Ebrach – Learning from nature: Integrative forest management

C2

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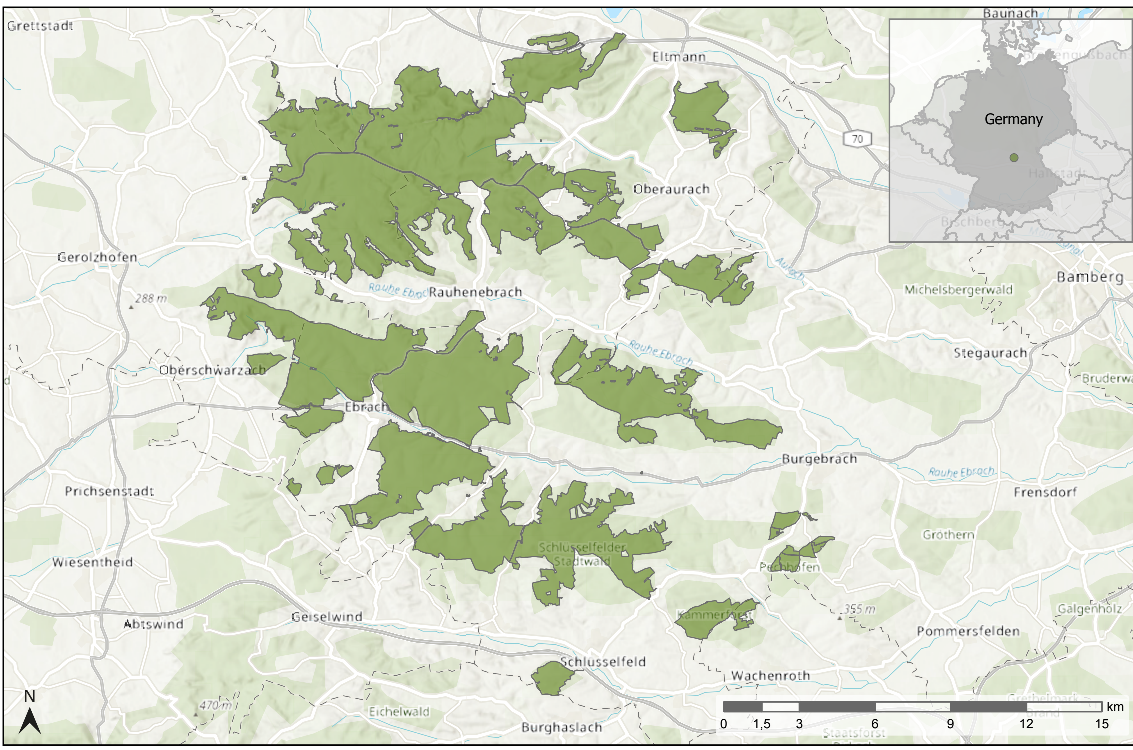
Since the reorganisation of the Bavarian forest administration in 2005, state forests have been managed by 41 regional state forest enterprises (Bayerische Staatsforsten, BaySF). The Ebrach State Forest Enterprise is made up of the state forests of the former forest districts Ebrach, Gerolzhofen, Eltmann, and Burgebrach. It manages an area of around 17 000 ha in the Steigerwald region, located in the Keuper uplands (formed in the mid-Triassic period) of Franconia between Würzburg and Nürnberg in north-western Bavaria. The State Forest Enterprise Ebrach is responsible for one of the most



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< Fig. C2.1. The Keuper uplands as part of the southern German Scarplands rise abruptly from the Franconian plateau and form the gently undulating landscape of the Steigerwald region with its extensive beech forests (Photo: Martin Hertel, Bayerische Staatsforsten AöR).

Statement

“Reconciling biodiversity conservation and timber production.”

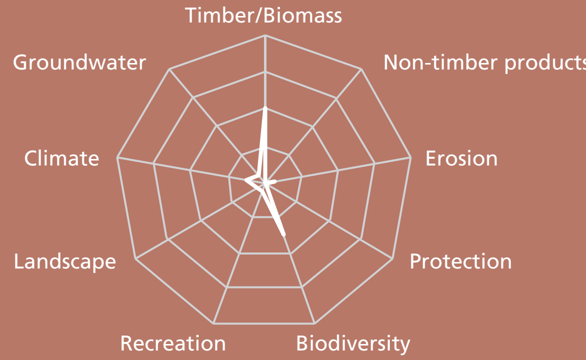

Table C2.1. General information on the forests of the State Forest Enterprise Ebrach.

Total forest area	16500 ha (1200 ha set-aside area; timber production on 15300 ha)
Main management types	Irregular group shelterwood, group and single-tree selection systems
Total volume	388 m³/ha (6400000 m³ in total)
Annual growth	10.6 m³/ha/a (168000 m³ in total)
Annual cutting rate	7.7m³/ha
Deadwood	23 m³/ha
Ownership	State forest
Climate	7.5 °C mean annual temperature, 850 mm mean annual precipitation
Geology	Mostly Keuper – gypsum and dolomite marls, clay and sandstones that were deposited during the Middle and Late Triassic epochs (about 220 million years ago)
Soils	Small scale mosaic of sandy, marly or clayey soils, mostly nutrient rich; 50 % of soils are largely impenetrable for fine roots, 75 % are sensitive to soil damage by forestry machines
Protected area	1200 ha set-aside area
Natura2000 area	SAC 11465.5 ha SPA 11528.2 ha

important beech *(Fagus sylvatica)* forests in Germany. The forests are composed of 75 % broadleaved species – beech ca. 44 %, oak (*Quercus* spp.) ca. 21 % – and 25 % coniferous species – Scots pine *(Pinus sylvestris)* being the main species ca. 13 % (fig. C2.2). The average growing stock is ca. 388 m³/ha with an annual growth rate of 168000 m³. The annual cutting rate amounts to approximately 120000 m³, of which 95000 m³ are sold as timber and 25000 m³ remain as lying deadwood in the forest. As can be seen from the difference between growth rate and cutting rate, it is planned to further increase the growing stock on the productive forest area. A system of permanent inventory plots (200 × 200 m) over the whole forest area provides accurate data as a basis for the 10-year forest management plans.

The overall management aim for the Ebrach state forests is to optimise the total value of all ecosystem services available rather than maximising a single service. Around 90 % of the broadleaved timber is marketed in the region to more than 25 sawmills, most of them family run businesses specialising in products from broadleaved species. Almost 20000 m³ of fuelwood sold to 2000 local commercial and private customers make Ebrach State Forest Enterprise one of the largest fuelwood producers in Germany. The enterprise provides employment for 60 forest employees and 12 local contractors and their staff. More than 600 springs and 241 ha of designated areas for drinking water production make the state forests a major provider of high-quality drinking water for the surrounding

Fig. C2.2. The richness of tree species is characteristic of the diverse Keuper soils. Past forest management practices have changed forest composition over the centuries from oak to beech dominated forests (Photo: Martin Hertel, Bayerische Staatsforsten AöR).

communities. Around 336 km of designated hiking trails are available for the many visitors who come to the Steigerwald region for recreation. Additionally, 10 trekking camp sites are available for exclusive outdoor experiences. Between 60 and 70 hunters have temporary hunting permits and more than 1000 hunters attend the 40 driven hunts every year. Both groups make essential contributions to meet the target of 1000 roe deer *(Capreolus capreolus)* that are killed annually based on a 3-year management plan. On average, seven roe deer are killed on every 100 ha per year. About 30 % of the game meat – including 200–300 wild boar *(Sus scrofa)* – is marketed directly by the forest enterprise.

With a special emphasis on saproxylic organisms, biodiversity conservation is central to the local integrative forest management concept (fig. C2.3). The centrepiece of this concept is a carefully selected and cross-linked system of set-aside and minimal impact forest areas linking dispersed habitats (Mergner 2018; MacArthur and Wilson 1967). The management concept is often called the Trittsteinkonzept ('stepping stone' concept).

Forest history and cultural heritage

The forests of the northern Steigerwald region were part of the Frankish crownland after the Franks' defeat of the Thuringians. They belonged first to the Merovingian dynasty, and later to the Carolingian dynasty. The administration of the entire region was in the hands of counts residing in the town of Volkach. At the beginning of the eleventh century the prince bishops of Würzburg were granted the count's rights over most of the eastern Frankish territories. In the year 1023 the hunting privilege for the Steigerwald forests was granted to Prince Bishop Meginhard I by Emperor Henry II, whereas the eastern part of the northern Steigerwald region came under the rule of the archbishops of Bamberg. Several ruins of castles and other buildings in the forest are evidence of this historic development (e.g. the ruins of Zabelstein Castle, Scherenburg Castle, and St. Gangolf's Church). This had a tremendous influence on the forest management practices of the time: the foresters of the prince bishops in Würzburg aimed at preserving the original character of the broadleaved forests whereas the foresters of the Bamberg realm were widely introducing Scots pine. From 1151 until secularisation in 1803, the forests directly around Ebrach belonged to the Cistercian monastery founded in 1127. Approximately 20 % of today's forested area was under agricultural use at that time. Several settlements were abandoned already in fourteenth century (so-called deserted sites) on the instruction from the Cistercian monks since timber production was more profitable than farming. During the seventeenth and eighteenth centuries the common silvicultural practice of 'coppice with standards' favoured tree species such as oaks *(Q. petraea)* and hornbeams *(Carpinus betulus).* In the second half of the seventeenth century, several glass kilns were established in the northern Steigerwald forests to make more efficient and direct use of the timber resources available. The crown and plate glass produced there was highly appreciated and was exported as far as Holland and England. The architect Balthasar Neumann used glass from Fabrikschleichach in the famous Würzburg Residence (a Baroque palace).

At the beginning of the nineteenth century, the forests of the Würzbug and Bamberg dioceses fell under the rule of the Kingdom of Bavaria. After that, the common practice of composition cutting (a special coppice with standards system dominated by oak and characterised by high growing stock) was converted to high forests dominated by broadleaves. The preconditions for beech dominance were created by new silvicultural practices where the canopy remained largely closed and also massive mast seeding occurred (e.g. in 1811, 1820, and 1822). As a consequence, from a misinterpretation of Karl Gayer's concept of mixed forests (1886), shelterwood cutting was introduced to establish mixed stands of beech, oak, hornbeam, Scots pine, Norway spruce *(Picea abies),* and larch *(Larix decidua)* from 1880 to 1913. After a ministerial assessment of the state of the forests in 1913 the introduction of group shelterwood cutting was ordered as the principal regeneration instrument

< Fig. C2.3. Approximately 500 saproxylic coleoptera species occur in the Steigerwald region, many of them indicators of near-natural forest conditions (e.g. *Triplax rufipes, Bolitophagus reticulatus, Mycetophagus quadripustulatus, Sinodendron cylindricum, Ampedus nigroflavus*) (Photos: Reinhard Weidlich).

with the aim to increase the share of conifers. This practice continued until the 1950s and caused oak regeneration to be disrupted. Beech as the main tree species decreased by almost 30 % of the original distribution in 1930. The amount of Norway spruce on the other hand, increased by more than 20 % in the newly established age classes. Fast growth in the early years after establishment resulted in generally low-quality timber. The hunting ideology during the Third Reich period (from 1933 to 1945) caused a sharp increase in the roe deer population that continued until the late twentieth century. As a consequence, natural regeneration dynamics ceased and forced clearcutting followed by re-planting with conifers became the common practice.

From the late 1940s until 1980, the annual cutting rate in the former forest district Ebrach was considerably higher than the Bavarian average of 6 to 6.5 m³/ha, e.g. from 1962 to 1971, approximately 9.5 m³/ha were harvested every year. The increased cutting rate was supposed to reduce the surplus stock of large and old beech stands that was stated in the forest management plan of 1962. A radical change of the silvicultural practices was introduced in 1973 by the district forest officer Dr. Georg Sperber: close-to-nature forestry, intensive reduction of the high roe deer populations, and fencing led to large-scale regeneration of broadleaved species. Intensive but careful treatment of the old beech stands is now represented in two-layered or irregularly structured stands. However, the planned increase of the growing stock was hampered by the windstorms Vivian and Wiebke in 1992. These storms resulted in approximately 150 000 m³ of downed timber. For this reason, the average growing stock of 330 m³/ha at the end of the twentieth century was comparatively low.

A special development characterises the forests around the village Fabrikschleichach. During WWII, the forests of the Steigerwald region had to deliver high amounts of timber to support the war economy. The annual cutting rate amounted to 15 m³/ha far exceeding sustainable levels. In contrast to his colleagues in the neighbouring forest districts, Moritz Pflaum, head of the former forest district Fabrikschleichach, did not accomplish this overcutting in the form of large-scale clearcuts but from intensive thinning and negative selection. This practice was more-or-less identical with the principles of modern elite tree concepts in broadleaved stands. As a consequence of early and intensive thinning, most trees have developed comparatively short trunks but large crowns; this reduces the risk of redheart (discolouration of the heartwood that reduces the value of the timber) in old beech trees considerably. The downside of this intensive management was the stark decrease of tree-related biodiversity. In contrast to the surrounding forests that did not experience such intensive management at that time, sensitive and little mobile fauna has disappeared, especially saproxylic insects.

Fig. C2.4. Historic maps from the eighteenth century illustrate the forest management practices of the Cistercian abbey of Ebrach with a strong focus on the production of large oaks (Source: Bavarian State Archive Würzburg).

Closer to nature: Aims and strategies

The main silvicultural aim in Ebrach is to preserve the beech-dominated character of the Steigerwald region and at the same time to maintain climate resilience of the forest ecosystems. Single-tree harvesting and natural regeneration are the basis to develop structurally diverse and uneven-aged forests. Securing and improving the habitat diversity for forest species, however, has led to rethinking the management principles of the close-to-nature silviculture that was the main strategy in Ebrach from 1973 (Bollmann 2011; Gossner *et al.* 2013). Thus, it becomes more and more important to manage the Ebrach forests as complex adaptive systems as suggested by Messier *et al.* (2013).

Aim 1: Preserving and maintaining the character of the beech-broadleaved forests of the Steigerwald

Strategy:
- No clearfelling
- Single-tree harvest
- Rejuvenation through natural regeneration of native tree species
- Introduction/enrichment of broadleaves and silver fir (planting/seeding) to pure conifer stands and pure beech regeneration
- Conservation of biodiversity by combining set-aside areas and minimal impact management (strict forest reserves, stepping stone habitats)
- Retention of deadwood and habitat trees

→ Work with nature, not against it!

Aim 2: Safeguarding public welfare

Strategy:
- Consequent adherence to the specifications laid out in Article 18 of the Bavarian Forest Law (BayWaldG): protective and recreative functions as well as biodiversity of the forest must be safeguarded and improved, interests of nature and landscape conservation as well as water protection must be considered in all forestry activities and measures, and special functions for public welfare must be provided
- Supporting research and education
- Acquiring funds to finance special functions for public welfare

→ Aim at highest overall benefit for society

Fig. C2.5. Remnants of old beech forests resulting from the changing silvicultural practices in the early nineteenth century can be seen in the strict forest reserve Kleinengelein. The trees reach up to 50 m in height and are around 240 years old. Regeneration of beech established around 1911 during the last shelterwood cut and form the present understorey. There are single relict trees from the previous coppice with standards practice with an age between 330 and 370 years (Photo: Daniel Kraus).

Aim 3: Economic efficiency
Strategy:
- Production and harvest of valuable timber within the framework of close-to-nature forestry
- Biological automation (e.g. reduction of tending effort)
- Consequent reduction of roe deer populations to reduce regeneration costs
- Avoiding timber products with low or negative profit margins
- Increase of income through non-timber forest products

→ Highest added value possible through minimal effort

Aim 4: Resilient and adaptive forest ecosystems in the context of climate change
Strategy:
- Vitality before timber quality
- Increase growing stock
- Increase water retention capacity of stands
- Maintain stable within-stand climate conditions
- Differentiate between forests that serve as sink and as storage
- Browsing reduction to support adaptation of natural regeneration to changing environmental conditions
- Favouring drought resistant tree species (native and to a lesser degree also non-native) (fig. C2.6)

→ Ecosystem services for future generations!

Fig. C2.6. A vision for climate-resilient future forests? Irregular mixed forests of beech *(Fagus sylvatica)* and oak *(Quercus petraea)* with groups of silver fir *(Abies alba)* and the wild service tree *(Sorbus torminalis)* in the northern Steigerwald region (Photos: Daniel Kraus).

Main products and other ecosystem services

The main aim of timber production is to harvest high-quality timber from broadleaves by selecting elite timber trees from a diameter between 20–30 m diameter at breast height (dbh). Competitors of the final elite trees are carefully selected for removal. Removal takes place early enough to enable the elite trees to maintain crown and stem diameter growth, and to reach target diameters rapidly. The final target diameters depend on the species and the final timber quality (table C2.2).

Table C2.2. Target diameters for different species.

	Good quality	Medium quality
Beech	70–80 cm dbh	50–70 cm dbh
Oak	80–100 cm dbh	60–80 cm dbh
Ash, maple, other broadleaves	70–90 cm dbh	50–70 cm dbh

Conifers reach the target diameter between 50–70 m dbh. However, for conifers, quality only plays a minor role (except for emergents of pine and larch with veneer quality from previous tree generations). Excellent quality timber of all tree species is usually marketed through auctions and submission sales (fig. C2.7). During the dimensioning phase mostly fuelwood and to a lesser degree industrial timber can be harvested.

Table C2.3. Typical timber assortments for beech.

High value sawnwood/veneer (A quality)	10 %
Regular sawnwood (B and C quality)	25 %
Industrial timber	5 %
Fuelwood	25 %
Deadwood	35 %

Besides the production of timber, there are several ecosystem services that are provided by designated forest areas (table C2.4).

Table C2.4. Overview of ecosystem services provided by designated forest areas.

Ecosystem Service	Area (ha)
Soil protection	3121.3
Water protection	5631.5
Recreation	4228.3
Climate protection	176.5
Drinking water production	241.2
Special habitat protection (forest)	170.1

Fig. C2.7. High-quality oaks are marketed mostly through submission sales. Veneer quality timber is sold at a price of 1000–3000 €/m³, timber for barrels at a price of 400–600 €/m³ mostly to French customers (Photo: Ulrich Mergner).

Economics

On average, around €6 million are generated by the forest enterprise per year of which 95 % (€5.7 million) come from timber sales. Income from hunting, especially from hunting permits and marketing of game meat, and other businesses contribute only 5 % to the total turnover. The annual costs amount to approximately €5 million of which 56 % (€2.8 million) are for own staff/personnel. On average, an annual profit of approximately €1 million is generated from forest management. Around 67 €/m³ is the average income from timber across all assortments (table C2.5).

Biodiversity concept

The management approach implemented in Ebrach can be described as an integrative approach which strives to ensure biodiversity conservation and timber production over the whole productive forest

Table C2.5. Breakdown of revenue and costs.

Turnover	€6.0 million		
		Timber sales	€5.7 million
		Hunting	€0.1 million
		Other	€0.2 million
Costs	€5.0 million		
		Personnel	€2.8 million
		Contractors	€1.8 million
		Material	€0.4 million
Profit	€1.0 million		

Fig. C2.8. A wide range of species from different groups are benefitting from the biodiversity concept (e.g. *Salamandra salamandra, Hericium coralloides, Rhagium mordax, Aegolius funereus*) (Photos: Daniel Kraus, Ellen Koller).

area (Mergner 2018; Kraus and Krumm 2013). Since most species dependent on old-growth elements and phases have become threatened, conservation of biodiversity in managed forest stands is mainly a question of retention of microhabitat structures (Larrieu *et al.* 2018; Kraus *et al.* 2016; Bauhus *et al.* 2009). To ensure diversity of forest dwelling species, structural diversity and the supply of living wood and deadwood as a resource is crucial (Lassauce *et al.* 2011; Jonsson *et al.* 2005).

A profound understanding of natural processes in forest ecosystems is seen as a prerequisite for implementing the Ebrach biodiversity concept. Altogether 1200 ha (representing 7 % of the productive timber area) are set-aside from forest management in the long term. These set-aside areas serve as the basis for safeguarding of biodiversity by securing survival and reproduction sites for sensitive and highly endangered species (fig. C2.8). In total, six strict reserves and more than 200 additional stepping stone habitats (smaller set-asides with longer habitat histories) are designated as donor areas for temporal colonisation of habitat structures such as habitat trees and deadwood in productive forests. Dispersal-limited and resource-limited species are thus able to spread and establish temporarily also in managed stands from these habitat patches, provided that they are evenly distributed over the entire forest area (Mergner 2018; Jonsson *et al.* 2005; Lassauce *et al.* 2011). Additionally, the strict forest reserves serve as learning sites on how relevant habitat structures develop over long growing cycles. Species assemblages found in these set-aside areas serve as qualitative target definitions of what should be reached on the overall forest area. The extensive research conducted in these living laboratories has produced the guidance for the management principles of the entire forest area.

Another important element of the enterprise's approach is minimal impact of management. This is mainly realised in old stands, or in younger stands with a high number of remnant old trees. This leads to a systematic build-up of habitat trees and deadwood. Currently, minimal impact of forest management activities affects 6400 ha. Positive selection of

Fig. C2.9. Approximately 160 m³/ha of deadwood can be found in the strict forest reserve Waldhaus (Photo: Daniel Kraus).

habitat trees already takes place in thinning phases to ensure that there are sufficient individuals with microhabitat potential in later stages. The selection of elite trees is set to be at 40/ha at most (in beech forest) to leave space for habitat trees to develop. In the case of admixtures with different harvest spans, even more elite trees per ha may be selected. The habitat trees are permanently marked (with a green wavy line) to ensure that these trees are retained. In total, the aim is to retain 155 000 habitat trees (10 trees/ha) in the productive forest area.

Large amounts of wood that is left to decay naturally are seen as crucial in Ebrach for biodiversity and nutrient sustainability (Stokland *et al.* 2012; Müller and Bütler 2010) (fig. C2.9). In later thinning phases and harvest, the Ebrach concept requires trees to be felled away from skidding tracks so that tree crowns remain in the stand. As a rule, the trunk is cut at the first strong branch and only the most valuable section of the stem is removed (fig. C2.10). This helps to reach the aim of increasing the amount of deadwood to 20 m^3/ha in forests older than 100 years and 40 m^3/ha in forests older than 140 years.

The deadwood concept is not only important for the conservation of forest dwelling species. The latest scientific evidence suggests that retention of wood in the forest is crucial to ensure sustainable nutrient cycling – mainly cations like potassium, calcium, phosphorus, and magnesium are stored in wood and may serve as long-term sources of these nutrients since they are released continuously by large decaying, logs, and are thus made available for plant growth. Additionally, deadwood stores large quantities of water while decaying, or in the form of humus later on. In the light of a changing climate and forecasted prolonged drought periods, this important attribute of deadwood may also be seen as a measure to secure the future of our forests. Furthermore, deadwood probably plays a much more vital role in the composition of forest floors and their functioning as carbon sinks through microbial activity, mostly fungi and bacteria, which is another important reason why it should remain in the forest.

Fig. C2.10. After the tree is felled the trunk is cut at the first strong branch and only the more valuable section is removed. The whole crown remains in the forest to increase large dimensioned deadwood (Photo: Ulrich Mergner).

Table C2.6. Costs of integrative management in Ebrach State Forest Enterprise.

Loss from timber production	Area [ha]	Volume [m³]	Value [€]
6 strict reserves	430	2500	125000
200 Set-asides	760	4500	225000
10 habitat trees/ha (a 50 m²)	780	4600	230000
	1970	11600	580000
Losses from foregone timber revenue		25000	500000
Total loss	1970	36600	1080000

Integrative management: at what cost?

The cost of integrative management can be determined from reduced revenue and additional expenditures. Currently there are 1200 ha set-aside areas and approximately 750 ha additionally that are not available for timber production because they are the location of habitat trees. This amounts to ca. 16500 m³ of timber annually that is not harvested and marketed. When assuming an average timber price of 50 €/m³ for the set-aside areas almost €600000 are foregone annually. Additionally, 25,000 m³ of deadwood from timber harvesting (at an average price of 20 €/m³) amounts to another €500000. Altogether, the cost from reduced revenues is about €1.1 million per year.

On the other hand, the deadwood enrichment strategy by only harvesting sawnwood (and to a minor degree industrial timber) and leaving the complete tree crowns on site seems economically efficient. The total profit from complete processing (sawnwood + industrial timber/fuelwood) is higher, but per m³ it is more profitable to focus on sawnwood only. The average performance of a chainsaw operator in old beech stands is ca. 3.0 m³/hr when processing only sawnwood from the stems. The performance decreases to ca. 2.6 m³/hr with harvesting intensity since the time to produce one cubic metre of timber increases from 20 min/m³ to almost 23 min/m³ when processing the complete tree crown. Thus, it becomes evident that the added value is higher when a more valuable product can be harvested in a shorter time because the working time needed to harvest a certain amount of timber can be reduced; this time could be used for other tasks.

A recent study conducted in Ebrach showed that the Total Economic Value (TEV) provided by all ecosystem services far exceeds the income from timber (Stößel 2020; see Box C1).

Conclusion

Ebrach State Forest Enterprise can serve as a good practice example for integrative forest management where biodiversity conservation, timber production, and many other ecosystem services are managed in an optimised way. From a conservation perspective, it is far more important to focus on strategic planning of conservation instruments rather than on the total protected area. Therefore, habitat requirements and thresholds of target species as representatives of the typical forest community must be considered for the development and cross-linking of conservation instruments. In this context, the current status of the applied silvicultural system should be taken into account since a diversity of silvicultural systems and strategies across the landscape is needed to increase diversity in structures, functions, and biota, and consequently also support a broad range of other ecosystem services.

Hence, the current challenge in Ebrach is to identify the thresholds at which productive functions can be maintained and, at the same time, biodiversity can be protected. To be efficiently assessed, the biodiversity-friendly forest management in Ebrach is constantly surveyed within research programmes (Schauer *et al.* 2018; Zytynska *et al.* 2018; Doerfler *et al.* 2017). Especially species groups which are linked to old-growth structures, deadwood and natural disturbances serve as excellent indicators of the conservation success of the Ebrach integrative management approach.

Considering the new scenarios of increasing pressure on wood resources in Europe because of increasing wood demand, it is crucial to ensure that quality and efficiency of biodiversity conservation in forest management is not diluted by new management goals. The Ebrach biodiversity concept strives to reconcile timber production and biodiversity conservation in an optimal way.

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