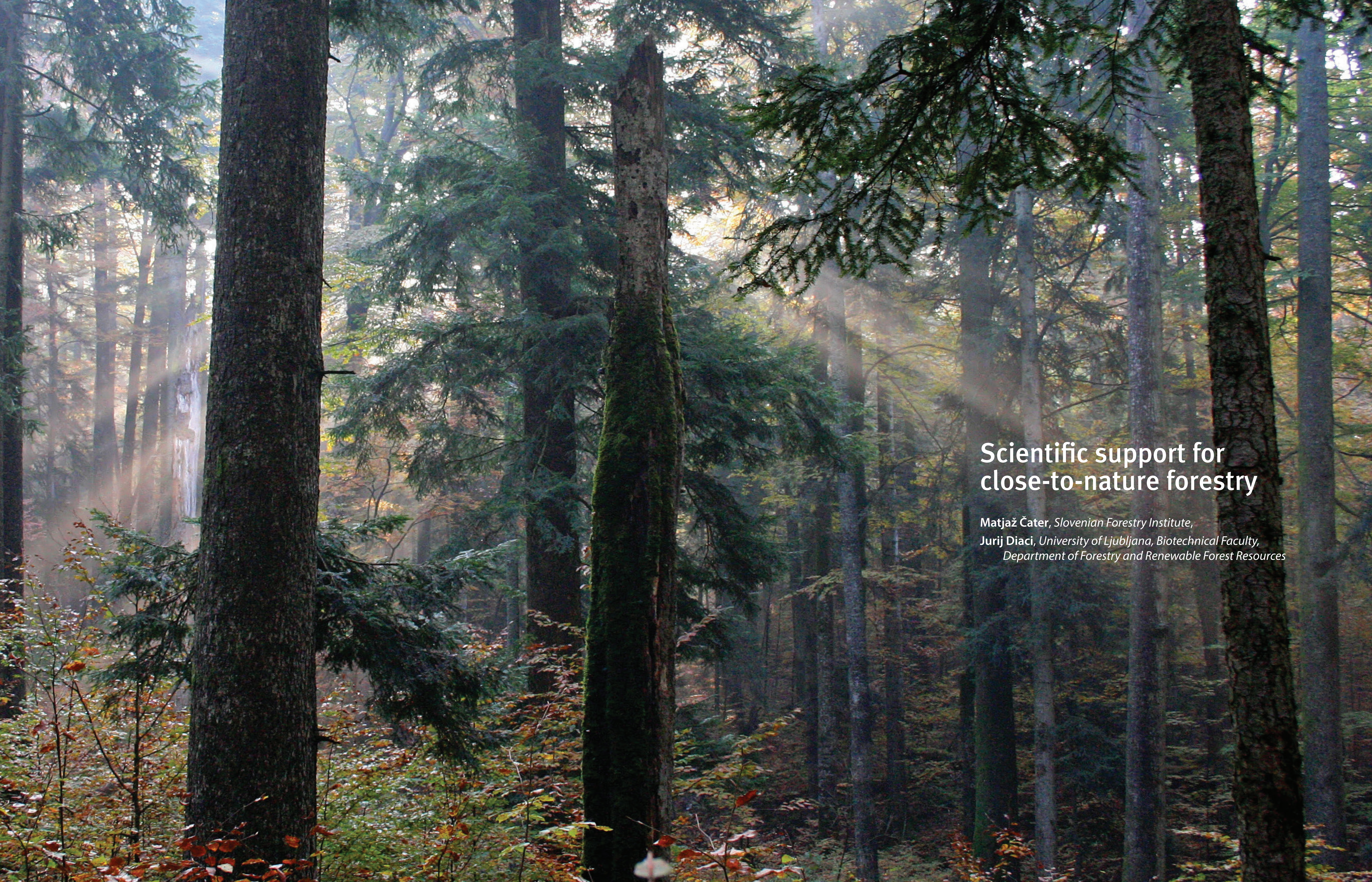

Scientific support for close-to-nature forestry

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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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