2008). For the further development of oak regeneration higher light levels in the open gap areas are necessary, but this still needs no more than a quarter of a hectare. The research of Levanič et al. (2011) examining the same bottomland hardwood ecosystems indicated that supressed oaks performed better under recurring droughts, which again indicates the significance of long regeneration periods, continuous canopy cover and the uneven-aged structure of these forest stands. Research and practice suggest higher resistance and resilience of CTN managed mountain mixed forests when compared to even-aged systems (e.g. Lenk and Kenk, 2007). Moreover, long-lasting or even perpetual regeneration allows the best possible adaptation to climate change. Research also suggests that small-scale patchy mosaics of stands offer the optimal protection against natural hazards.

Economic aspects of close-to-nature silviculture

There is quite some evidence that CTN silviculture is economically viable and comparable or even superior to conventional forestry (for an overview see, for example, Knoke, 2009). When making comparisons, the indirect as well as direct effects on management success should be considered. For example, the former includes sustained site productivity, lower management risks and low external costs, while the direct effects include less thinning and planting due to the use natural processes. However, most of the comparative studies to date have not considered management risks and external costs (Roessiger et al., 2011). CTN management is ideal for growing large-diameter valuable trees, which is often one of the management goals. In yearly tree auctions in Slovenia and Central Europe, the highest prices for veneer logs reach up to 10,000 EUR per m^3. And although not every large diameter tree is valuable, all high-priced trees are large diameter ones. Thus, crop trees should be harvested individually, when they attain the highest market value. With biological rationalization there is still the potential to reduce the costs of CTN silviculture (Schütz, 1999a), especially in managing post-disturbance even-aged forests.

Close-to-nature silviculture in recreational and protection forests

Mimicking the natural disturbance regime is not an option in all forests. This is especially true for recreational / urban forests and forests with a direct protection function. Experience shows that CTN silviculture is well suited for urban and recreational forests. Non-management may be risky for visitors due to falling trees, and often results in large-scale natural disturbances with complete loss of forest climate. On the other hand, conventional forestry has a heavy impact on the functioning and appearance of the forest and causes abrupt change in the landscape mosaic. Regular low impact interventions in the form of CTN silviculture preserve stand climate, ensure safe passage through the stands for visitors and enable revenues from the sale of timber. City forests in Celje represent an excellent example of the use of free-style silviculture in urban forests (http://green4grey.eu/). Moreover, in forests with protection functions the selection system or CTN silviculture are the best options for the long-term provision of such functions against various natural hazards (Brang et al., 2006). In forests with direct protection functions, collaboration among foresters, professionals and scientists from civil engineering, geology and geography is important.

Figure 17: City forest tree house, Celje (Photo: M. Čater)

Critique of CTN silviculture

The pros and cons of CTN silviculture have often been debated (see e.g. Wagner and Huth, 2010; O'Hara, 2016). Most critiques are related to a rather narrow understanding of CTN silviculture, as the exclusive application of a single-tree selection system. This type of management creates small-scale complex structures and may lead to homogeneous forest landscapes, while natural disturbance regimes are more complex and include several agents, variable time periods and intensities, and several spatial levels. In this way, CTN silviculture may systematically disadvantage light demanding species. However, this depends heavily on the site and array of tools applied within the CTN silviculture approach. A further critique of CTN silviculture is that planting is rarely applied, which reduces the possibility of introducing future climate-adapted species and provenances (Brang et al., 2014). The concept of potential natural vegetation is important for CTN silviculture in order to set the silvicultural goals, although this requires adaptation, as it is difficult to assess in altered landscapes, as it refers to the past and neglects the disturbance regime. All ecological paradigms should be adapted to the expected environmental changes in the future and based on reliable scenarios. For example, it is necessary to consider processes such us more intense disturbance regimes, non-native plants, insects, and pathogens as well as pollution.

Pro Silva federation for networking knowledge

Close-to-nature silviculture developed in different parts of Europe, and to facilitate the exchange of knowledge and highlight best management practices, the Pro Silva federation was formed in Slovenia in 1989. With an emphasis on sustainability, it promotes the use of primarily natural processes to minimize ecological and economic risks (https://www.prosilva.org/). The Pro Silva principles are implemented in a number of exemplary forests. It is possible to commence the change from a regimented type of forest management to the advocated type of management and silviculture at almost any stage of forest stand development (Schütz, 2001b). Based upon a wide range of stand types, forest conservation, forest protection, management and utilization have multiple components from conservation to regeneration and amelioration, for example: forest preservation mitigating the consequences of past management, forest restoration, tree mixture regulation, and wildlife management, along with many other elements.

The members of Pro Silva are national associations of professional foresters, forest owners and members of general public who advocate and promote CTN silviculture principles. At present it connects 27 European countries and five observer states from other continents. Pro Silva organizes conferences and field trips, publishes books, launches statements on important forestry topics and maintains a database of the best practical examples. To gain mutual understanding between research and practice, common work is carried out on research plots and demonstration projects, and visualizations are also produced. Joint meetings with members of the interested public are often organized. Some European countries and areas, such as Bavaria, Baden-Wuerttemberg and Lower Saxony in Germany, along with Switzerland, Croatia and Slovenia, have adopted CTN principles for all of their forests. While other areas which had virtually no CTN practices 25 year ago, such as Hungary, Ireland or the UK, have since increased the share of CTN forests up to 10 or 20%. One of the goals of Pro Silva is the preparation of scientifically based responses to current problems in relation to forests and forestry. A few summaries of the CTN silviculture guidelines in connection with some of the current development challenges are presented below.

Pro Silva and biodiversity

The preservation of species diversity is regarded as a prime function of forests, irrespective of any recognizable link with human needs. A high level of healthy and robust biodiversity implies the settlement of all ecologic niches, providing a strong buffer against invasive alien species. The preservation of species diversity has, in addition to its intrinsic value, considerable relevance to the use of the forest ecosystem by society, including both traditional and also potential products which might have future market value, and can thus result in reduced ecological and economic risk. The ways of preserving and developing natural biodiversity include the use of indigenous tree species, as numerous species are associated with indigenous tree habitats in their co-evolutionary development. Enhanced forest structural diversity is achieved through forest regeneration, tending and exploitation as a means of creating appropriate habitat niches in space and time, allowing enough quantity and distribution of standing and fallen dead and hollow trees, along with old groves in the forests. Special biotopes in the forest, such as wetlands, rocky outcrops, dunes, and so on, are protected, and unsustainably high wildlife densities which over-graze the forest are regulated, with the reintroduction of extinct predators. Forestry serves biodiversity in general and species diversity in particular. Together with economic planning, the preservation and maintenance of biodiversity in the forest is an integral element of forestry, and the conservation of biodiversity must be included and facilitated in mid-range management planning (Schütz, 1999b).

Non-indigenous forest species

The vegetation pattern which evolved in European forests during the postglacial migration of forest species, forming the existing forest regions, is regarded as a precious natural asset, which must be preserved and maintained. It should be respected as the most important basis of all silvicultural measures. Non-indigenous species (exotics) can, under some circumstances, supplement the indigenous vegetation pattern and increase the economic yield of forestry. All forest species which did not previously form part of a given natural plant association, and which have been introduced from distant locations, are regarded as exotic; their introduction should only be permitted after critical qualitative and quantitative analysis (Schütz, 2011).

Landscape conservation

Forest ecosystems are the most important natural component of the landscape. Taking a holistic view of the landscape and its mosaic of different ecosystems, the adoption of Pro Silva principles of forest management has beneficial effects on the whole landscape.

Silvicultural nurturing of the forest is essential for treating the whole landscape, where tending represents the keystone for managing forests. Management is considered to scale from a single stem to the stand and from the stand to the whole site and landscape, regarding man as part of the landscape. Forest management involves harnessing of available energy and directing this energy into parts of the ecosystem which would maximize the intended management objectives.

A multi-purpose forest provides optimal landscape protection by conserving energy, water resources, natural fertility, and enhancing the functions of the area. Such a forest will contain a relatively large volume of timber in a permanently varied structure, composed of trees which are fully suited to the site, while forest edges will be carefully managed to protect the interior. A holistic approach reinforces fragments of forest and strengthens links between them, to create a network of semi-natural habitats within and around cultivated land and urban areas (Schütz, 2011).

Figure 18: Silvicultural nurturing of the forest is essential for treating the whole landscape (Photo: M. Čater)

Conclusions

Close-to-nature silviculture developed as a response to forest degradation and clearcut management. It is science-based and practically oriented, focused on mimicking natural processes and combining different felling regimes; the main aims are dedicated to forest continuity and permanent improvement of forests by tending. CTN silviculture is ecologically sustainable, economically profitable and socially acceptable. The practice of CTN silviculture is well developed for the temperate region, and less so for boreal, subtropical and tropical regions. However, most principles are general and could be implemented elsewhere. It is an excellent companion of organic agriculture and sustainable living. Overall, CTN silviculture was never a myth, nor a new age movement, but a serious alternative forestry practice, supported by sound scientific evidence. Its influence in Europe is constantly growing, and it seems likely that it represents an important tool for achieving a more sustainable society.

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Sustainable wildlife management

Matija Stergar, *Slovenia Forest Service,*
Aleš Poljanec, *Slovenia Forest Service, University of Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Forest Resources*

Lynx (*Lynx lynx* L.) (Photo: M. Krofel)

Introduction

The ecological and geographical diversity of a country is reflected in the diversity of wildlife species' habitats it includes. In Slovenia three autochthonous large carnivores are present: the brown bear, the wolf and the Eurasian lynx. Among seven wild ungulate species, four are native (roe deer, red deer, wild boar, chamois) and three are allochtonous (Alpine ibex, mouflon, fallow deer). Similar to many other European countries, Slovenia has been characterized by the increasing density and spatial spread of large mammals, especially bears, wolves, red deer and wild boars (Jerina and Adamič, 2008; Stergar et al., 2009); some species have also colonized the country recently, and were not present in the past, such as golden jackals and beavers (Krofel et al., 2017).

Along with the population dynamics of the abovementioned species, the intensity of their environmental impacts has also increased. The main emphasis of wildlife management is usually on the negative impacts on the environment. Through browsing of seedlings and saplings, wild ungulates can affect forest regeneration and tree species composition. When browsing is too intensive, forest regeneration becomes hindered or even completely absent (Klopčič et al. 2010, Simončič et al. 2018). The economic value of young trees is reduced by bark stripping caused by red deer (Vospernik, 2006; Mansson and Jarnemo, 2013). In agricultural landscapes, wildlife causes damage to crops, grasslands, livestock, and so on (Schley et al., 2008). In some areas local inhabitants find themselves in conflict when wildlife species (e.g. bear, wild boar) enter their settlements or even urban centres (Cahil et al., 2012). Traffic safety can also be endangered by the passage of animals (van der Grift et al., 2013), and wildlife species transmit certain diseases to domestic animals, and even to humans (Ruiz-Fons et al., 2008).

Figure 19: Wild boar (*Sus scrofa* L.) (Photo: Stane Draškovič Pelc)

Less is known about the ecological roles of these same species. By spreading the seeds of plant species on their hair or in the gastrointestinal tract, animals play an essential role in the dispersion of many, especially pioneer, tree species. Animals often feed in one type of landscape (e.g. on grasslands), and then defecate in another (e.g. in a forest), providing the horizontal distribution of nutrients between different types of landscape. Wild boars may accelerate the nutrient circle by rooting, which enables the faster growth of tree (and other plant) species. Bear and wild boars remove carrion and thus inhibit the transmission of infectious diseases, while wild ungulates represent key food for large carnivores (Pokorny and Jelenko, 2013; Eisenberg, 2014).

Several direct benefits of wildlife can be seen in the economy and ecosystem services. The hunting of wildlife species represents a source of meat, and its production in Slovenia (around 2,000 tonnes / year) is comparable to the amount of meat obtained from breeding sheep and goats (Jerina et al., 2010). Hunting is also a form of recreation, with around 20,000 hunters registered in the country. Wildlife-related ecotourism (e.g. observing and photographing animals in the wild) is also becoming more popular (Karamanlidis et al., 2016).

The planning and management of wild ungulates and large carnivores, such as bears, wolves and lynxes, which are considered rare and endangered on a European scale, requires special attention (Kaczensky et al. 2013).

The planning approaches used for the management of wild ungulates and large carnivores are different.

i. In Slovenia wild ungulates are considered game, whereas large carnivores are protected species on a European scale. Consequently, the legislative background for the management of both animal groups is different.

ii. Large carnivores are more charismatic than wild ungulates, and people also perceive their negative impacts as more dramatic (e.g. endangering human life, predation of domestic animals). Therefore, large carnivores attract much more attention from the broader public, and greater engagement and pressure from different stakeholders for their management.

iii. Wild ungulates and large carnivores differ significantly in ecological and biological characteristics. Compared to ungulates, large carnivores are represented in lower population densities and larger home ranges.

Wild ungulate management

Since 1993, game management planning in Slovenia has been under the competence of the forestry profession (Slovenia Forest Service). This system significantly facilitates the consolidation of forest and game management, providing an ecosystem approach and holistic forest management. Nevertheless, for decades some parts of Slovenia have faced the problem of over-browsed forest regeneration, which makes achieving forest management objectives much more difficult. In 1996, the Slovenia Forest Service started the systematic inventory of the browsing of forest regeneration across the whole country. The method was revised in 2010 and ever since has provided a useful and effective tool in forest and game management. The inventory of browsing of forest regeneration has been performed every three years since 2010, and the results of the three consequent measures revealed the relatively high browsing impact in some parts of the Dinaric and Alpine mountains (Terglav et al., 2017), which has been an important argument for changing the deer management practices in these areas.

Besides forestry, wild ungulates also have important impacts in other sectors, for example in agriculture, where they can cause considerable local damage. In addition, the environmental impacts of wild ungulates can influence the well-being of other stakeholders or the broader public.

The process of the preparation of management plans, which is primarily the responsibility of the Slovenia Forest Service, is therefore transparent and participatory. All interested stakeholders can participate and influence management decisions in the process of developing the plans.

Wildlife ungulate management is hierarchically organized in spatial and temporal terms. Slovenia is divided into 15 hunting management units, which, in terms of populations of locally dominant game species, present complete ecological units. Game management units are further divided into hunting grounds. There are 423 hunting grounds in Slovenia, of which 12 (13 % of the country) are managed by the state (special purpose hunting grounds) and 411 are managed by hunting clubs (voluntary associations).

The fundamental goals and strategies of game management are defined by the long-term (10-year) plans of hunting management units. The annual plans of these units follow the long-term plans and present their level of implementation (https://www.gov.si/teme/upravljanje-z-divjadjo/), by defining and quantifying measures for achieving long-term objectives (e.g. the degree and structure of the cull of animal species, measures in the environment). The most detailed level of game management planning is seen in the annual plans of hunting grounds. Measures from the annual plans of units are broken down to the level of hunting grounds, with the suggestions and interests of hunting managers also considered within the professionally acceptable limits.

Figure 20: Central European red deer (*Cervus elaphus* L.) (Photo: Petra Draškovič Pelc)

The main emphasis of game management is based on control, and future plans for the next management period are developed based on the analysis of population and environment states, as well as an analysis of the previous management. Unlike other countries, Slovenia does not estimate the density of ungulates, but instead uses indirect indicators to assess population trends, i.e. whether the population grows, decreases or remains unchanged, and indicators are used to show the intensity of the environmental impacts of game species. Particularly important among these indicators is the damage to forest regeneration (due to wild ungulates), which, besides the trends of game populations, also shows the balance between game and forest vegetation, and defines the carrying capacity of the environment for game (Stergar et al., 2013).

Management of large carnivores

The management of large carnivores in Slovenia is the responsibility of the Ministry of the Environment and Spatial Planning. However, under the authority of the Ministry, most of the operational tasks in the area of large carnivore management are performed by the Slovenia Forest Service. Every year, this body prepares a proposal for a central management document, i.e. an act on the yearly cull of brown bears and wolves. The proposal is discussed by a broader group of experts in the Ministry, and is then submitted to a public hearing, in which amendments and improvements can be suggested by anyone, ensuring the necessary public participation in the process.

The management of large carnivores, because of their potentially negative impacts, charismatic and endangered nature, perhaps poses an even greater challenge in terms of management than wild ungulates. The key to the management of large carnivores is searching for the fragile balance between the favourable conservation status of their populations and assuring coexistence with humans on the other. Two management approaches are used to achieve this. The first is influencing population density by culling. This measure is used to maintain the populations of large carnivores under the social carrying capacity of the environment, which is the level that is still sustainable for the local residents. The other group of measures are preventive ones to decrease conflicts – measures to protect property, e.g. livestock, beehives, orchards (electric fences, livestock guarding dogs) and measures to prevent large carnivores (especially bears) from entering settlements (bear-proof garbage containers and compost bins; see also https://dinalpbear.eu). Much effort is given to rising awareness of the importance and proper use of these measures.

Measures to mitigate conflicts with large carnivores once they appear are also used. A system of state compensation for damage to property caused by large carnivores (and other protected animal species) has been established. The pre-condition

for compensation is the use of minimum protection measures. The intervention group for large carnivores also works to mitigate conflicts; trained specialists deal with difficult situations, where large carnivores enter settlements, endanger human lives, are involved in traffic accidents, etc.

Achieving the goals in the management of large carnivores is monitored in different ways. We rely on updated methods to assess the abundance and other population characteristics of large ungulates (Skrbinšek et al., 2019). The systematic use of automatic cameras has been applied to monitor the lynx population (Fležar et al., 2019). Due to the well-organized hunting in Slovenia, additional data on large carnivores is also systematically provided from the hunting ground managers (e.g. annual counts of bears).

An important step towards effective large carnivore management was made by associating and collaboration with neighbouring countries, which share the populations of bears, wolves and lynxes (Croatia, Italy, Austria). Together, we strive towards uniform monitoring and management of the populations of large carnivores on the cross-border scale (see https://dinalpbear.eu).

Future challenges

Wildlife management can be considered as balancing among various human interests. The perceptions of different interest groups (e.g. farmers, rural residents, hunters, urban residents) about the goals and management of animal species are often diametrically opposed. Expressing interest and influencing management decisions is a necessary part of a democratic society, but it can also be a serious impediment to professional wildlife management. For effective governance, management decisions require both the appropriate legislative background and to be made based on sound expert knowledge.

European legislation for large carnivores is outdated and should be adjusted to the current conditions of their density and distribution, as in many parts of Europe they are no longer endangered (Chapron et al., 2014). Such an approach would decrease the possibilities for blocking the procedures for the culling of large carnivores that we have witnessed in Slovenia and other European countries in recent years. However, the cooperation of all European countries facing similar problems is required to achieve this.

Figure 21: Brown bear (*Ursus arctos* L.) (Photo: Petra Draškovič Pelc)

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Figure 22: Grey wolf (*Canis lupus* L.) (Photo: M. Krofel)

Forest protection and predominant risks to forests

Andreja Kavčič, *Slovenian Forestry Institute*,
Barbara Piškur, *Slovenian Forestry Institute*,
Maarten de Groot, *Slovenian Forestry Institute*,
Nikica Ogris, *Slovenian Forestry Institute*

The growing human population, globalization and changing climate have been the main drivers of distinct changes in forests and other ecosystems over the past two centuries. Abiotic and biotic disturbances, such as forest degradation, extreme drought, forest fires, lack and surplus of precipitation, an increase in the intensity and frequency of extreme weather events, outbreaks of pests and diseases, as well as the introduction and establishment of certain alien species, have impaired forest health to such a degree that the economy, ecosystem services and human health and well-being in general are greatly affected.

Forest health has thus become one of the main concerns of contemporary forestry, and forest protection has increased in importance.

Reporting, Prognostic and Diagnostic Service for Forests

Forest protection is ingrained in the Slovenian forestry and has been an integral part of forest management practices for decades regardless of forest ownership. Forest health issues in Slovenia are covered by the public forestry service, which brings together the Slovenian Forestry Institute and the Slovenia Forest Service. One of the highlights of the close collaboration of both institutions is the e-portal "Varstvo gozdov Slovenije", which was developed and is maintained by the Department of Forest Protection at the Slovenian Forestry Institute and is publicly available at www.zdravgozd.si.

One of the integral parts of the public forestry service is the Reporting, Prognostic and Diagnostic Service for Forests, which deals with biotic and abiotic threats to such ecosystems. The service monitors and provides forecasts for the occurrence and spread of biotic (forest pests and diseases) and abiotic disturbances (e.g. forest fires, windthrows, ice storms), carries out forest and tree health diagnostics, provides advisory services, creates guidelines and develops new knowledge through basic and applied scientific research.

The activities of the public forestry service are coordinated and funded by the Ministry of Agriculture, Forestry and Food (Directorate for Forestry). In addition, forest protection in Slovenia involves certain plant protection activities, which are coordinated and funded by the Administration of the Republic of Slovenia for Food Safety, Veterinary Sector and Plant Protection (e.g. plant health surveys and diagnostics of quarantine plant pests).

The compliance of forest protection activities with the forestry and plant health regulations is supervised and ensured by inspectors of the Inspectorate for Agriculture, Forestry, Hunting and Fisheries and the Food Safety, Veterinary and Phytosanitary Inspection, respectively. The collaboration that occurs with forest owners and organizations related to forestry is of the utmost importance in the pursuit of healthy forests. Therefore, the Slovenia Forest Service is in close contact with forest owners and is also involved in the system of protection against natural and other disasters, which is governed by the Ministry of Defence. Public forestry service strives for healthy and resilient forests supporting sustainable, close-to-nature forest management with multipurpose forest development.

Forest protection challenges

Bark beetles

In recent decades Slovenian forests have been confronted with increasingly bigger challenges regarding abiotic and biotic disturbances. In 2014, an ice storm damaged more than half of Slovenian forests and induced an unprecedented outbreak of spruce bark beetles. This bark beetle disaster continued in the following years due to drought and windthrows, which provided suitable conditions to support the beetles' development and population growth. The ice storm damaged around 9 million m^3 of wood, mostly conifers. Additional 2 million m^3 of Norway spruce per year were consequently damaged by bark beetles in the following years. More frequent abiotic disturbances are expected in the future, and it is highly likely that they will bring about outbreaks of bark beetles and other pests and diseases.

Figure 23: Norway spruce forest damaged by a windthrow and subsequent bark beetle attack (Photo: A. Kavčič).

Invasive alien species

Globalization and climate change bring another threat to forests, i.e. alien invasive species, which can have even more devastating consequences for forests than native ones. We have already seen the havoc of the ash dieback caused by the fungus *Hymenoscyphus fraxineus* Baral et al., the Dutch elm disease caused by *Ophiostoma ulmi* (Buisman) Melin & Nannf. and *O. novo-ulmi Brasier*, or chestnut blight caused by *Cryphonectria parasitica* (Murrill) Barr. Sanitary felling of ash has risen severalfold in years after the first discovery of the disease in 2006. Currently, ash dieback accounts for 70% of the sanitary felling of ash. Recently, *Phytophthora* × *multiformis* (Brasier & S.A. Kirk) Husson, Ioos & P. Frey was recorded for the first time in Slovenia, and is already causing a distinct dieback of alders, the key species in the riparian forests of the NE part of Slovenia.

Figure 24: Ash dieback (left) and an oak heavily infested by the oak lace bug (*Corythucha arcuata* Say) (right) (Both photo: A. Kavčič).

In recent years, reports on the first findings of invasive plant pathogens and pests have been growing in Slovenia (e.g. *Eutypella parasitica* R.W. Davidson & R.C. Lorenz (1938), *Petrakia liobae* Beenken, Andr. Gross & Queloz, *Xylosandrus crassiusculus* Motschulsky (1866), *Dryocosmus kuriphilus* Yasumatsu (1951), *Corythucha arcuata* Say (1832), *Lecanosticta acicola* (Thüm.) Syd., *Dothistroma* spp. Hulbary). However, there are even more species waiting on our doorstep, such as the emerald ash borer (*Agrilus planipennis* (Fairmaire, 1888)), Asian longhorn beetle (*Anoplophora glabripennis* (Motschulsky, 1853)), pine wood nematode (*Bursaphelenchus xylophilus* (Steiner & Buhrer) Nickle), and thousand cankers disease (*Geosmithia morbida* M.Kolařík, E.Freeland, C.Utley, & Tisserat), to mention just a few. No tree species is safe from this threat.

Protection against abiotic and biotic disturbances

Forest protection activities in Slovenia focus on preventive action, such as the improvement of forest resilience to negative environmental influences, and early warning and rapid response to possible future forest pests and diseases.

Computer-based models for short- and long-term forecasts of ice storms, forest fires, outbreaks of bark beetles and the spread of certain tree diseases have recently been developed for Slovenia. A phenology model for the European spruce bark beetle, (*Ips typographus* L.), called RITY, has been produced to model the development of this species on a local scale, which will improve the monitoring of bark beetle populations in Slovenia. In addition to this, we are currently testing different pheromone lures for *Ips typographus* and different types of traps to identify the most cost-effective approach for bark beetle monitoring. The possibility of using remote sensing technology for the detection of forest damage in Slovenia is also being investigated, while much effort is directed into training of forestry professionals in all aspects of forest protection.

Growing reference collections of insects and fungi associated with forests and woody plants, with specimens from Slovenian forest as well as potentially hazardous non-native species, represent an important source of information and add value to the diagnostic infrastructure.

Early warning and rapid response systems for biological invasions have become a top forest-protection priority. We perform annual plant health surveys for selected pests and diseases that pose the highest potential threat to forests, the so-called quarantine organisms for forests, as well as develop methods and introduce new diagnostic procedures for early detection of these organisms. Contingency plans and pest risk analyses for possible quarantine pest outbreaks in Slovenia are being prepared in order to strengthen the readiness to respond to these relatively unknown threats.

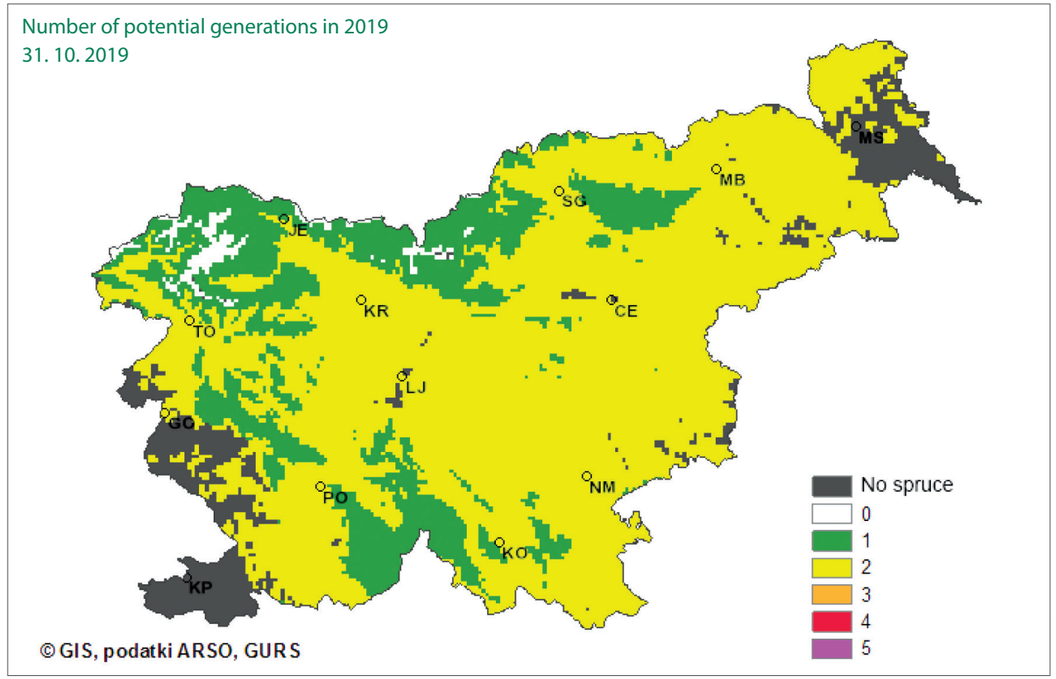

Figure 25: Predicted no. of potential generations of the European spruce bark beetle, according to RITY-2 (source: www.zdravgozd.si).

The consistent support from policymakers, forest owners and the general public is a prerequisite for any action to be effective. Therefore, forest protection activities include number of awareness-raising and educational events for the relevant ministries and other forestry-related institutions, forest owners and the general public. An information system ˝Invazivke˝ (www.invazivke.si) that has been developed within the project LIFE ARTEMIS shows how the general public as citizen scientists can contribute to forest protection by early detection of invasive alien species. Due to the great success of this information system, it was later introduced to the whole Danube region and translated into six languages (https://danubeforesthealth.eu) in the project REFOCuS.

Forest protection challenges are common to countries in a wider European area and require combined efforts in our striving for healthy forests. Slovenia collaborates closely with research laboratories worldwide, and is actively involved in international associations from the field of forest protection, e.g. EPPO – European and Mediterranean Plant Protection Organization, REUFIS – Forest Invasive Species Network for Europe and Central Asia, EMN – European Mycological Network, EMA – European Mycological Association, and EFSA - European Food Safety Authority, thus actively contributing to global forest protection and plant health issues.

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Figure 26: Sixtoothed spruce bark beetle (*Pityogenes chalcographus* L.) (Photo: A. Kavčič)

The forest as a resource and wood-product market

Špela Ščap, *Slovenian Forestry Institute*,
Nike Krajnc, *Slovenian Forestry Institute*,
Mitja Piškur, *Slovenian Forestry Institute*

The volume and the structure of timber removal in Slovenian forests

The structure of timber removal in Slovenian forests shows that from 1999 to 2013 rejuvenation felling prevailed (in average 38 % of total felling). The volume of salvage logging was on average 27%, while selective thinning represented an average of 26 % of the total felling in that period. A record level of felling (6.36 million m^3), which for the first time exceeded the allowable cut, was achieved in 2014 due to restoration of damage caused to forests by an ice storm, which affected 9.32 million m^3. The volume of felling in all other years from 1999 to 2014 has otherwise lagged the allowable cut determined by the forest management plans, reaching only 65% of its value. The allowable cut in 2014 amounted to 87% of the annual growth assessed for the whole country. The large volume of felling in Slovenian forests also continued in 2015 due to noticeable increase in sanitary felling of Norway spruce caused by bark beetle outbreaks, the consequence of the ice damage in 2014. A very high volume of felling (6.1 million m^3) was then carried out in 2016 due to damage restoration caused by bark beetles. According to the Slovenia Forest Service, a total of 2.2 million m^3 of conifer trees were felled during 2016 due to damage caused by bark beetles. Another natural disturbance affected Slovenian forests in the middle of December 2017, where 20% of forests were damaged by strong winds. The estimated damaged exceed 2.2 million m^3 of timber, which was also the most extensive recorded windthrow damage in Slovenian forests in the last 20 years. Due to the frequent occurrences of natural disasters in Slovenian forests in the years from 2014 to 2017, the amount of felling increased significantly. Of the total volume of felling in these years, salvage logging represents the major type, accounting for an average 63% of the total felling in Slovenian forests.

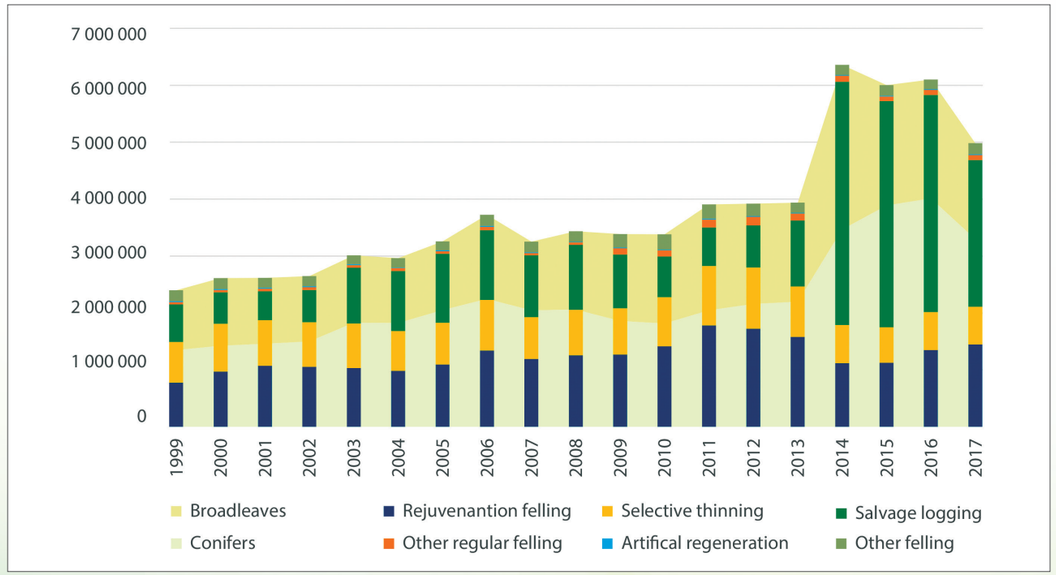

Figure 27: The structure of timber removal for the period 1999 – 2017 in gross m^3 (source: Slovenia Forest Service, calculated by the Slovenian Forestry Institute).

Roundwood production in Slovenia

In 2017, the production of forest wood assortments amounted to 4.6 million m^3 (without bark), with 2.9 million m^3 being coniferous species and 1.7 million m^3 broadleaves. In terms of the structure of forest wood assortment production, sawlogs and veneer logs (54%) prevail, followed by wood fuel (24%), pulpwood (20%) and other industrial roundwood (2%). The purchase of forest wood assortments from private forests in 2017 amounted to 1 million m^3, of which 80% were coniferous. Total roundwood exports in 2017 amounted to 2.6 million m^3.

In 2018, the scope of forest wood assortments was influenced by the restoration of damage caused by strong winds. In the middle of December 2017, one fifth of Slovenian forests were damaged by strong winds, and 2.7 million m^3 of trees, mainly conifers (spruces and firs), were affected. This priority restoration was reflected in the lower number of felled deciduous trees, which in turn resulted in a deficit of beech logs in Slovenian sawmills. Additionally, the demand for deciduous wood of lower quality expressed by fibreboard manufacturers in Slovenia and neighbouring countries remains high.

The damage caused by bark beetles was lower in 2018. In the first eight months, the amount of conifer trees felled due to damage caused by bark beetles compared to the same period in the previous year was down by 68%. This indicates a reduction in bark beetle gradation, which was a consequence of the ice damage in 2014.

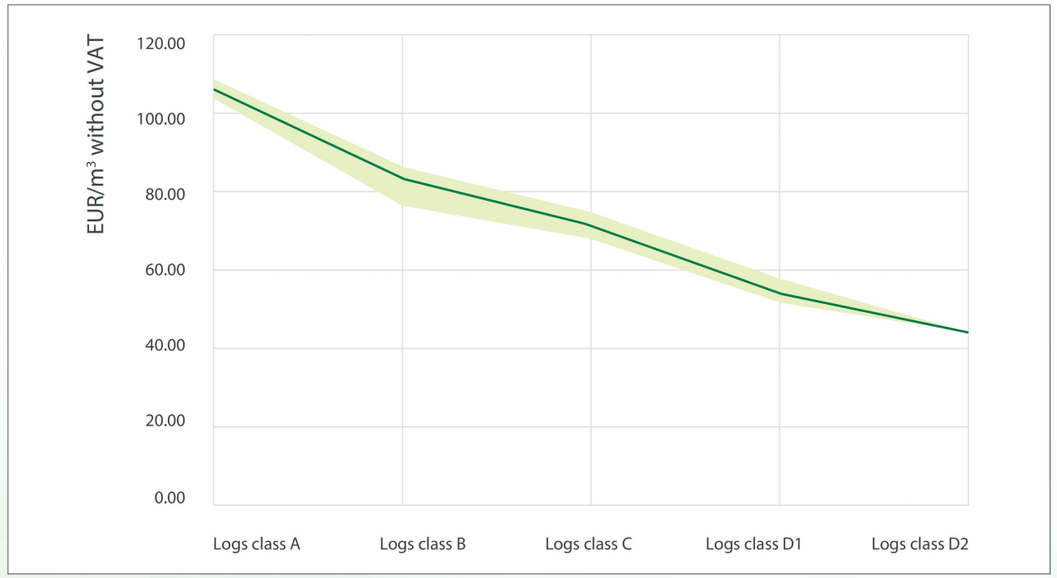

Figure 28: The average market price of spruce logs in EUR/m^3 without VAT from 2017 – 2019 (the black line shows the average market price and grey area shows the range between min and max market price in the period of data collection (source: Slovenian Forestry Institute).

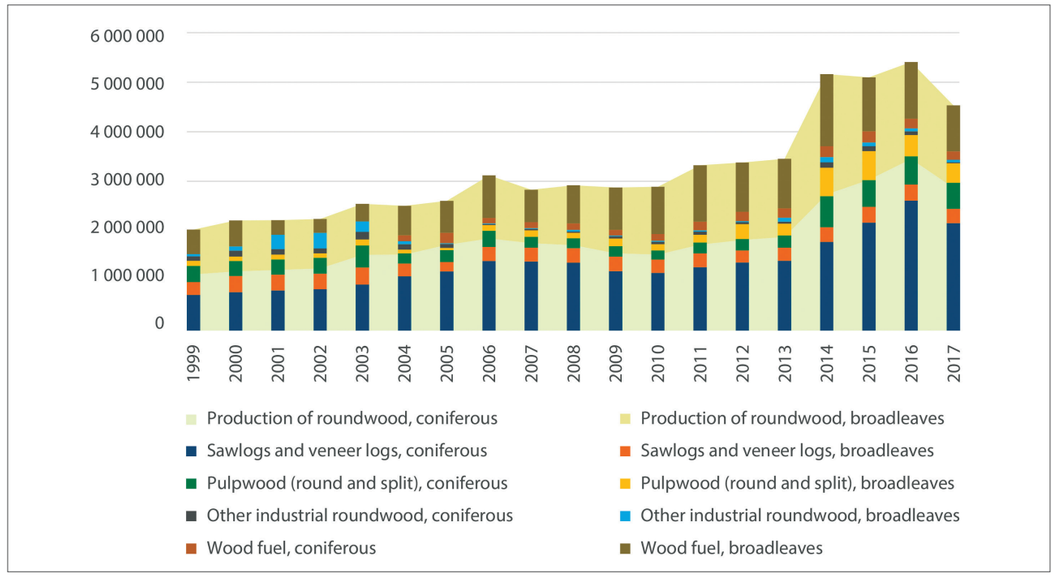

Figure 29: Production of roundwood in Slovenia for the period 1999 – 2017 in net m^3 (source: Statistical Office of the Republic of Slovenia).

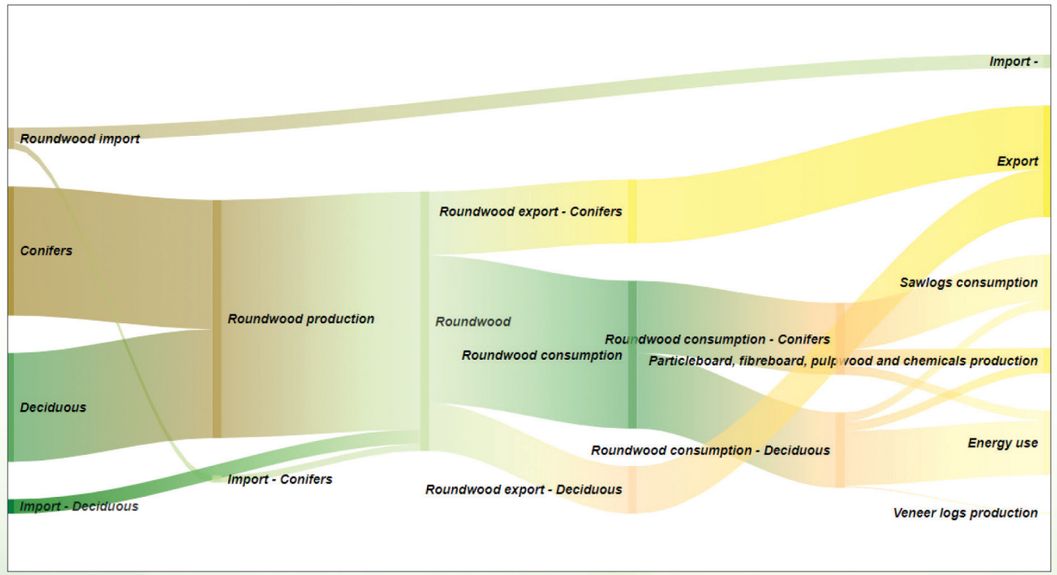

Figure 30: Roundwood flows (coniferous and deciduous) in Slovenia (data for 2014 – published at: http://wcm.gozdis.si/en/wood-flows-and-prices).

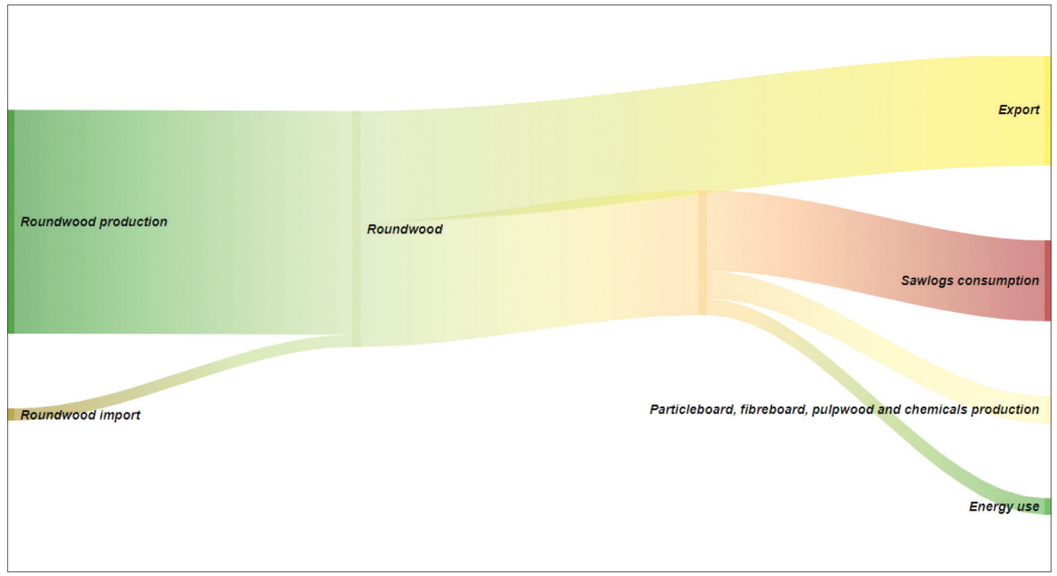

Figure 31: Roundwood flows for coniferous only in Slovenia (data for 2014).

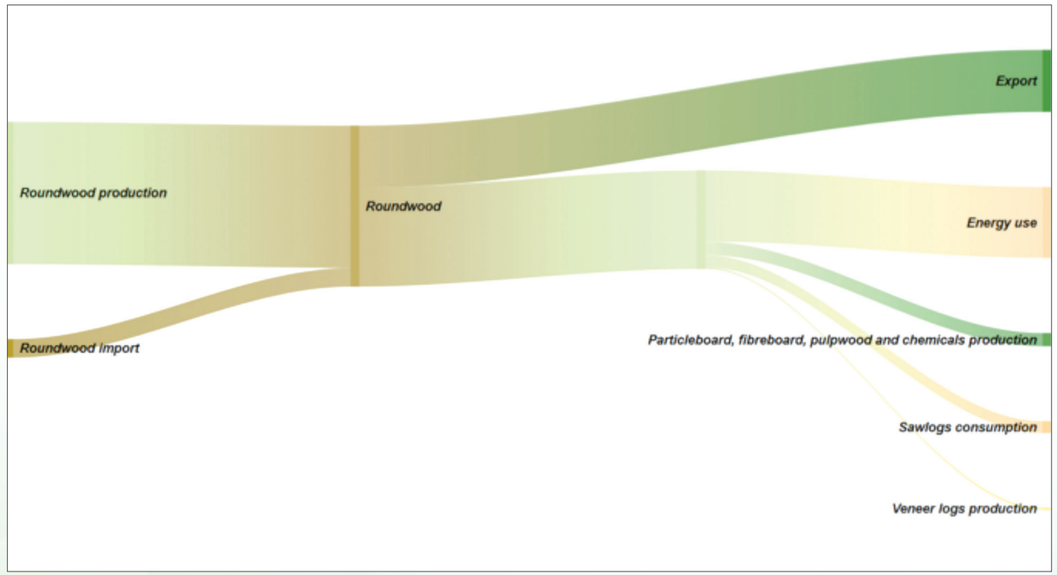

Figure 32: Roundwood flows for deciduous only in Slovenia (data for 2014).

Figure 33: Large storage of wood after restoration felling in Kočevje. (Photo: SFI archive)

Wood biomass market in Slovenia

The largest consumers of wood fuels are households, using some 1.6 million tons, predominantly firewood acquired from their own forests or the market. The largest single consumer of wood for energy purposes remains the district heating system in Ljubljana, with an installed capacity of 152 MW, which utilizes the co-incineration of coal and wood. The thermal power plant and the district heating plant use more than 100 000 tons of wood chips per year.

The price of firewood with humidity levels of approx. 20% and lengths between 25 and 33 cm was EUR 158 per ton at the beginning of the heating season 2018/2019 (October 2018), which is on average 5% more compared to the end of the last heating season (May 2018). The price of firewood has been increasing since May 2017. The Slovenian Forestry Institute monitors wood fuel prices and regularly publishes them online at http://wcm.gozdis.si/cene-lesnih-goriv.

The wood pellets market has changed dramatically since 2016, with exports now exceeding imports, and Slovenia becoming a net exporter of wood pellets in 2017. The main consumers of wood pellets are households, followed by larger public buildings and other users. The most recent collection of data on pellet production in Slovenia (concluded by the Slovenian Forestry Institute in June 2018) shows that there are currently 20 producers of pellets in the country. Only one of these has a yearly production of above 50 000 tons, and only one of a yearly production between 15 000 and 50 000 tons. The total production of pellets in Slovenia amounted to 115 000 tons in 2017. The level of production in the last three years has been relatively constant, and dependent mostly on the raw materials available.

Pellets produced by small producers are mainly sold on the local market. The biggest wood pellet producers in Slovenia have an EnPlus certificate and can export their products. The pellet market is dynamic, since some of the imports from Balkan countries are then exported to other EU markets. Pellets are predominantly exported to Italy (97% in 2017 and 92% in 2018). Compared to 2016, the export of wood pellets increased by almost 50 000 tons (36%) in 2017 and reached over 190 000 tons. In contrast, the import of wood pellets decreased by almost 20 000 tons (almost 10%) over the same period. Most pellets are imported from Romania (40%), Austria (15%) and Bosnia and Herzegovina (14%).

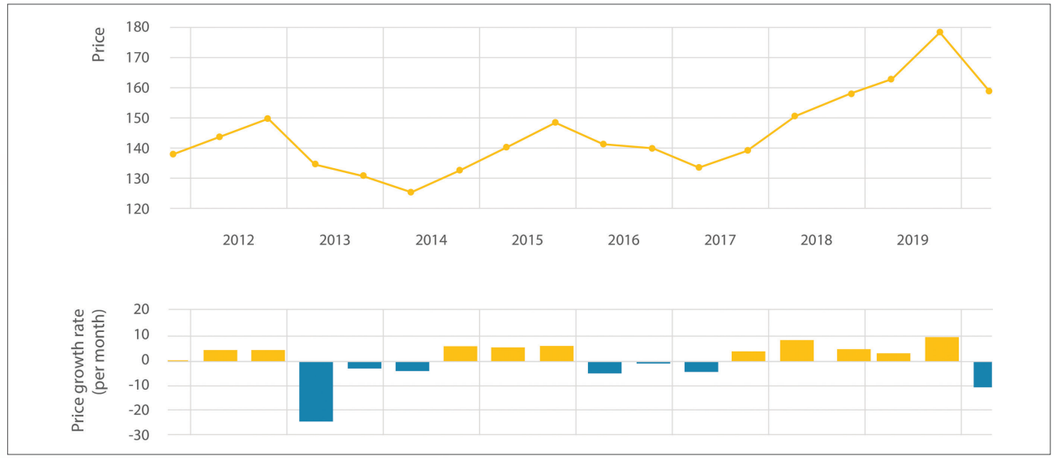

Figure 34: Price of firewood (in €/t with VAT) during 2011 and 2017

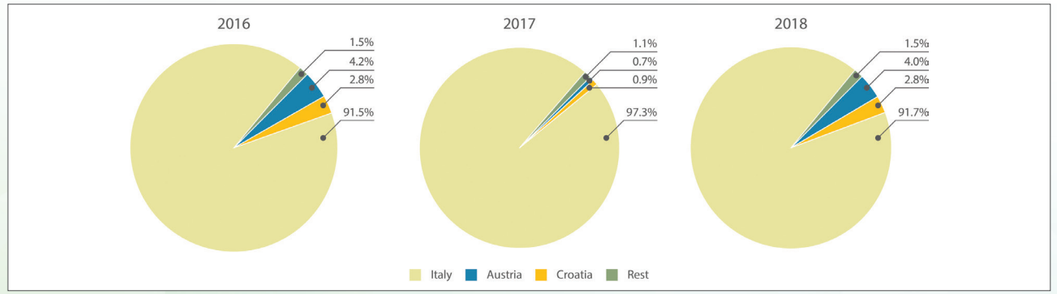

Figure 35: Comparison of exports of wood pellets by countries in the period 2016 – 2018 (source: Statistical Office of the Republic of Slovenia, calculated by the Slovenian Forestry Institute)

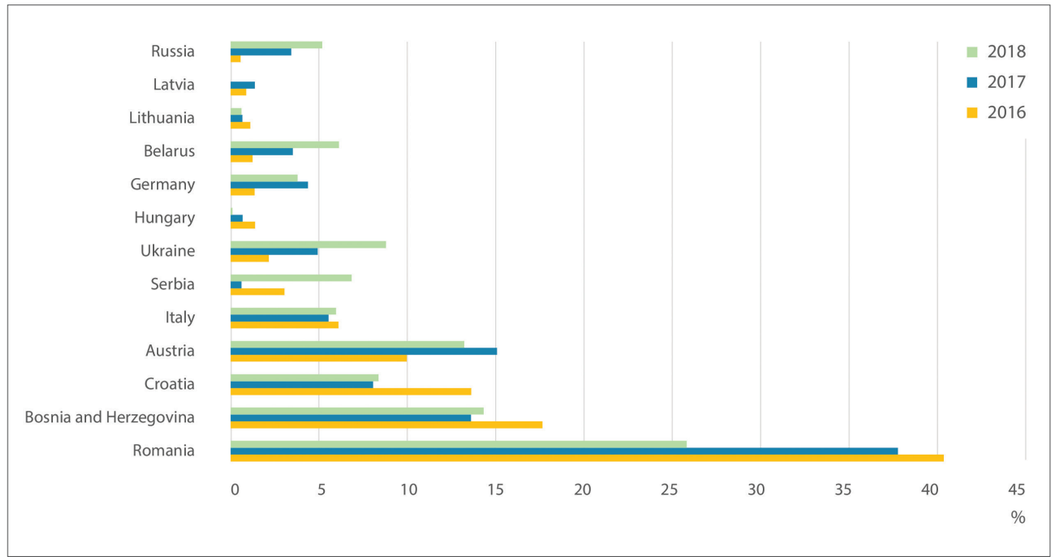

Figure 36: Comparison of imports of wood pellets to Slovenia by country in the period 2016 - 2018 (source: Statistical Office of the Republic of Slovenia, calculated by the Slovenian Forestry Institute).

Pellets, although the most expensive form of wood biomass, are 35% cheaper (EUR 60/MWh) than heating oil, whose price fluctuated around EUR 103/MWh in the second half of 2018. The difference between the prices of heating oil and pellets increased by 9% in comparison with the previous year. A ton of pellets, packed in 15 kg bags, cost EUR 283 on average after the beginning of the heating season 2018/2019. In comparison with the same period in the previous year, prices increased by 5%.

The quality of the wood pellets available on the Slovenian market improved in 2018 in comparison with 2017. This is evident from an independent analysis of pellet quality on the Slovenian market, as the share of pellets classified as A1 (68%) increased in 2018. Three years before this, in 2015, the pellet samples belonging to the A1 quality class only accounted for 27% of the total, while in 2017 this percentage had risen to 60%.

Wood chips are predominantly used for energy purposes, and the Thermal Power Plant Ljubljana is by far the largest consumer, with an annual consumption of over 100 000 tons. The consumption of wood chips in the production of wood products (fibreboards, pulp, chemicals) amounts to less than 10% of the total consumption in Slovenia. Wood chip manufacturers are technologically well equipped. There were more than 200 woodchippers in Slovenia in the first half of 2018, with over 50 that can achieve a production capacity of at least 100 nm^3/h. Yearly production scope remains at a high level due to restoration following the damage caused by bark beetles and the wind damage in 2018. According to data collected by the Slovenian Forestry Institute, in 2017 the production of wood chips exceeded 2.2 million loose m^3. The production of wood chips in Slovenia has increased more than fivefold over the last 10 years (from 0.48 to 2.2 million loose m^3). Slovenia is a net exporter of conifer wood chips and a net importer of deciduous wood chips. With regard to the import of wood chips, deciduous wood chips prevail (80 – 90%), while exports are dominated by conifer wood chips (70 – 80%). Last year, wood chip exports exceeded 350 000 tons, and imports increased by 10%. Wood chips are predominantly imported from Croatia and exported to Austria and Italy. We can see that the increase in the export of green wood chips in recent years has been due to the lack of domestic users and new demand generated in neighbouring countries.

The price of the best-selling wood chips (with a humidity of approx. 30% and particle size of approx. 31 mm) averaged EUR 90.8/t at the beginning of the heating season 2018/2019, which is approximately 17% more compared to the same period in the previous year.

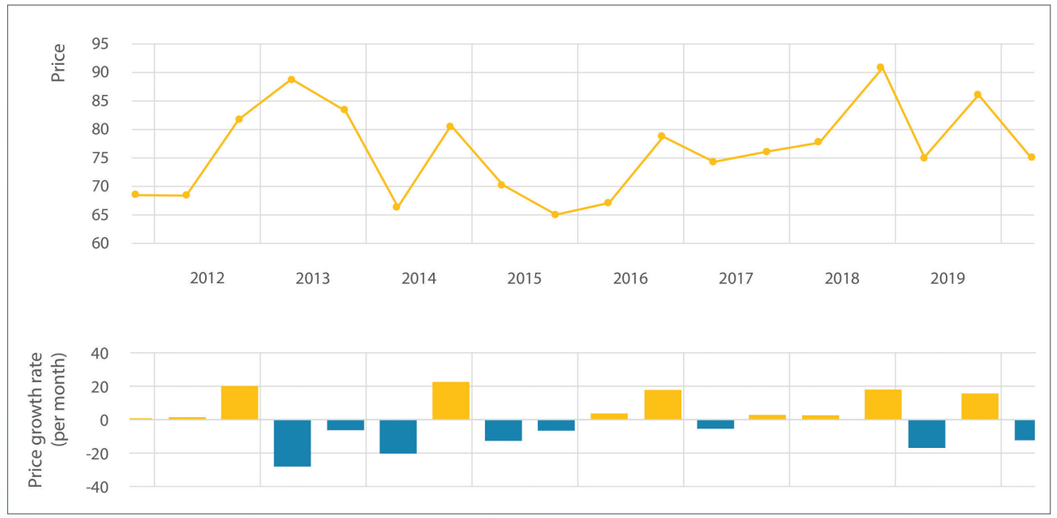

Figure 37: Price of wood chips on the Slovenian market in the period from 2011-2018 (in €/t with VAT).

Use of roundwood in Slovenia

From an economic point of view, the use of roundwood in industry or manufacturing is the most important use of wood. The wood industry includes business entities that process round timber into sawn wood, veneer, wood pulp, particle and fibreboard and chemical products (e.g. tannin). The production of solid wood fuels (pellets, briquettes and chips for energy production) is not included in this subchapter.

The use of roundwood in industry is divided into the production of sawn timber at sawmills, which are also the largest roundwood consumers in Slovenia, the production of veneer, pulp, fibre and particle board, and the use of other industrial timber.

Most logs are processed in the sawn timber industry. Sawmills with up to five employees predominate in Slovenia, while the largest share of production is done by medium size sawmills (more than 20 employees). The structure of sawmill processing is dominated by conifer logs, with a more than 75% share of the total.

The sawn softwood industry in Slovenia is still hindered by the unfavourable structure of sawmills (in terms of size and technological equipment), however investments have been secured for new, larger plants as well as for upgrades, technological modernization and an increase of the capacities of existing Slovenian sawmills, indicating significant structural changes in the future.

Figure 38: Sawn beech wood from Slovenian forests. (Photo: SFI archive)

Table 8: **Structure of sawmills according to number of employees and amount of wood processed per year** (year 2016, source: the Slovenian Forestry Institute)

Business entities (number of employees)	Structure according to the number of business entities [%]	Structure according to cross-cutting of logs [%]
Complementary activity on a farm	20	3
0-1	46	9
2-4	16	12
5-9	6	14
10-19	4	14
Over 20	8	48

Slovenian sawmills continued to maintain a high level of wood processing activities in 2018, which is a consequence of increased quantities of logs on the market due to restoration following ice damage, damage caused by bark beetle gradation, market surpluses and lower log prices.

Sawn hardwood production is strongly influenced by the positive trends in Europe and difficulties in the supply of logs. Owing to favourable market trends in sawn beech and oak wood, in the coming years we could see an increase in both production and exports.

Important companies in Slovenia processing low quality and small diameter wood are producers of particle board (Lesonit, d.o.o.), mechanical pulp (Količevo Karton, d.o.o., VIPAP Videm Krško, d. d.) and chemicals (Tanin Sevnica, d. d.). The largest wood processing companies are among these (Lesonit, d.o.o. and Količevo Karton, d.o.o.) process more than 500 000 m^3 per year.

Producers of mechanical pulp are important, since they are the only larger user of low quality and small diameter coniferous wood. The scope of mechanical pulp production increased by 9% in 2017. Production is expected to remain at the same level in 2018 and 2019. Pulp exports are negligible, as the production in Slovenia is entirely integrated. In 2017 pulp imports decreased by 2.4% and was expected to increase by 2% in 2018.

Figure 39: Industrial wood chips for the production of fibreboards in the company Lesonit d.o.o. (Photo: SFI archive).

The production and consumption of all types of wood-based panels remains at a relatively high level, which indicates a continuation of the positive trend in the construction of buildings and the whole construction sector. A similarly high level of production and consumption is foreseen for 2018 and 2019.

Imports and exports have an important role in the development and status of roundwood use. In the last 15 years (after 2004, when Slovenia entered the EU) we can see increase in roundwood exports, and the restoration of damaged forests pushed these to a record level, reaching more than 3 million m^3 in 2016.

Certified wood products

A total of 265 000 ha of forests are certified by the FSC system, which represents more than 20% of the total forest area in Slovenia, where these are predominantly state forests (90%).

The area of forests included in the PEFC national certification scheme increased significantly in 2017, as the SiDG company (Slovenski državni gozdovi, d.o.o.) entered the regional PEFC certification scheme with its total area of 231,500 ha of certified forests in November 2017. A total of 286,000 ha of forests are now certified according to the PEFC system in Slovenia.

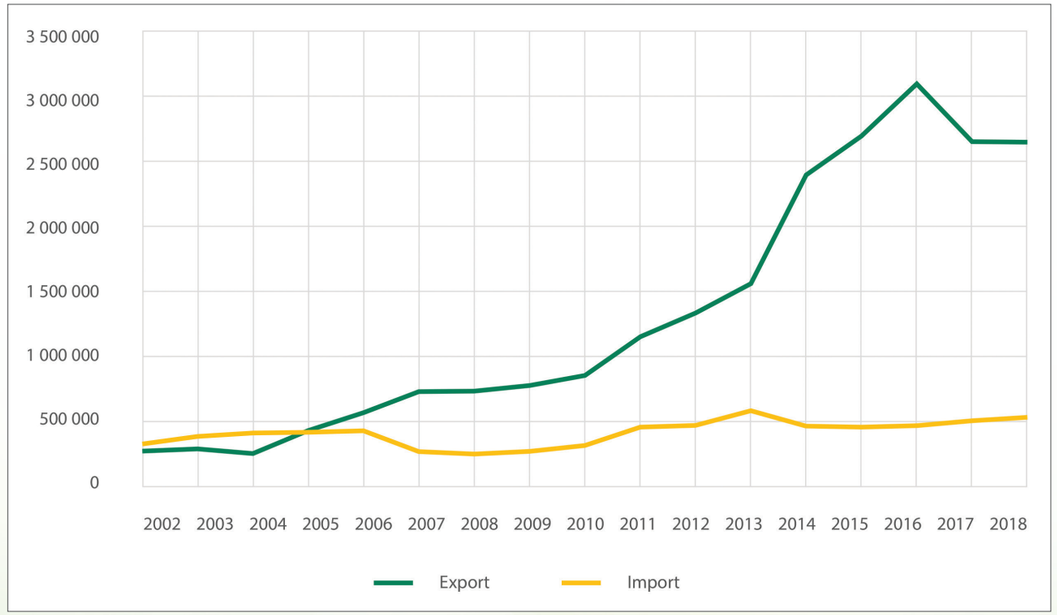

Figure 38: Exports and imports of roundwood in Slovenia
(source: Statistical Office of the Republic of Slovenia, calculated by the Slovenian Forestry Institute).

Photo M. Čater

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Non-wood forest products

Anže Japelj, *Slovenian Forestry Institute*,
Tine Grebenc, *Slovenian Forestry Institute*

Slovenia has a long tradition of using non-wood forest products. The definition of non-wood forest products (NWFP) here follows the Millennium Ecosystem Assessment report, being "products of biological origin other than wood derived from forests, other wooded land and trees outside forests", namely mushrooms, forest fruits, medicinal herbs, chestnuts, pine kernels, acorns, game meat, pelts, resins, etc. The popularity of different products varies in time and partially reflects the related market demands/options, although a significant portion of non-wood forest products is probably used or consumed directly (within families or local communities) without registered trading.

Around 10% of the overall production of forest goods in Slovenia is attributed to NWFP (Wong and Prokofieva, 2014). The most evident reasons for this are cultural tradition, ecological conditions and value chain organization. While the timber industry has a long tradition and is well organized with relatively strong intrapreneurial linkages, the NWFP sub-sector is different. In many countries those goods are related to everyman's right, while timber production is not. Many of the peculiarities related to the NWFP sub-sector are closely connected with the high level of self-consumption, widespread grey market, eruption of conflicts between users and landowners, and the weak connection with official forest management. NWFP are being increasingly recognized as having potential for the creation of new green jobs, especially in rural areas, an important element in achieving a circular economy and one of stepping stones towards a bio-economy, which was made very clear in the 2018 revision of the Bio-economy Strategy (Updated Bioeconomy Strategy, 2018). An important aspect of NFWP is the variety in type of goods. More than 160 fungi species, approximately 25 taxa of lower plants and almost 450 of higher plants are either picked in the wild or cultivated, all as NWFP. And this is not even counting animal-based products. Almost half (47%) of all the NWFP value generated in 28 EUR countries in 2010 came from ornamental plant production, 30% from foods, and a fifth (21%) from other plant products (excluding animal-based products) (Forest Europe, 2015).

NWFP are not only important in terms of entrepreneurship; they are deeply rooted in several cultures to sustain communities and as an outdoor activity related to spending time in forests, socializing, and learning about nature. In 2016 more than half of all households in Slovenia went into the forest and picked a NWFP at least once (Vidale et al., 2015a). The results from the 28 EU countries indicate great variety in such activities, and rank Slovenia third from the top. This well-established culture of NWFP picking in Slovenia has its origins in securing one's livelihood and nowadays plays an important role in re-connecting with nature and as a recreational activity among the general public. Households in Slovenia collect wild berries (47%), especially bilberries, strawberries and blackberries, aromatic and medicinal herbs (38%), such as elderberries, forest nuts (32%), especially sweet chestnut, mushrooms (30%), ornamental greenery (25%), like flowers, kernels, moss, foliage and branches, along with a few who collect tree sap (3%) and very few truffles (0.2%). The low collection rates for tree sap and truffles seem reasonable, as lots of knowledge and special equipment is needed for both, and the same survey showed that almost three quarters (74%) of all household members that collected NWPF had no special training in plant or fungi identification. Four fifths (80%) also indicated that NWFP collection did not contribute to their overall household income.

The NWFP market in Slovenia is poorly structured in terms of value chains and flow of goods. Only a few entrepreneurs are registered in the official registry of enterprises (e.g. 30 for mushroom picking and selling), although research shows a greater extent of collection and trade (Vidale et al., 2015b). A more focused analysis of value chains for forest honey and mushrooms reveals that entrepreneurs often act as sole traders and combine the activities of collection, possible processing and selling, and that the producer has the key role in price generation. A poorly developed market with little specialization of individual production, processing and marketing phases is present, limiting the room for innovation. Competitiveness in terms of new products or business models is not consistently pursued, and may be restricted to larger firms, which generally act as wholesalers/retailers. There are only a few of these, and they secure a large part of their merchandise from imports, mainly from east and south-east Europe. Presumably there is a large grey market that is mostly represented by single-person producers, who sell much of their products to either middlemen or individual end-users, such as households and restaurants.

Many challenges to market development derive from the regulatory framework, which vaguely distinguishes between recreational picking and collecting NWFP as a business activity. The relatively strict limitation on what one is allowed to collect, such as 2 kg of mushrooms per person per day (Rules on Forest Protection, 2009), hampers entrepreneurship where larger quantities are needed to meet the market demand, despite the recent introduction of vouchers, which upon tax-related payment allows the collection and trade of NWFP as a business activity. The landowner as a key subject is omitted from this arrangement. However, beekeeping and especially hunting are more effectively regulated, because both have received more attention in terms of the government either establishing development programmes (such as for beekeeping) or placing concessions and generating revenue (with hunting). Several tools are available for small- and medium-sized enterprises to implement innovative products or processes, like the Rural Development Programme, loans from the state development bank and especially the Slovene Enterprise Fund. Those businesses that offer the most innovative NWFP-based products, like pharmaceutics, often apply for such start-up initiatives.

Truffles, the most valuable mycorrhizal fungi distributed in most northern hemisphere forest ecosystems, are traditionally the best known and highly exploited non-woody forest product in Mediterranean countries, with annual outcome estimate over EUR 500 million, while in other areas in Europe and globally they remain understudied. Apart from their ecological importance they have a high economic impact with the potential for ensuring work in rural forested areas and ensuring a better forest-based income for many underdeveloped areas in central, southern and southeastern Europe. The environmental changes, high human impact on forest ecosystems, intensification of forest management approaches and truffle hunting in native truffle sites all resulted in a drastic fall in truffle production over the last century, along with the reduced importance of natural sites and increased truffle production in agroforestry plantations. The trend of neglecting of natural truffle sites could be changed with modified forest management. However, in most European countries there is still a significant lack of knowledge and information about the cultivation of truffles in controlled forests or agroforestry systems. The large knowledge pool with regard to truffle biology in the Mediterranean area and their high global economic value makes truffles unique and as an ideal model or test example of other NWFP, and the subsequent development of well-planned approaches for their cultivation in forest- and agroforestry ecosystems. The high economic value of truffles has an enormous potential to trigger various technical, technological and organizational innovations, particularly when dealing with the monitoring of soil conditions, tracing of mature truffles in soil, optimization of cultivation in forests and agroforestry systems, prolonged truffle storage possibilities and uses. This potential should not be limited to Mediterranean climates and countries only, but should involve all the main parts of the truffle areas in Europe, within their otherwise circumboreal distribution.

Future challenges

Providing a consistent regulatory framework is the first key step in designing transparent and secure entrepreneurship environment to further mobilize forest resources and provide opportunities for the creation of new jobs in forestry. Secondly, financial support needs to be provided in order to establish new firms which will not be operating in a hi-tech area, such as pharmaceutics. Some NWFP simply offer a limited array of products that do not involve technologically advanced approaches, but still provide market niches with potentially high added value. Finally, efforts should be made to promote environmentally friendly and locally produced goods, as this might further increase the interest of consumers, although this needs to be approached strategically, with one valuable example from practice being the Slovenian honey trademark.

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Figure 39: Black truffle (*Tuber melanosporum* Vitt.) (Photo: M. Čater)

Organization and national legislation of the Slovenian forestry sector

Damjan Oražem, *Slovenia Forest Service*,
Primož Simončič, *Slovenian Forestry Institute*

In 1993, and after five decades, the Forest Act adopted by Parliament passed the responsibility for managing forests from the state back to their owners. Since forests are, under the Slovenian Constitution, a natural resource for ecosystem services available to all inhabitants, the state has limited the absolute availability of this resource in the same way as for other key natural resources. Forest owners can now, for example cut trees only according to the forest management plans (FMP), which are adopted by the state after gathering the opinions of all stakeholders (the forest service, owners, local communities, NGOs, etc.). To compensate for restrictions, facilitate the implementation of forestry regulations and ensure the sustainable, close-to-nature and optimal functioning of the ecosystem services of forests, the state provides forest-management guidance free-of-charge through the public forest service and many state subsidies are available for forest investments. In forests, the application of chemicals continues to be prohibited, free access is assured and limited recreational harvesting of forest products, as well as beekeeping and hunting, are allowed. Bees, which are essential for agriculture, acquire about 80% of the pasture in forests.

To facilitate the achievement of goals in dialogue with the state, forest owners over a certain threshold of the amount of cadastral income are obliged to join the Agriculture and Forestry Chamber (https://www.kgzs.si/). At present, over 90 000 or 22% of all forest owners are enrolled in the Chamber. The Chamber holds the PEFC certificate for Slovenia, with 24% of Slovenian forests certified by the end of 2018. Forest owners may voluntarily merge within the framework of cooperatives and forest owners' societies according to their interests. At the end of 2018 approximately 4 000 members and their cover organization, the Association of Forest Owners of Slovenia (https://www.slovenski-gozdovi.org/), were part of some thirty organizations. Most of their current activities are related to non-productive integration elements, with some political demands.

Ministry of Agriculture, Forestry and Food

The highest authority in the country responsible for the regulation, development and protection of forests is the Ministry of Agriculture, Forestry and Food (MAFF; http://www.mkgp.gov.si/). The field of forests and forestry at the Ministry is managed by the Forestry Division within the Directorate for Forestry, Hunting and Fisheries. It monitors the forest conditions and develops system solutions for the sustainable development of forests ecosystems and biodiversity, as well as all the environmental, production and social functions of forests. The Ministry includes the State Secretary, who also covers the field of forestry and the Directorate for Forestry and Hunting.

Roles of the Forestry Division:

- monitoring of forest conditions and system solution development in the fields of forests, forestry, forest nursery and seed production;
- conducting proceedings for the adoption of administrative plans;
- monitoring the proceedings of silvicultural and safety measures or biological investments in forests;
- monitoring and reviewing the operations of the Slovenia Forest Service;
- monitoring of educational and research activities within the Division's work scope;
- designing and monitoring programmes for the construction and maintenance of forest roads and monitoring forest-work technologies;
- monitoring economic performance and forestry activity costs, developing standards for forest investment and co-financing;
- monitoring of the forest products market;
- fixing the prices of services which are co-financed from the budget of the Republic of Slovenia.

Forestry inspection is carried out by the Forest Inspectorate, operating within the Inspectorate of the Republic of Slovenia for Agriculture, Forestry, Hunting and Fisheries (http://www.ikglr.gov.si/), and this body employs 16 inspectors in total.

Approximately half of Slovenian forests are part of the NATURA 2000 network for the protection of rare plant and animal species and habitat types. This work, in addition to the protection of large carnivores, is governed by the Ministry of the Environment and Spatial Planning (MOP; http://www.mop.gov.si/). A considerable part of the operational work in the mentioned area, in particular the elaboration of proposals for the management of large carnivores, the assessment of damage by protected animal species, the operation of the intervention group for dealing with problems with large carnivores, and the like, is carried out by the Slovenia Forest service.

The Forest Act (1993) established the Public Forestry Service (PFS) for the implementation of forestry regulations, which are mainly performed by the Slovenia Forest Service (SFS) and the Slovenian Forestry Institute (SFI). The SFS activity is fully financed from the budget of the Republic of Slovenia, and services for are virtually free of charge for users.

Slovenia Forest Service (SFS)

SFS (http://www.zgs.si/) is a key public institution, established on 1st of May 1994 by the Republic of Slovenia, which performs public forestry service in all Slovenian forests, irrespective of ownership, as directed by the Ministry of Agriculture, Forestry and Food. SFS performs tasks based on approximately one hundred legislative regulations, the basic Forest Law, the Law on Forest Reproductive Material, the Conservation of Nature Act and the Law on Wildlife and Hunting. SFS monitors the state and development of forests, implements forestry and hunting planning, takes care of silviculture and forest protection, designates trees for felling, directs building of forest road and skidding ways, takes care of tree seed-banks, develops a forest database, takes over subsidized works, monitors the EU's Common Agricultural Policy, advises forest owners and informs decision makers and the general public about forest developments, among other tasks. Ten of the 12 special purpose hunting reserves (HRSP) in Slovenia are managed by SFS, where activities related to hunting tourism are carried out, and the activities of HRSP are entirely financed by the revenues from this. SFS participates in several international projects, which supports the acquisition of the required knowledge and experience, and the implementation of measures in some areas of forestry, hunting, nature protection and forest functions. SFS employs 655 people (2019) in the PFS-area, 62 to carry out HRSP work, and more than 20 who work exclusively on projects. The number of personnel has decreased by about 100 over the last ten years due to cost-saving measures by the state. The SFS operates in the central and 14 regional units of Slovenia, the latter being divided into 69 local units and 400 forest districts.

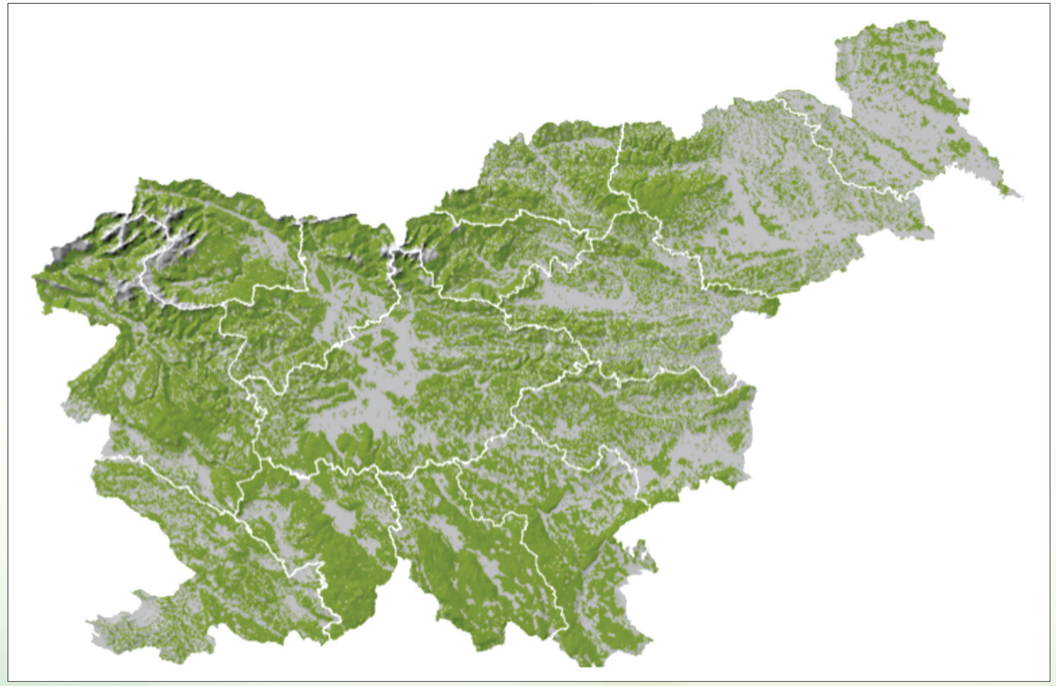

Figure 40: 14 Regional units of the Slovenia Forest Service

One of the basic tasks in the implementation of forestry policy in the development of forests is forestry and hunting planning and its implementation through forest owners. SFS produces forest management plans at three levels by applying prescribed procedures involving all stakeholders, including owners, local communities or the state, nature conservation organizations, non-governmental organizations, hunters and others:

- **Strategic:** 14 regional forest plans are provided, one for each regional unit every 10 years, with the average size of approximately 100 000 ha per unit. Guidelines from the Institute of the Republic of Slovenia for Nature Conservation (IRSNC) are included, and public discussions provide further input in the process of establishing the plans. Content: strategy of forest and game management, solving large-scale problems, forest functions and multipurpose forest management. Plans are adopted by the government based on a previous agreement with three ministries (the ministries responsible of forestry, environment and culture).

- **Tactical:** from 233 forest management plans in total, 10% are elaborated every year; the average size of the unit is about 5 000 ha. These plans are provided based on data from the 102 000 permanent sample plots, terrestrial stands inventory and other sources. Guidelines from the IRSNC are included, the local community is obliged to give an opinion and public discussions are held as part of the process of developing a plan. Content: defined management goals guidelines and measures, defined available cut and silviculture/protective measures, measures for NATURA 2000, etc. Such a plan is adopted by the Ministry of Agriculture, Forestry and Food.

- **Operational:** silvicultural plans are provided for units of 30 to 50 ha in size, based on the forest stand inventory data. They represent the background for the selection of harvested trees and for financial subsidies. Content: detailed description of the forest conditions and management goals (available cut, management approach, technology limitations, etc.). Remarks from public discussions are integrated into the plans, which are eventually adopted by the local forestry units.

Game management plans are included at the long-term (strategic) and annual (operational) levels. Annual game management plans are adopted by the Ministry of Agriculture, Forestry and Food.

The implementation of plans considers the requirements of forest owners after logging, construction of roads, silviculture, protection, forest restoration and the like. In all procedures, the SFS issues official decisions and approves regular works or imposes certain tasks in the case of forest risks (diseases, insects).

The SFS also educates forest owners to carry out safer work with more economic value. Public relations are of great importance, and are achieved by popularization of forests, informing the public, providing information of public interest, and so on. One of the main target groups for long-term education is primary school children.

One of the most extensive tasks for SFS owners is the selection of trees for felling. In regular logging, the forest owner expresses a request (for logging) and in accordance with the forest management plan, together with the district forester, they select and mark the trees. The owner receives a legal decision approving the action and later performs the felling, harvesting and transport of the trees either alone or with the help of the appropriate company. After the completion of the work, the district forester checks the appropriateness of the execution and records the quantity harvested. In the case of sanitary felling, damaged or attacked trees are usually first discovered by an employee of the SFS who issues an order for remediation to the owner within the appropriate deadline. If the

owner of the forest does not perform the requested work, and in cases when there is a possibility that disease will spread, the execution is provided by SFS at the expense of the forest owner.

In Slovenia about 20% of all forest areas are in state ownership, and until recently these were managed by the Fund of Agricultural Land and Forests. In practice, these forests were managed by the previously state-owned forest management companies which had been granted 20-year concessions. After the expiry of the concession contracts, starting from July 1, 2016, the newly established Slovenian State Forest Company (SSF; http://www.sidg.si/), started to manage state forests, including the management, disposal and purchase of forest areas. In the future, the company will carry out up to 20% of forest production in its own capacity, while other facilities will be leased by the company based on tenders. Wood from state forests is sold based on the government regulations, and mostly based on long-term contracts with business partners, partly also on bidding.

The basic national forestry document is the Resolution on the National Forest Programme (NFP, 2007, http://www.pisrs.si/Pis.web/pregledPredpisa?id=RESO56), adopted by the National Assembly of the Republic of Slovenia. It is a basic strategic document aimed at defining a national policy for the sustainable development of forest management. RNFP aims to preserve the forest and ensure its multifunctional role, including the environmental, social and economic aspects. Based on the current situation and goals set, the document contains a long-term vision of management, which, in addition to the development guidelines of the narrow forestry sector, also identifies links in the field of environmental protection and nature conservation, economic sectors related to timber processing, and all other areas that are interested in forests and forestry.

The National Forest Programme (NFP) also implements the Environmental Action Programme at the national level, defining the following priorities: climate change, nature and biodiversity, environment and health, and quality of life, natural resources and waste. The European Strategy for the Sustainable Use and Management of Natural Resources is also a starting point for the NFP, based on regional characteristics and an ecosystem approach. Based on the RNFP, the National Assembly adopts the Law on Forests. The Government and the MAFF adopt the relevant regulations based on the Forest Law.

Slovenian Forestry Institute (SFI)

The Slovenian Forestry Institute is a public research institute of national importance, which conducts basic and applied research on forests and forest landscapes, forest ecosystems, wildlife ecology, hunting, forest management, and other uses of the resources and services forests provide. The scientific knowledge from these fields helps further the research on forest biodiversity and its management in relation to climate change.

As part of its research programme and related studies, the Institute also provides forestry and environmental services in the public interest. Another of the Institute's functions is to provide scientific knowledge on all aspects of sustainable development, with the purpose of increasing knowledge and awareness of the importance of forests within the environment and the importance of forest management. In short, the Institute is a scientific, professional, and cultural storehouse for Slovenia's relationship with its forests and the resources and services they provide.

The institute bases its research on scientific excellence and professional competence. The research it conducts on forest biodiversity and its management in relation to climate change gives the Institute a key role in increasing knowledge and awareness of the importance of our forests and the way we interact with them. The Institute's work reinforces its position in society. Highly regarded both at home and abroad, it is Slovenia's principal treasury of knowledge, innovation, and creative ideas in researching forests, forest ecosystems, wildlife ecology, hunting, forest management, and the use of the resources and services that forests provide. As part of its research programme and related studies, the Institute acts with public authority granted under the Forest Act and provides forest and environmental public services.

Department of Forestry and Renewable Forest Resources at Biotechnical Faculty (University of Ljubljana)

Sustainable development is not possible without professional foresters. The study programme qualifies students for complete ecosystem forest work in accordance with modern principles of close-to-nature, multipurpose and sustainable management. Such a scheme requires linkage among ecological, economic and technical sciences. It requires knowledge of forest ecosystems, the social aspects of forest management, the various techniques and technologies used in forest management and familiarity with modern methodological tools. An advantage of the study programme is the emphasis on individual and seminar practice, which is partially carried out in the forest.

Students obtain a university academic degree in forestry. Graduates can obtain employment in public forestry services, organizations for wildlife management and nature conservation, schools (upper secondary and higher education) and private business sector. More and more opportunities are provided by self-employment – independent entrepreneurs (primary wood processing, forest construction, wood trade, arboriculture, ornamental tree production, ecotourism, private advisory agencies in forestry, biological engineering, spatial planning, mountain area management and sanitation of ecological points). There are also increased employment possibilities in (non)forestry secondary schools and in the sphere of extracurricular activities. The spheres of waste and communal management are also promising. Due to the abundance of forests and their importance in Slovenia, the demand for forestry professionals in administration, and in nature conservation governmental and non-governmental organizations, is increasing. The tradition of close-to-nature forest management in Slovenia also provides employment possibilities abroad.

Forestry secondary level education in Slovenia is carried out by the Secondary Forestry and Wood School of Postojna (http://sola.sgls.si/) and the Secondary School of Forestry Maribor (https://www.lsmb.si/). Higher vocational education in the direction of forestry and hunting is carried out by the Higher Vocational College Postojna (http://www.vspo.si/).

In addition to the listed organizations, which originate from the sphere of owners or are directing forest development, other bodies with influence on forest decisions are, for example, hunting clubs, the Hunting Association of Slovenia, non-governmental organizations, local communities, etc.

Figure 41: Slovenian Forestry Institute (Photo: R. Šipić)

Slovenian State Forest Company

Damjan Južnič (Slovenski državni gozdovi - SiDG)

The Republic of Slovenia established the Slovenian State Forests company (Slovenski državni gozdovi d.o.o. - SiDG) to manage state-owned forests on some 235 000 ha, based on the principles of sustainable, multifunctional and forestry compatible management in order to achieve the highest possible rate of return and quality of timber assortments.

The average growing stock of state forests is 321 m^3/ha. Coniferous and deciduous trees represent 48% and 52% of the growing stock, respectively. Prevailing tree species are beech (36%) and spruce (32%). Other tree species with a significant share are fir (11%) and oaks (4%). The remaining share includes noble deciduous species (6%), hard deciduous species (5%) and minority tree species (6%). The total growing stock of state forests is approximately 80.5 million m^3, while the annual increment is about 1.85 million m^3. The gross annual harvest is around 1.5 million m^3.

State forests cover almost 12% of the Slovenian territory, including 5 996 ha of forest reserves and 21 637 ha of protection forests. Commercial forests, primarily managed for timber harvesting, prevail. In recent years, in addition to natural disasters (windstorm, ice storm, snowstorm), the biggest threat to forests has been insects (particularly spruce bark beetle), which are also the most frequent reason for sanitary felling. On average, sanitary felling in state forests accounts for approximately 25% of the total cut, and in different years it ranges between 10 to 48%.

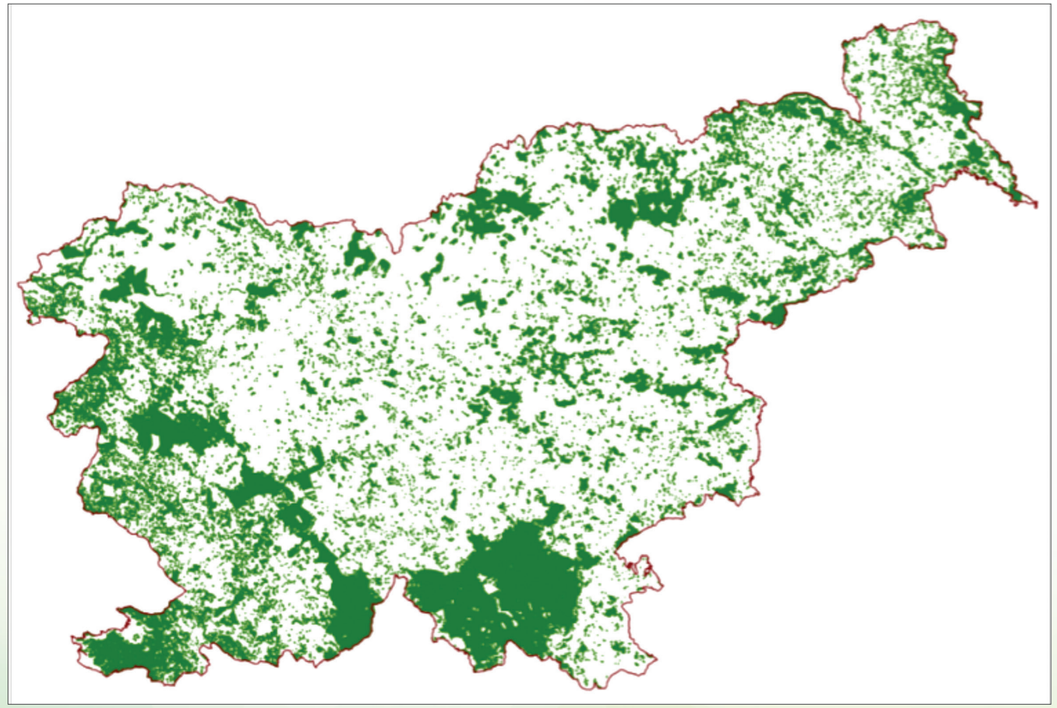

Figure 42: Forests managed by SiDG

The main activities pursued by SiDG are forestry, sale of forest wood products and logistics, management of real estate and acquisition of forests, wood processing and other activities for developing all other forest functions. Individual activities are described below in detail.

In 2018, and from all its activities, SiDG generated EUR 76.9 million of revenue, of which EUR 14.3 million was pre-tax earnings. A total of EUR 14.57 million was paid to the forest fund in 2018.

Most work (harvesting, silvicultural and forest protection work, work for other forest functions, construction and maintenance of forest infrastructure) in state forests is subcontracted through public tenders. Framework agreements currently apply for a period from one to two years. Only some of the harvesting and transport is currently carried out by SiDG's own capacities, while the rest is subcontracted through public calls for tenders. Calls for tenders have two stages; in the first, all qualified contractors (tenderers) with adequate capacities (signing a framework agreement) are selected. The second stage includes applying for calls for tenders for actual projects, for which the contractors then bid on. A certain call for tenders may also include several different work sites, i.e. lots.

Four framework agreements for subcontracting include harvesting, silvicultural and safety services (GVG), wood transport and forestry construction.
In 2018, a total of 5 000 public contracts or calls for tender were put out in the field of forestry.

In 2017, 1 141 205 m^3 of wood were cut in state forests with the average price of logging and skidding reaching 16.84 EUR/m^3. Damage due to wind in December 2017 and October 2018 caused larger quantities of trees than planned to be cut in 2018. The offered works exceeded demand which, in addition to the exceptional increase of risk at work, also had an impact on the price of logging and skidding. In 2018, 1 515 925 m^3 of wood was logged and skidded, of which the damage due to wind represented approximately 1.2 million m^3 (over 95% of spruce and fir). Salvage cutting due to wind damage continued and concluded in 2019. The average price of logging and skidding was 21.73 EUR/m^3. In 2018, the total costs of production (logging and skidding, silvicultural works, forestry infrastructure and transport) were 23.98 EUR/m^3.

In 2018, the 10 largest harvesting contractors cut 670 702 m^3 of wood, which was 42.2% of the total, and the average price of the respective services was 22.32 EUR/m^3. Other contractors cut 845 223 m3 of wood in total, i.e. 55.8%, and the average price of these contractors was 21.27 EUR/m^3.

Due to wind damage in 2018 there was a large share of coniferous trees in the assortment structure of forest wood products. Coniferous and deciduous trees accounted for 82.85% or 1 256 000 m^3 and 17.15% or 259 900 m^3, respectively. In 2017, coniferous and deciduous trees accounted for 61% and 39%, respectively.

The share of coniferous logs was 73.13% or 918 500 m^3, while other roundwood accounted for 26.87% or 377 500 m^3. Norway spruce logs represented 538 500 m^3, European silver fir logs 383 000 m^3, pine 10 000 m^3 and European larch 4 500 m^3 in coniferous tree species assortments.

The share of deciduous logs was 19.48 % or 50 600 m^3, while other roundwood accounted for 80.52 % or 209 300 m^3; beech logs (44 000 m^3) accounted for almost all deciduous roundwood in 2018. A notable share of logs was also detected for oak (3 700 m^3). Noble deciduous species, i.e. maple, ash, linden, elm, accounted for a small part. In 2018 the main buyers were sawmills, the wood-based panel industry, pulp and paper industry and other large and small wood processors. A total of 528 734 m^3 of forest wood products were sold to the 10 largest buyers, i.e. 36.42% of volume sold.

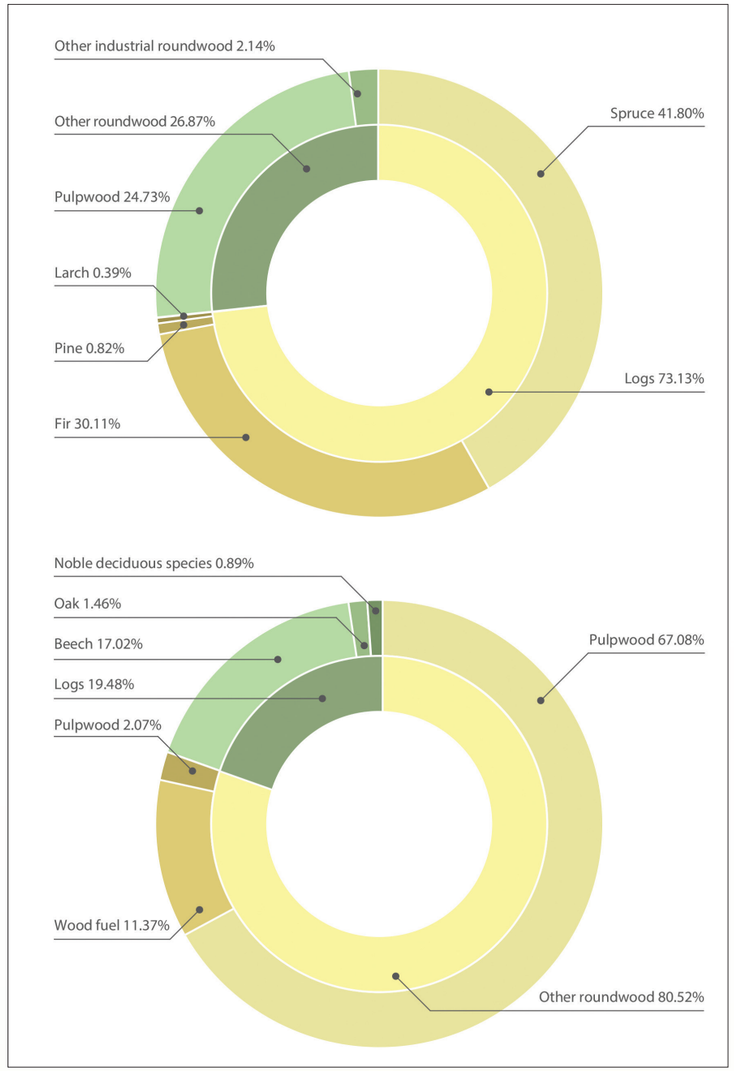

Figure 43: Assortment structure of conifers (up) and broadleaves (down) in 2018.

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Silva
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