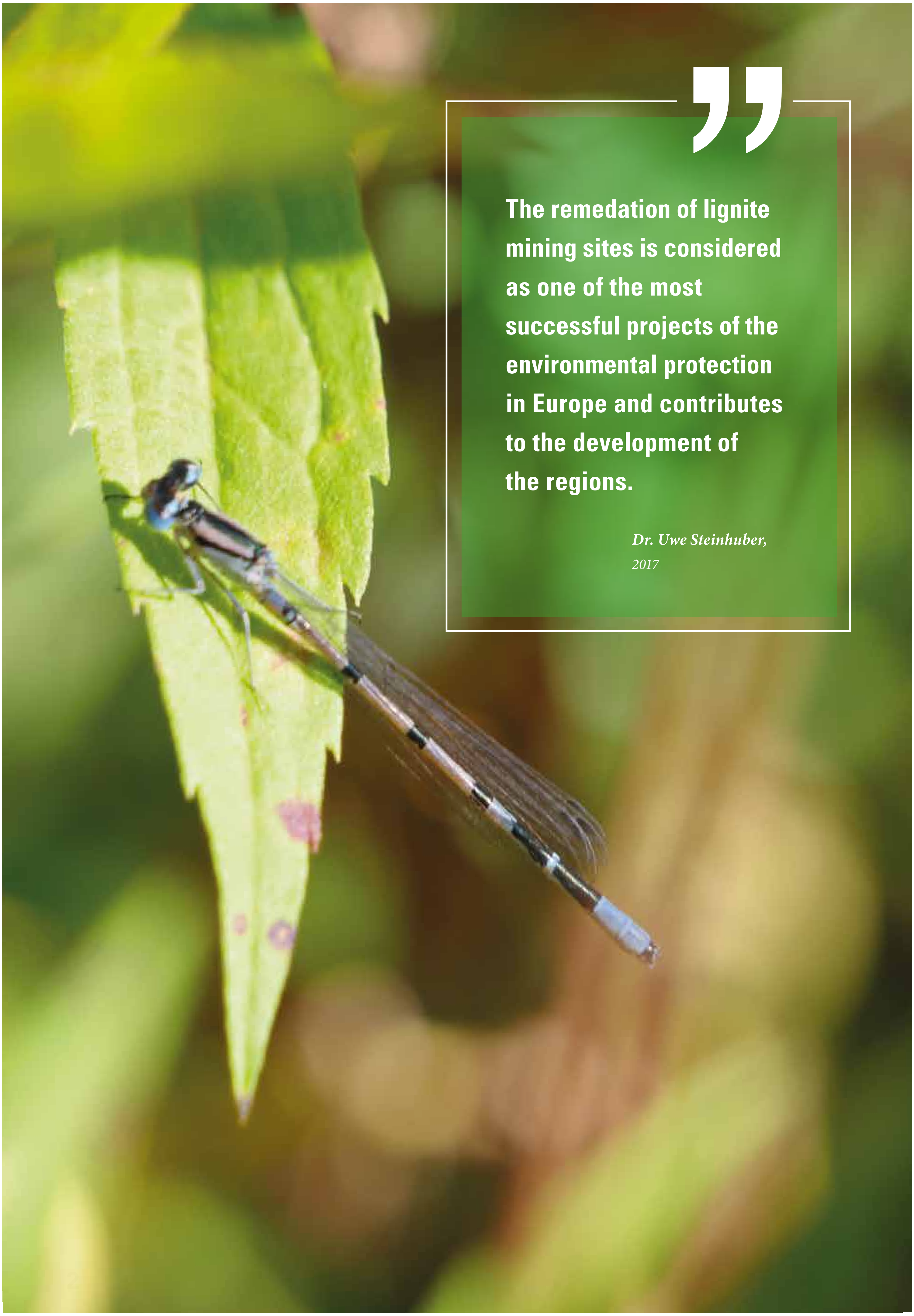
Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft mbH

PREPARING THE GROUND FOR THE FUTURE

Mine Recultivation



> **The remedation of lignite mining sites is considered as one of the most successful projects of the environmental protection in Europe and contributes to the development of the regions.**
>
> *Dr. Uwe Steinhuber, 2017*

CONTENT

Making Landscapes **Usable Again**

Landscapes are created and transformed by human activity and the influence of natural forces. Resource extraction constantly changes a landscape and its features. While existing features are destroyed in the excavation area, new features are then created, post excavation.

Furthermore, the extraction of resources not only changes the actual mining area, it also transforms surrounding areas. For example, a farming village becomes a location peripheral to an open-cast mine, then eventually an attractive tourist destination with a harbor and a wide range of leisure activities. These developments also impact the use of existing fields and meadows as sites for buildings, sports facilities, horse pastures and so on. Open-cast lignite mines are temporary, unique and massive interventions, resulting in landscapes that are detached from their historical background, which can offer new directions for development. Open-cast lignite mining not only changes the landscape, it also changes history.

Mine recultivation is therefore an instrument for counteracting the earlier incursion into nature. The process is only completed once no significant or subsequent impairments of the natural ecosystem remain, and the landscape has been restored or redesigned in a manner appropriate to that landscape. In addition to the "Bundesberggesetz" (Federal Mining Act) and its associated ordinances, the legal basis for the rehabilitation of areas formerly impacted by lignite mining is the rehabilitation plans initiated by the states of Brandenburg, Saxony, Saxony-Anhalt and Thuringia. This regional planning, which was declared binding in cabinet resolutions of the respective state parliaments, was jointly developed by municipalities, districts authorities, associations and LMBV, as the agency responsible for the rehabilitation. These rehabilitation plans define the objectives for the respective post-mining landscapes, the essential works to be done and future uses, and their proportions – such as agricultural versus forest or water areas, areas for nature conservation or for the development of tourism.

Legal Basis for Recultivation

A school class is searching for insects on the post-mining area.

In its closure of operations plans, based on the Federal Mining Act, LMBV describes the necessary work procedures, equipment, time frames, as well as any necessary expert assessments and legal requirements.

These have been approved by the mining authorities. It is not a conclusive description of the necessary work to be done, but rather an open process in which new findings or incidents can be incorporated and lead to changes and adjustments to the submitted plan. European and German federal environmental law provide the scope of action for proper rehabilitation that is done in the public's interest.

In addition, state-specified guidelines, rules and programs, in which soil qualities, forestry objectives or agricultural management principles are defined, are important for the practical implementation of recultivation. LMBV aims to carry out these standards in all of its operations.

Conveyor-bridge F60 in active mining site Nochten of LEAG

Recultivation:

The Great Challenge

The challenge for everyone involved is to identify long-term sustainable development goals, and to align terrestrial recultivation objectives with them.

This is an ongoing process. Consequently, plans can be adapted to new findings. So far, an area of 178,819 hectares has been cultivated in Germany (DEBRIV 2018), of which approximately 106,800 hectares fall under the responsibility of LMBV.

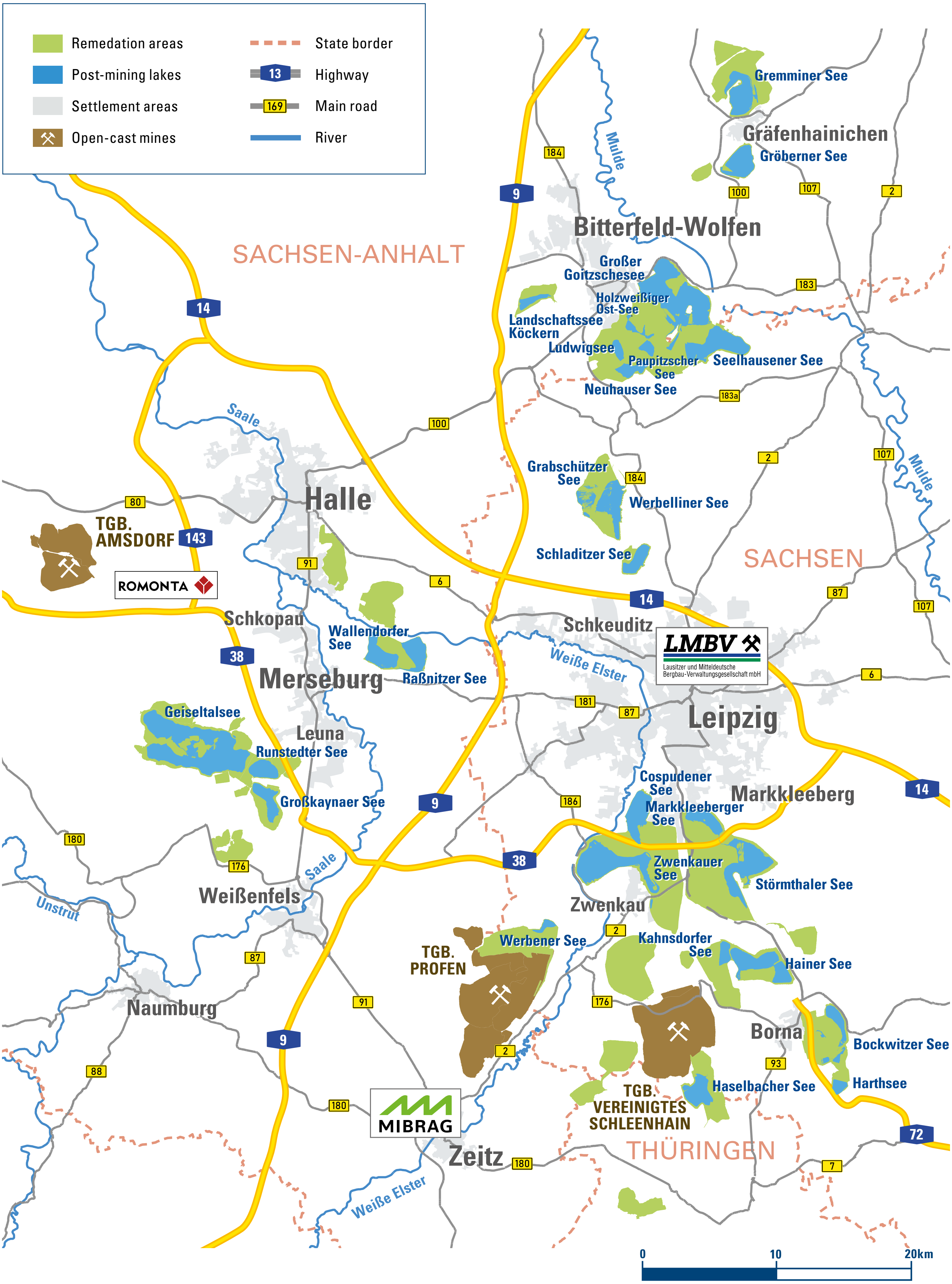
The deficit of successful recultivation at the beginning of rehabilitation in early 1991 was around 54,500 hectares. The recultivation level of LMBV is now at 88 percent. Around 12 percent of terrestrial areas still need to be redeveloped, predominantly into forests or nature conservation priority areas. The water balance has already been restored to over 80 percent. The flooding of 120 residual mining pits is creating new lakes on 28,568 hectares, with a wide range of possibilities for subsequent use, as well as new habitats that were not available prior to mining. In implementing its recultivation work, LMBV works with numerous scientific institutions and partners of industry.

One could say that the restoration of the East German open-cast mining landscape is the largest “landscape construction site” in Europe!

Neuhausen Lake (front), Paupitzsch Lake (center), Great Goitzsche Lake (back)

The remediation of former potash, spar and ore dumps, as in Bischofferode, is also part of LMBV´s work.

Central German Region




Remedation areas
Post-mining lakes
Settlement areas
Open-cast mines
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Bad Liebenwerda
Grünewalder Lauch
Lauchhammer
Senftenberg
LMBV
Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft mbH
Schipkau
Südteich
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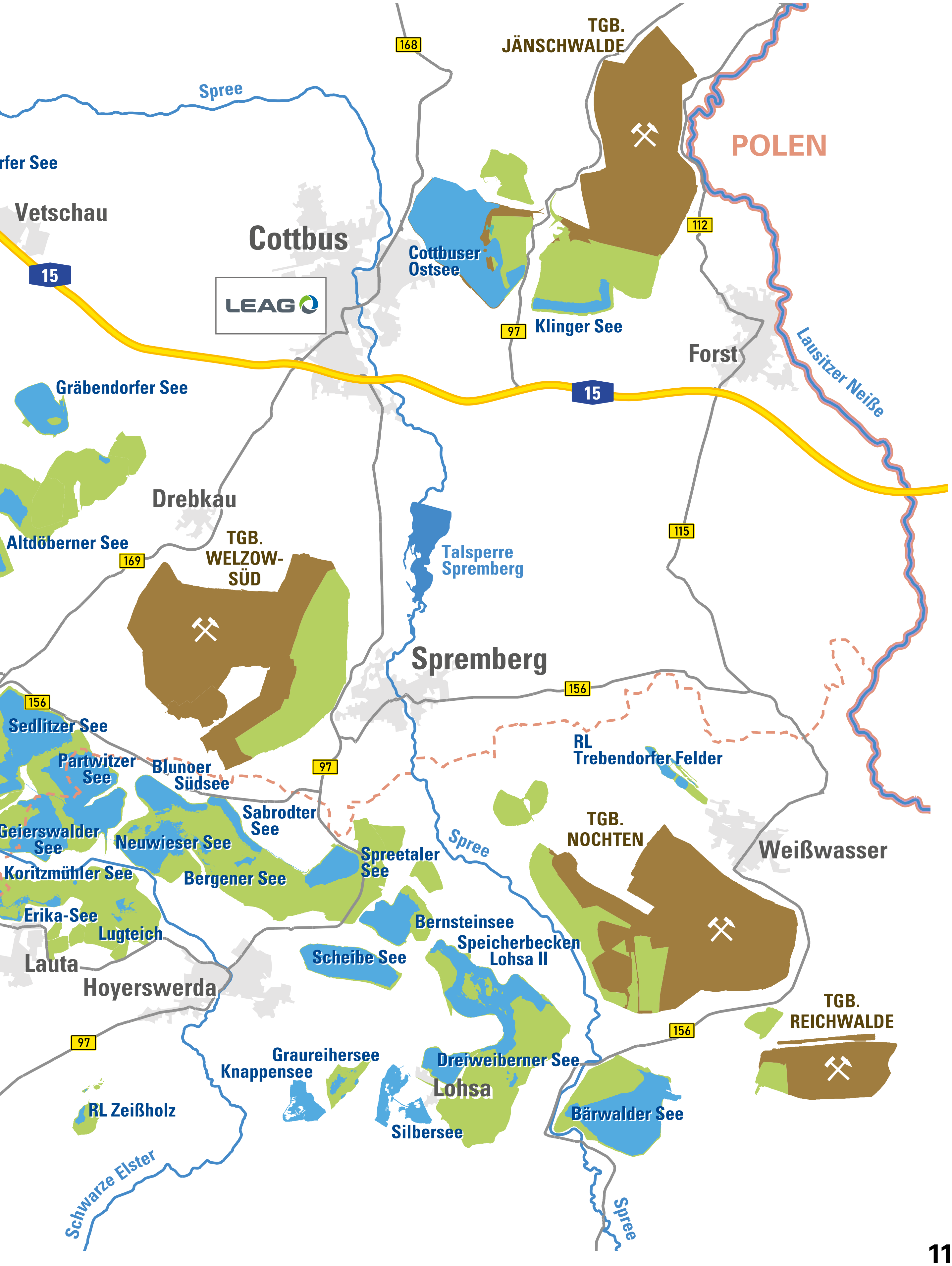
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Silbersee
Schwarze Elster
Spree

Soil – A Precious Habitat

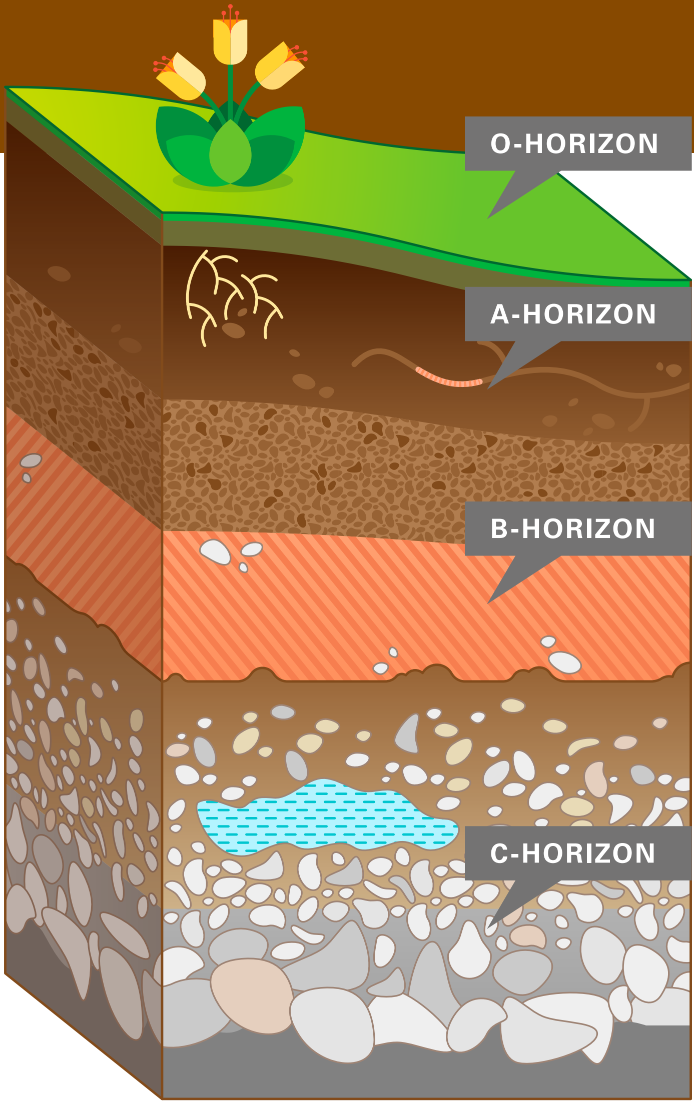
The extraction of lignite with large machinery (conveyor bridges, bucket chain and bucket wheel excavators) in open-cast mines destroys the natural soil.

The technology of soil dumping practiced in the past, usually without the separate extraction and storage of topsoil, led to a mixing of the different geological layers. Substrates that had been stored deep underground for millions of years reached the surface. Their properties nevertheless determine the direction and speed of soil development, as well as the yield potential of the dumping area. In the Lusatian and Central German lignite mining regions, the uppermost soil layer, enriched with humus, consists mainly of Quaternary substrates. These are composed of meltwater / valley water sands as well as glacial (Pleistocene) bedrock sands. This is followed by mighty Tertiary-basin sediments of carboniferous / sulfur-containing sands, silts and clays. Lusatian open-cast mining

Gentle soil application on site Schwarze Keute near Klettwitz, 2017

stockpiles and dumps consist, up to 90 percent, of sands and clay-sands, while in the Central German mining region, large areas are comprised of high-quality Pleistocene substrates, sand-loess and loess, as well as loess-loam, alluvial-loam and alluvial silt. They are used for the creation of agricultural areas.

In the Lusatian mining region, the Tertiary substrates and substrates of mixed Tertiary and Quaternary origin, which form the uppermost layer on about 60 percent of dumping areas, have significantly poorer properties. One particular feature is the power plant ash that has been dumped or washed out in the vicinity of power plants, on approximately 1,100 hectares. Quaternary sandy soils, such as those found in Lusatia, possess good aeration and water conductivity due to their high volume of coarse pores. However, they drain quickly and bind nutrients poorly. Their pH values are neutral to slightly acidic. The Quaternary cohesive substrates of Central Germany are cha-



racterized by high mineral and nutrient reserves, favorable pH values and a high water storage capacity. Tertiary dumped substrates, in contrast, contain coal components as well as iron disulfides (pyrite, marcasite), which lead to extreme acidification (pH value < 2,5) and a high salt concentration in the ground water upon exposure to air and water. Soils affected by open-cast mining are characterized by a lack of humus and nutrients, a lack of or low biological activity and often a lack of water storage capacity. This results in an extremely unfavorable starting position for the growth of the new landscape.

ESTABLISHING SOIL FERTILITY

The sustainable restoration of soil fertility and the role of soil as a living environment and production site are the primary goals of recultivation. The path-way from dumped substrate to fully functioning soil is a long one. In this context, recultivation is about taking the first steps and determining the direction of that pathway. Appropriate management and undisturbed soil development must follow. Good soils will then be created, even when starting with difficult substrates. Geological soil mapping is the first step on this path. On behalf of LMBV, specialized experts investigate and evaluate the dumped substrates in each area, and specify the work that will be needed.

Depending on the intended function for the area, whether as agricultural land, forest or for special nature conservation purposes, these processes may vary. Professionals at LMBV request tenders for the services that are needed, which are then implemented by specialist companies. As a rule, the following services may be provided: compacted soil is loosened to a depth of 100 centimeters with ground chisels or penetration loosening systems. Depending on the substrate, the age of the dumping site and its previous use, both cohesive substrates and sandy mixed substrates can have very high compactness. That leads to a deterioration of the physical properties of the soil. Soil improvement, with long-acting natural lime, is the next step. The lime, differentiated according to expert assessments, is worked into the soil to depth of 100 centimeters, in several stages.

To perform this task, heavy-duty spade tillers are pulled by powerful tractors. From 4 to over 600 tons of finely ground lime marl are required per hectare. Basic fertilization, with the essential nutrients of nitrogen, phosphorus and potassium, is usually applied in two doses. The first dose is

Lime incorporation by means of a deep spade rotary hoe

worked into surface of the soil by disc harrows. The second dose is applied later, when the first plant cover can absorb and process the nutrients. By subsequently greening the area with selected grasses, clover, lupine or alfalfa, the ground is covered, initiating humus formation and binding the introduced nutrients to the plants. Greening also prevents dust immissions to surrounding towns and villages. The geological quality verification of the soil determines the success of soil improvement measures, after six months at the earliest. If targets have not yet been reached, additional work takes place accordingly. LMBV has developed obligatory working instructions for both initial appraisals and follow-up quality verifications, in cooperation with scientific institutions, consultants, mining authorities and active mining companies.

SOIL FUNCTIONS (BIOLOGICAL)

Living Space Function

- Living space for plants, animals, organism and humans

Regulation and Buffering Function

- Regulation water and matter cycles
- Buffering
- Filtering and storage

Production Function

- Life base
- Potential for biomass production (food, animal feed, renewable energy)

Agricultural Recultivation – Synergies Between Humans and Nature

Sunflowers on a recultivated mine-site

Agriculture is largely deprived of its base of production when the land is used for mining. The restoration of such areas is therefore part of the mining process.

Land to be used as a competitive agricultural production site places particularly high demands on the soil substrate and the entire recultivation process. Only the most valuable soil substrates can be utilized. Glacial till, dump sands and loam sands, as well as silt and loam, are particularly suitable as final layers. In order to ensure deep soil fertility in the medium term, at least one meter of coverage is necessary. Since these soil substrates usually have good pH values, soil improvement with lime is rarely required. However, the tendency for damaged soil compaction is greatly increased. A decisive contribution to the success of recultivation is made by the application of soil via large open-cast mining machines (so-called spreaders) with a low height of fall, leveling and surface preparation utilizing as few transits as possible, and long-term soil-conservation treatment during the recultivation phase.

The aim is to achieve a compaction of between 1.5 to 1.6 grams per cubic centimeter and a coarse pore volume of at least 8 percent. The location, size, shape and terrain of the area are further decisive aspects for the agricultural use of a dumping site. A slightly wavy surface with an inclination of at least 0.5 to a maximum of 7 percent ensures the drainage of surface water without the risk of erosion into the receiving waters, and meets the requirements for the machine processing of dumped surfaces. Strips of wood are integrated between the 20 to 30 hectare large fields and meadows, to reduce wind erosion and evaporation, as well as for the development of yield capacity and biotope networks with the surrounding open-cast mining areas.

The accumulation of humus, the formation of soil structure, the development of soil life and necessary nutrient cycles are processes that take many years. The alternating cultivation of certain grasses (rye grass, winter grains) and legumes such as alfalfa and lupine have proven to be effective on young soils. Such recultivation crop rotations take between seven and fifteen years, depending on the location. The subsequent cultivation of field crops, oil crops and maize allows for harvesting and further develops the soil. Well-recultivated agricultural areas are at least equivalent to those of the surrounding landscape.

However, they only reach their full yield potential after two to three decades. Since Lusatia already has inherently poorer soils compared to the Central German lignite mining region, there is a deficit of approx. 8,000 hectares between rehabilitation and the utilization of agricultural land. In Central Germany, the ratio is roughly balanced. New developments in the field of raw materials production for energy recovery, i.e. as surfaces for wind turbines and solar modules, have increased the need for economically viable open spaces.

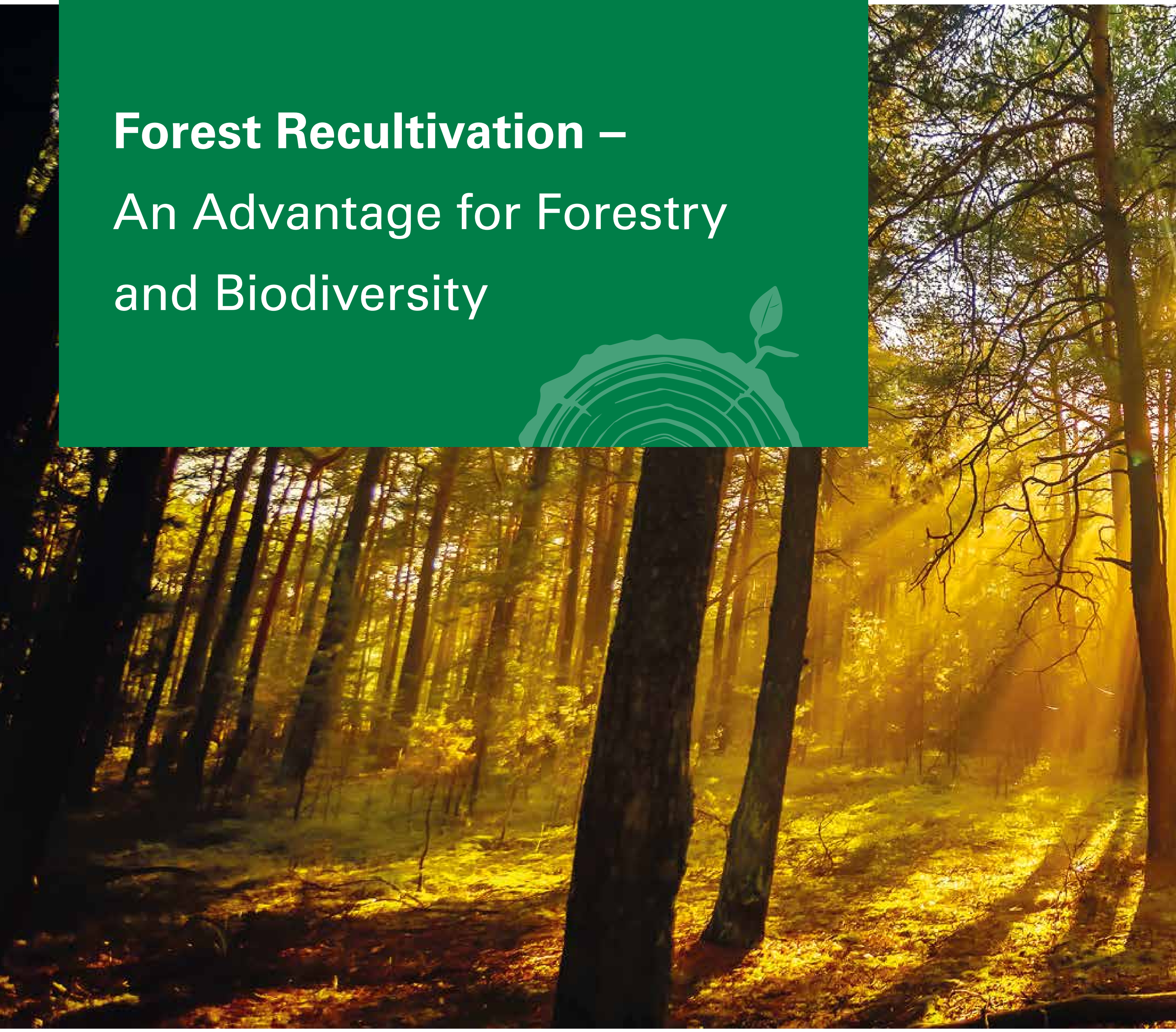
While the above applies, in principle, to the cultivation of raw materials, in other cases the land is only required as a support surface and not for its production potential. Therefore, poorer agricultural locations can also be used for these purposes.

Top: Aurochs on a recultivated agricultural area near Leipzig

Middle: Vineyard on the IBA Terraces, former Meuro opencast mine

Bottom: Aerial photograph of a rape field

Forest Recultivation – An Advantage for Forestry and Biodiversity



In East German lignite mining regions, forest recultivation plays a key role in post-mining landscape development.

Especially due to their ecological balancing function and their influence on groundwater quality, the dumping site forests that are currently being established make a significant contribution to the revitalization of the natural and cultural environment that has been severely disturbed by the extraction of raw materials. Forest cover in the predominantly agricultural Central German region accounts for about 40 percent of the recultivation area. In less densely populated and less industrialized Lusatia, forest rehabilitation encompasses around 30,000 hectares. That amounts to 60 percent of the reclaimed area.

REFORESTATION TODAY

At lignite mine dumping sites, especially in the open-cast mines or mining areas that were closed down in 1999, initial reforestation is considered to be difficult, due to the very low availability of

Afforested wood on a former Lusatian mining dumpsite

nutrients (nitrogen, phosphorous, potassium), extensive biological inactivity and the lack of available organic matter in the raw soils. Ecosystem processes, such as nutrient cycling, can only be established very slowly.

The development of young crop plants is initially inhibited. Due to strong acidification and intense silicate weathering, the sulfur-containing Tertiary substrates, predominant in the Lusatian mining region, are extremely hostile to vegetation and are at risk of erosion. The mixing of Quaternary and Tertiary layers of varying texture and chemistry often leads to a small-scale substrate heterogeneity, which further complicates the reforestation process.

REFORESTATION PLANNING

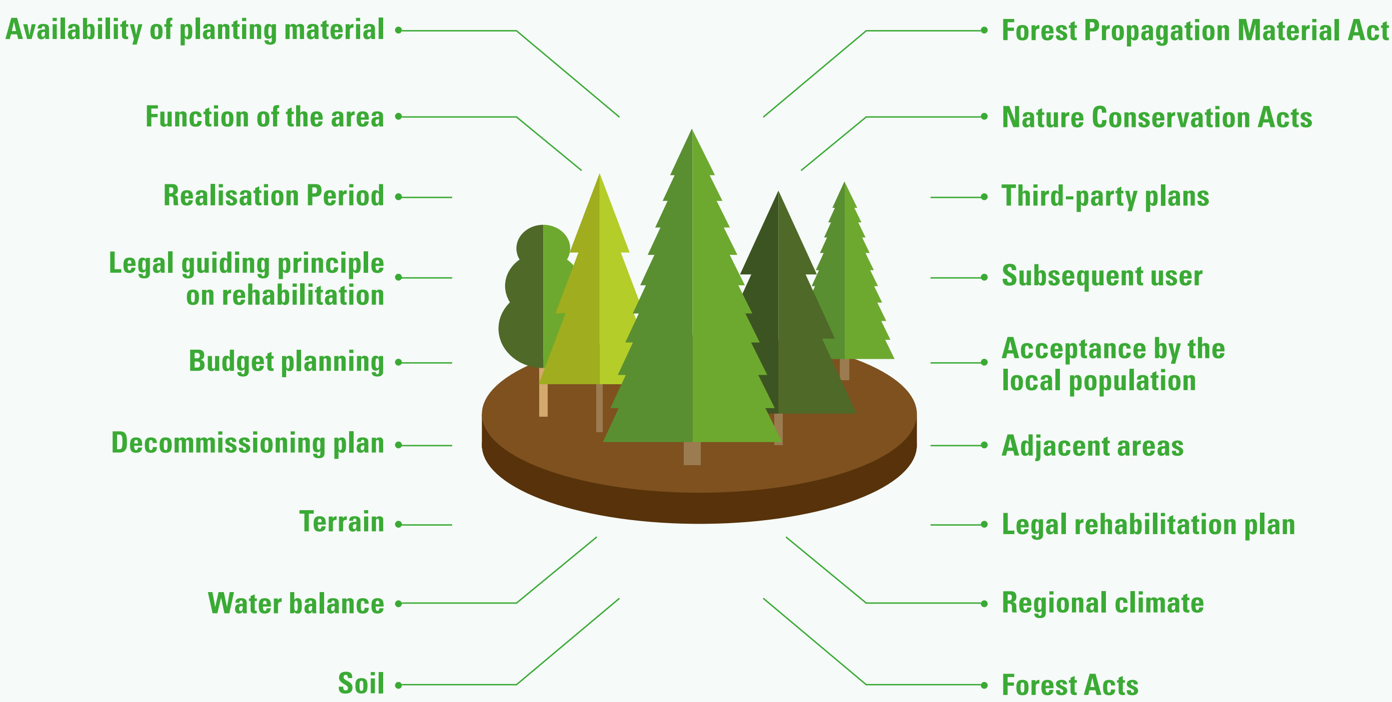
The categories of land usage defined by the rehabilitation plan form the basis for future surface-level design and landscape development, i.e. the distribution of subsequent primary uses as agriculture, forests, restoration areas, bodies of water, roads and paths, as well as commercial uses and other forms of development. These are linked to usage-related targets such as, for example, soil quality for agricultural areas or root permeability of substrate horizons for future forest areas. Forestry recultivation ensures that future forested areas will enable the long-term sustainable development of soil fertility, fulfill their protective and recreational functions, and be utilized economically.

Tree species are selected based on the location, with a high proportion of hardwood and great ecological diversity. Native tree species should be preferred and pure forest groves should be avoided, depending on the local conditions. If necessary, existing mono-structured forest complexes are to be broken up by appropriate modification measures. Additionally, forest edges should be deliberately designed and their structure should meet requirements for fire protection and for their biotope network.

The following diagram illustrates the essential site-related, operational and legal factors that influence forestry decision-making. Plans for planting are drawn up for the planned areas, and these are coordinated with the responsible forest authorities.

LMBV generally awards recultivation services to specialist companies by public tender. All activities in connection with reforestation (procurement, delivery of planting materials, felling), working methods (planting procedures) and the equipment to be used are defined, in terms of

DECISION CRITERIA FOR AFFORESTATION



Large tree planting at channel 12

Pine seedling

measures and deadlines, in the recultivation service contracts. Specifications are made for the quality of the plants or seeds (assortment, plant age, origin) and crop protection. These prepared planting plans form a central component of the recultivation contracts. Today, after more than 100 existing indicator sites in the Central German and Lusatian regions, a practicable scheme has been derived for the selection of location-appropriate tree species that ecologically support their dumping site soil classification. From an ecological point of view, and in order to minimize the operational risk, mixed groves are generally aimed for. In this process, the flexibility of forest design increases as trophic levels and water storage capacities improve.

Planting

The planting of forest groves plays the greatest role in recultivation. Due to the difficult substrate conditions, possible soil improvement deficiencies and the evaporation-intensive open-space climate, population losses during the growth phase amount to about 10 to 40 percent of the initial plant numbers. In addition, crops experience an initial growth depression ("transplant shock"), especially for semi-shade and shade tree species. A relevant height increase is not detectable until the third or even fourth year of standing. Crown height development lags behind that of comparable reforestation populations in the land surrounding the former mine. Compared to mature forest sites, similar cultivation and production goals require up to 25 percent higher planting rates. Based on proven recultivation practices, planting distances of 2.0/1.8 x 1.0 meters to 1.5 x 0.7 meters (or 2.0/1.8 x 0.5/0.6 meters) are selected. As a rule, commercially available plant assortments (age 1+0, 2+0, or 20/40 and 30/50 height in cm) from approved and selected (or tested) propagation material from the regional area of origin are used.

Planting in autumn (November/December) has proven more advantageous for hardwood trees than in spring, due to the risk of late frost and frequent spring drought on exposed post-mining areas. Planting is usually done by machines. Planting by hand, which is considerably more cost-intensive, is carried out on difficult-to-access dumping sites such as steep slopes, riparian zones and for small-scale special measures (wind, erosion protection, forest edge planting). When mixed

Afforestation on Neuberzdorf Height, former opencast mine Berzdorf 2008

tree species are introduced, the quantities for that area must be adapted to the mixture ratios. The mix of primary and secondary tree species is based on the potential canopy cover of mature trees and is therefore carried out in groups of various sizes. For reasons of work organization and the control of results, a row-by-row mixture is often preferred in recultivation practice. Red alder or poplar, fast-growing tree species, are often introduced in broad groups of 4 x 4 or 6 x 6 meters as a substitute canopy, especially in stands of oak, for a limited time. Their easily degradable leaf litter accelerates soil development.

In addition, the alder's atmospheric nitrogen-binding favors forest growth. At medium to rich locations, in particular, the co-cultivation of red alder leads to a stronger structuring and self-differentiation of tree stands. Any potential natural seeding of birch, willow and pine may also be desirable for the developing forest canopy.

Sowing

For the establishment of pioneer pine and birch forests, artificially establishing tree stands by sowing is more suitable. This applies in particular to difficult-to-access dumping sites, such as riparian zones, depressions and steep embankment systems. However, aspects of the tendering requests (snow cover seeding and guarantee of snow at the time of execution), monitoring and warranty, as well as time constraints (time of sowing), may present an obstacle to sowing. Vegetation-free raw soils, especially nutrient-poor and low-sorption sands, are particularly suitable for sowing. In contrast, at dumping sites that are favorable for colonization, the seed is often overrun by competing long grasses (calamagrostis/reed-grass growth) or herbs (sweet clover). The ideal time for sowing is early spring, as snow-cover seeding. The melting snow ensures that the light pine and birch seeds stick together and are incorporated into the water-saturated topsoil.

To achieve loose stands of birch, the seed quantity should be between 15 and 30 kilograms per hectare, for an average germination capacity. Up to 40 kilograms per hectare are needed for quick-drying dumping sands, and for achieving dense pioneer forests; an admixture of pine seeds (0.5-1 kg/ha) is possible. In older groves, common and sessile oaks can subsequently be inexpensively established by offering up their acorns in installations set up for animals that engage in hoarding or caching. In order to establish forest groves on steeper slopes, birch seed is also introduced by a hydroseeding technique. Seeds of the tree species to be used must comply with the state's recommendations on region of origin.

BRUSHWOOD HEDGES AND STUMP WALLS

Canopy twigs and root stumps are typical left-overs of woodwork done in preparation for restoration work. This results in a quick and inexpensive way to create brushwood and stump walls. As elements of forest edge design, they structure the landscape and link the various post-mining biotopes (stepping stones, biotope network). The first colonizers are commonly nitrophilic ruderal plants, such as black elder or blackberry, as well as robinia. Although the hedge walls usually only belatedly develop vegetation, with few tree or shrub species, they offer immediate protection to small mammals, birds, reptiles and insects.

Stump wall in Meuro

SMALL-SIZED CLEARINGS

By refraining from correcting every small-scale planting failure, undeveloped areas within forest populations are created, which serve as habitats for various animal species. Along the edge zone of the forest, these open areas give the forest profile a certain irregularity and, consequently, a more natural appearance. These clearings, however, can only be tolerated to the extent that they do not jeopardize forest functionality and the operational objectives of forestry.

Hoverfly

Natural Reforestation

Contrary to renaturation areas (nature conservation priority areas), planned forest areas may also be subject to natural reforestation. This is undoubtedly the most cost-effective way of establishing a population. This is offset, however, by the long period of time it takes until such areas exhibit the characteristics of a forest, as defined by state

The hoopoe (Upupa epops) likes to live in post-mining landscapes

law, and reach the specified rehabilitation goals. Moreover, if forests were only established via succession, valuable site potential for demanding deciduous tree species would be wasted. The prognosis for succession sequences requires detailed knowledge of the abiotic site factors and ecological interactions. However, this remains fraught with uncertainty. For establishing a population, it is first necessary to determine whether the sites are fundamentally suitable for forestry. Areas that are intended for forestation via succession must generally be improved with lime to a sufficiently deep level. It often already becomes clear in the initial stage of succession whether woody plants will establish themselves in the long term, alongside herbs and grasses. Thus, under certain circumstances, constricting long grasses can block forest development for decades. As "site preparers", pioneer and preforest tree species such as pine, birch and aspen play a key role in a forest's natural succession sequence. Highly competitive robinias also take up more and more space. Self-settlement begins in the young raw-soil phase and reaches its peak in the shrubland and pre-forest phase. Depending on site conditions, established birch can already bear fruit after 5 to 15 years, thus initiating further impulses towards colonization.

Furthermore, with advanced population development, diaspores introduced by birds become increasing important. Intermediate and climax tree species are supplemented by planting procedures

WET OR SANDY AREAS WITH LITTLE VEGETATION

Water-logged surface areas are often found after construction vehicles have driven over cohesive raw soils. Substrates containing bottle clay with clay contents of more than 40 percent by volume also have a strong tendency towards water logging. Due to the difficult site conditions, such areas are excluded from planting, and potentially they are surrounded with shrub and tree willows. Sandy areas with little vegetation are created, in turn, on sulfur-acidic dumping site substrates, as a result of insufficient lime improvement.

Due to their mosaic-like distribution and small surface areas, they can only be re-improved with disproportionately high effort. They therefore persist as ecologically valuable raw soil locations, and provide a preferred habitat for soil colonizing insects.

Sandy area in nature reserve Grünhaus

in areas with a diverse age structure and a varied population profile, such as forest edge areas with a significant recreational function. Under the loose canopy of birch/aspen pioneer forests, location-attuned sowing of sessile oak and common oak, common ash, horn-beam, common beech, but also native shrub species such as buckthorn, spindle and hawthorn, can develop comparatively well. The more the to-be-forested areas lie towards the interior of a dumping site, the lower the proportion of succession groves there can be. The distance to the nearest diaspore donors is decisive. Distances of over a kilometer can hardly be expected to provide sufficient seed input. No special, easily established protective functions, such as immission, erosion or visual protections should be planned for the forest areas to be created.

Integrated Nature and Landscape Conservation

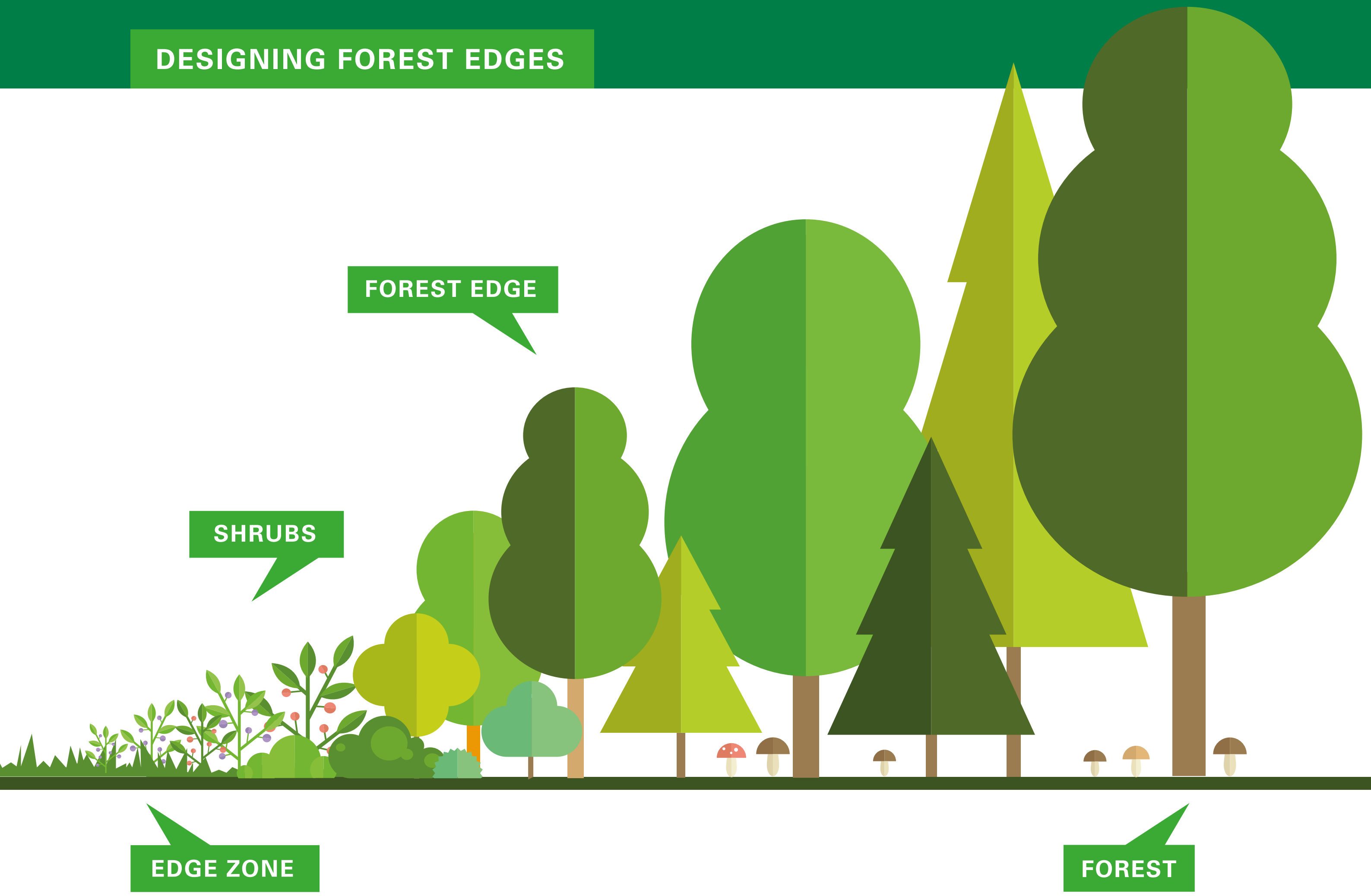
Site-appropriate forestry is undeniably a form of forest management that is very close to nature. Furthermore, over the course of forest recultivation, additional elements that promote nature conservation are introduced into the post-mining landscape with relatively little extra effort.

The boulders and stones that were deposited during the ice ages are collected and stored during ongoing mining operations. Larger quantities of ice age debris are also obtained during the leveling and initial rehabilitation of dumping sites. Via the creation of boulder and stone heaps, specialized biotopes can be integrated into the initially structurally poor reforestation areas, at an early stage. They provide refuge and living space for many warmth-loving small mammals and reptiles, thereby accelerating the re-colonization of larger dumping site complexes.

Forest Edges

Tiered and subdivided forest edges serve not only to improve forest structure, but also aesthetics

DESIGNING FOREST EDGES



(recreational functions), species and biotope protection (biotope networks), wind/erosion protection as well as, consequently, a reduction in the risk of forest fires. A distinction must be made between exterior boundaries (demarcations from other types of land use) and interior forest boundaries. The former connect the post-mining forests with the surrounding agricultural or restoration areas, or the boundaries of open-cast mines. In this way, abrupt demarcations are avoided and a harmonious integration of ecotones is encouraged. The outer edges of the forest are planted with shrubs, followed by second and first-order trees towards the interior of the forest. Their width can be up to 50 meters in the primary direction of the wind. In contrast, internal forest boundaries are much narrower. They follow existing paths and lanes, as single to multi-row strips of woodland.

Due to the predominance of low-sorption dumping sites, native wild rose and willow species, blackthorn and intrusive hawthorn have all proven particularly suitable for the creation of forest edges. Among fruit trees, wild pears show the most adaptability to such locations. Sea-buckthorn exhibits the most reliable guarantee of growth for the poorest of locations. However, its rapid spread via root runners and birds quickly makes it a costly maintenance problem, which is why it is no longer used in the recultivation of post-mining rehabilitation.

Forest edge plantings usually require fencing to prevent wild animal browsing, which inevitably results in unfavorable configurations of fencing. Forest entry points must remain accessible for roaming wildlife, which is why a one to ten-meter-wide opening is maintained for every 100 to 150 meters of planting or fencing. For these purposes, natural wildlife passages are taken into account.

MAINTENANCE MEASURES

Forestry law requires the care for and proper management of forests on recultivated areas, including all maintenance measures that serve to safeguard plant cultures and functionally-appropriate population development. Interventions must promote vitality and stability. They should guarantee a yield expectation adapted to the location.

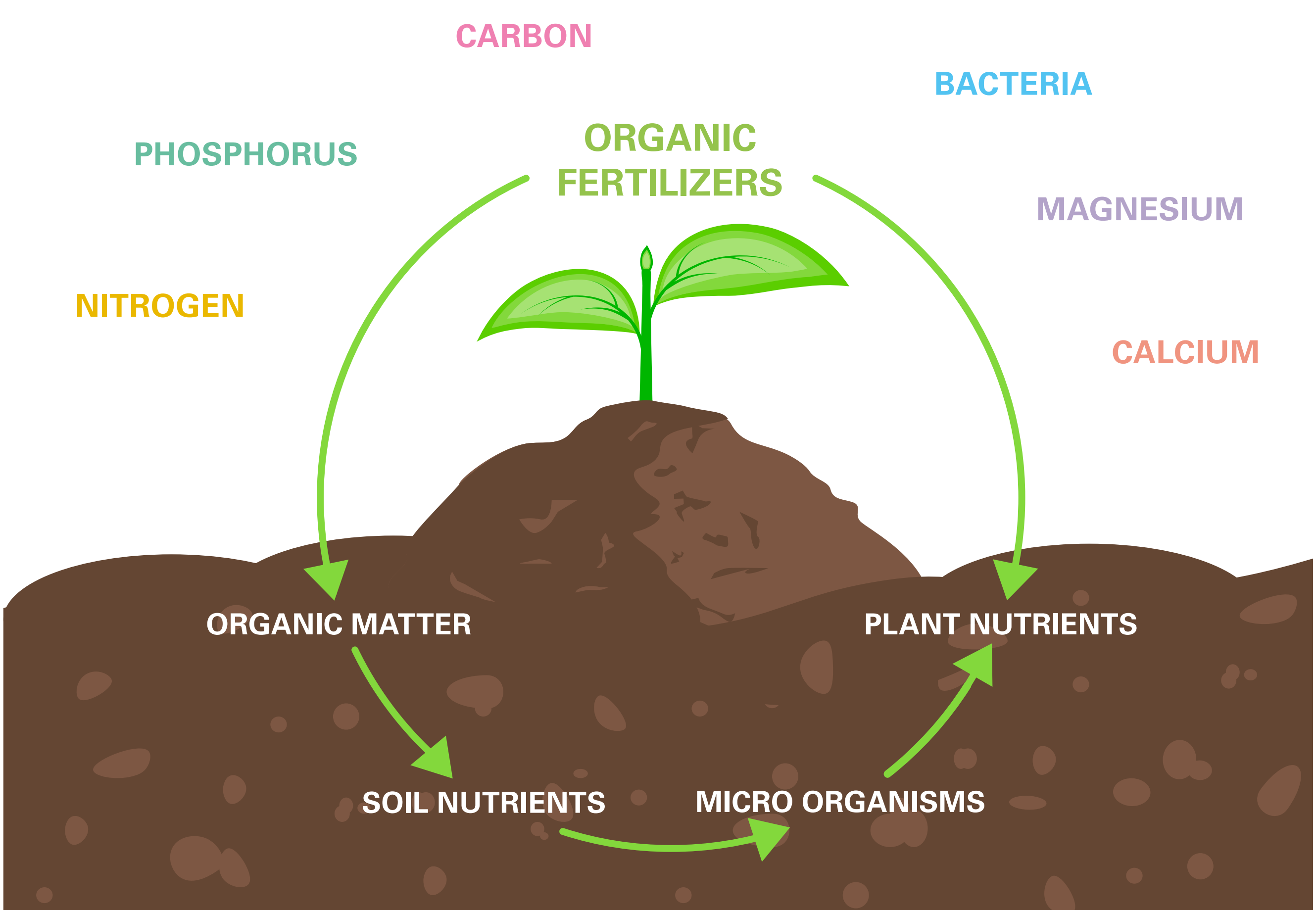
Controlled Growth Management

The main focus of cultivation during the initial growth phase is on the regulation of accompanying growth, i.e. keeping space cleared for woody plants by suppressing unwanted grasses and herbs. In particular, constricting long grasses (e.g. reedgrass) and herbaceous plants, such as sweet clover, require controlling interventions. The amount of care required varies depending on location quality, spectrum of ground vegetation species, species of woody plants being used, the range of plants and the weather conditions in the respective year of cultivation. In general, shade-tolerant tree species are less sensitive to the competitive pressure of ground vegetation than shade-intolerant species such as oak and pine. The intensity of care is also dependent on the quality of the location.

Fertilization Measures

Irrespective of their geological situation, dumping site raw soils are characterized by very low levels of available plant nutrients, especially nitrogen (N) and phosphorus (P). In addition to critical response conditions and microstructural deficiencies, it is

NUTRIENT CYCLE




Wolf cub


Red Fox vixen


Hare cleaning itself

mainly the insufficient availability of nitrogen that inhibits plant growth. In contrast, there are generally no shortages of calcium, magnesium and micronutrients. Supplemental NP fertilization is therefore essential for the secure growth of forest crops. Mineral fertilization takes place beginning in the third year of cultivation, when the fine root system has established itself and original nutrient reserves of the mostly fertilized nursery plants are exhausted. A lasting improvement in nutritional status can generally only be achieved by repeating the supplementation of N two or three more times, after an interval of one to three years.

By the end of the thickening phase, the nutritional situation of unfertilized and treated populations is equalized. This is attributable to the establishment of ecosystem nutrient cycles. Atmogenic nutrient inputs accelerate this process. In exceptional cases, targeted supplementary fertilization may still be necessary. Beforehand, the supply of nutrients is assessed by means of representative leaf or needle analyses.

FOREST PROTECTION

The forest laws of the federal states require the owner of a forest to take preventative and combative measures to protect the forest. That means, the owner must also ensure that development on recultivation areas must be appropriate to the location and function of the forest. Traditionally, this includes all measures for the monitoring, forecasting, preventing and controlling of abiotic and biotic harmful factors, in particular the prevention of damage caused by wildlife. Damage by wildlife during recultivation is one of the most common types of damage to cultivated plants. Since the use of smaller assortments of plants has proven successful in post-mining reforestation, and growth is often delayed in the first few years after planting, compared to mature sites, valuable hardwood crops must be provided with wildlife protection fences. In order to enable fences to be effectively monitored for damage and the intrusion of wildlife, fenced-in forest land should not exceed and area of five hectares. Alternative methods of individual protection, such as the use of chemical browsing repellents, are significantly more expensive after only a few years of regular use (especially when high initial plant numbers are involved). The use of robinia posts or galvanized steel posts and a knotted netting, which varies in wire thickness depending on the wildlife species that are present, has proven to be a reliable fencing material. The distance between posts is about 5 meters; fence height from the ground up is at least 1.6 meters for roe deer, or 1.8 meters for red deer. The fence is embedded 20 centimeters into the ground.

ADDITIONAL HARMFUL BIOTIC FACTORS

While harmful insects and fungi play a subordinate role in the recultivation phase, mice in particular can threaten populations of oak cultures. Preventative measures against mouse infestation include constant monitoring of the area, individual protection for valuable hardwood plantations, as well as the promotion of natural enemies, for example by means of supportive structures for birds of prey (perching stands). If operational objectives become jeopardized, the concealed application of rodenticides in bait stations is imperative. Combating harmful forest insects is only necessary in exceptional cases. Younger pine cultures are occasionally attacked by the common gray weevil or the common pine sawfly. Despite the loss of an entire crop of needles, experience has shown that pine trees recover in the following years, so that chemical control is usually unnecessary.

HARMFUL ABIOTIC FACTORS

Due to their exposed, open-land situation, forest cultures are particularly vulnerable to weather conditions such as storms, frost or drought. The introduction of protective plant cover can mitigate such microclimatic extremes and accelerate humus and soil formation. This favors the development of woody plants, with similar effects being achieved by the extensive cultivation of fast-growing pioneer tree species (poplar, alder). In contrast, the risk of forest fires at dumping site areas is significantly lower than in the sometimes heavily grass-covered pine monocultures surrounding open-cast mines. This can primarily be attributed to the higher proportion of hardwood, favorable stand structures and an optimized forest edge design. Fire extinguishing ponds are also systematically created and maintained within future forest areas. Beyond their fencing, these liner ponds have shallow water areas that serve as both wildlife watering and spawning grounds.

In addition, there are fixed firewater tapping points at the newly created post-mining lakes. Close coordination with the district or local fire department responsible for general fire protection is indispensable.

Fisheries in Post-Mining Lakes – A New Habitat Underwater

Rudds in the Partwitzer Lake

Brood of whitefish before placement in the opencast mining lake Gräbendorf

LMBV, as the owner of newly created bodies of water in a post-mining landscape, is the owner of fishery rights.

It is therefore responsible for meeting fishery management requirements established in the fishery laws of the respective states. Prerequisites for the fulfillment of this obligation are an approximately reached final water level for the respective body of water, a minimum 5.5 pH value of the water, as well as secured, safely accessible shore areas. Flood waters from surrounding rivers and waterfowl are both used for bringing fish into the new lake. The most important prerequisite for the development of fish species communities that approximate natural conditions, and allow for post-mining lakes to be used for fishery purposes, are pH values above 5.5. For most fish species, lower pH values lead to restrictions in reproduction, deteriorated conditions for growth, and ultimately to death. Various fish species and age groups differ from one another in terms of their acidity tolerance.

FISH SPECIES IN POST-MINING LAKES

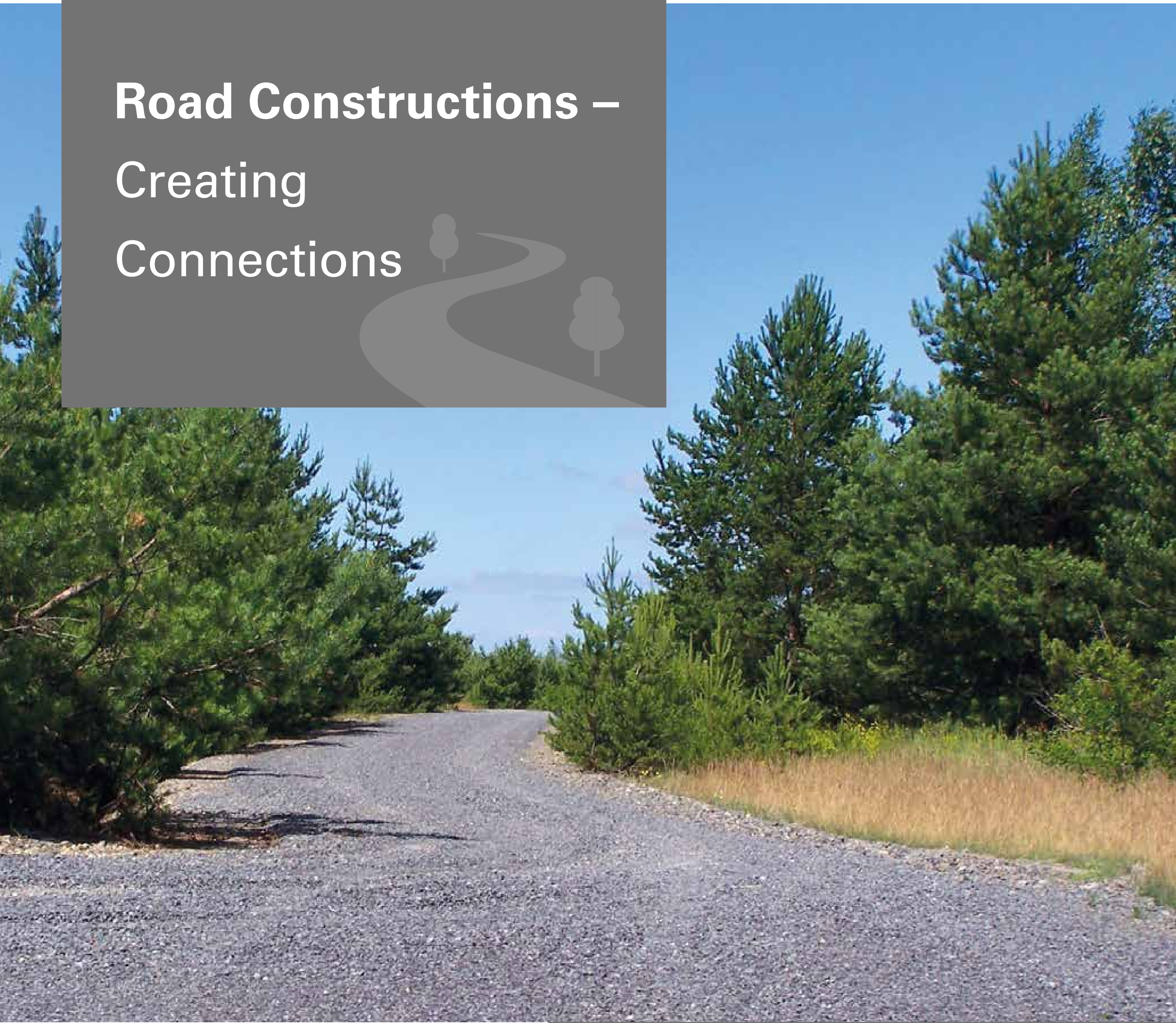
ENGLISH NAME	SCIENTIFIC NAME
Common bream	*Abramis brama*
Siberian sturgeon	*Acipenser baerli*
Bleak	*Alburnus alburnus*
Common bullhead	*Ameiurus nebulosus*
Eel	*Anguilla anguilla*
Asp	*Aspius aspius*
Stone loach	*Barbatula barbatula*
White / Silver bream	*Blicca bjoerkna*
Crucian carp	*Carassius carassius*
Prussian carp	*Carassius gibelio*
Spined loach	*Cobitis taenia*
Vendace	*Coregonus albula*
Vendace	*Coregonus sp.*
Common carp	*Cyprinus carpio*
Pike	*Esox lucius*
Threespine stickleback	*Gasterosteus aculeatus*
Gudgeon	*Gobio gobio*
Pope / Ruffe	*Gymnocephalus cemua*
Pond perch / Common sunfish	*Lepomis gibbosus*
Belica / Moderlieschen	*Leucaspius delineatus*
Ide / Orfe	*Leuciscus idus*
Dace	*Leuciscus leuciscus*
Chub	*Leucisucs cephalus*
Rainbow trout	*Onchorhynchus mykiss*
Perch	*Perca fluviatilis*
European bitterling	*Rhodeus amarus*
Common roach	*Rutilus rutilus*
Brown trout	*Salmo trutta*
Pike-perch	*Sander leucioperca*
Rudd	*Scardinus erythrophtalnus*
Sheatfish /Wels catfish	*Silurus glarnis*
Doctor fish	*Tinca tinca*
32 Fish species	

LMBV commissions fishery assessments by specialist institutions for these newly created bodies of water. A fish fauna and fishery mission statement for the respective lake is drawn up, and resulting management requirements for LMBV or its subsequent users are established. The determination of these guiding principles forms an important basis for all further measures for the development of fish stocks and for the future use of fisheries. Primary fish species that cannot enter the lake on their own are introduced by LMBV as an initial stock, in order to prepare the water for fishery management.

Channels (inlets and outlets), built to flood the post-mining lakes, connect two different types of water bodies: rivers with flowing water systems and lakes with still water systems. Different species of fish and fish food sources live in them. In order to enable migratory fish species, such as eel or trout, which are found in both types of water bodies, to pass through the artificially constructed channels, fish ladders are built at certain locations.

Fish ladder at river Mulde reservoir

Road Constructions – Creating Connections



Main service road in the recultivated area of the Nochten opencast mine

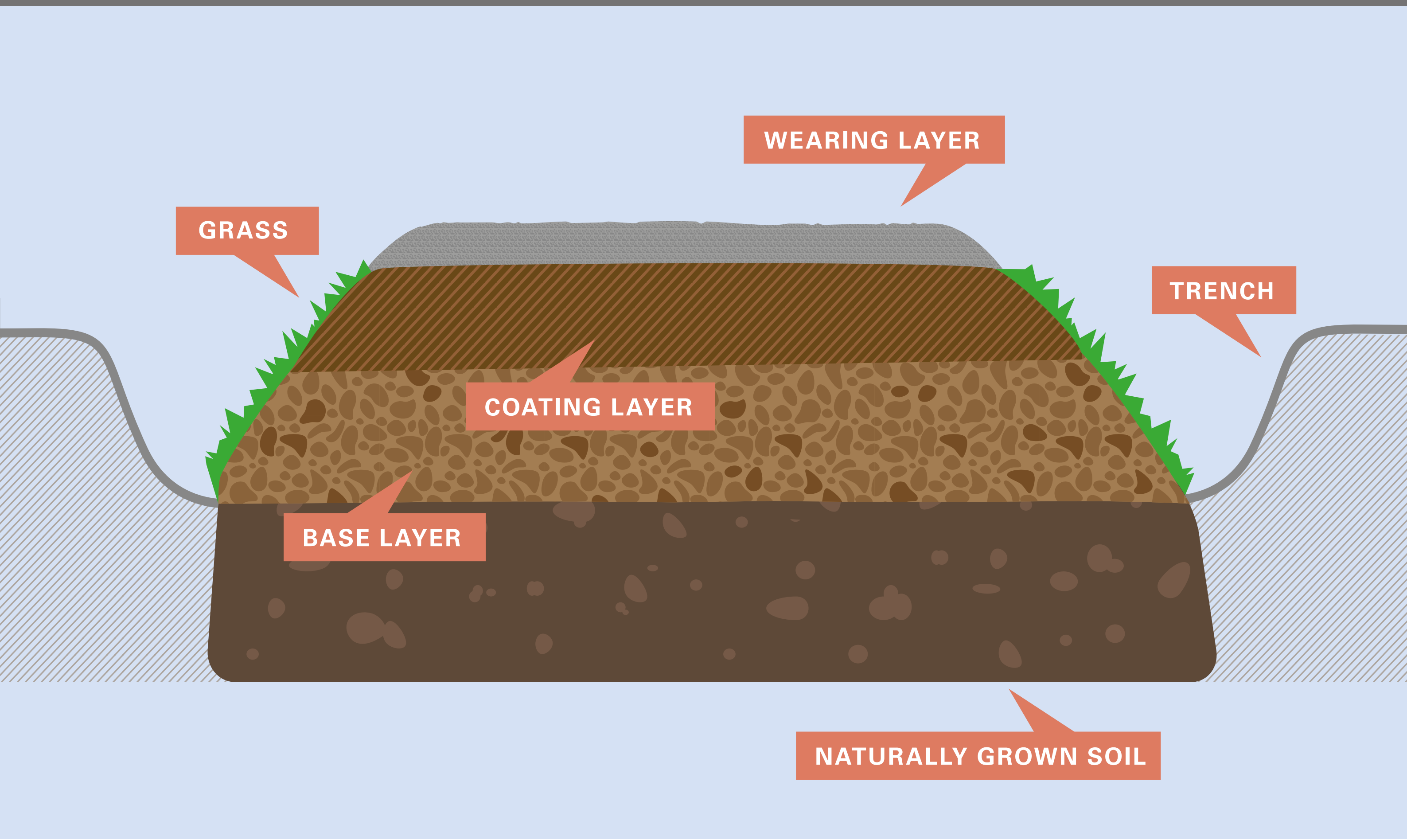
The management, protection and recreational use of, in particular, agricultural and forest recultivation areas require the creation of service roads. Their role is:

- to enable the traffic and transport operations required for economically viable cultivation,
- to divide areas,
- to connect product and material storage locations,
- to direct non-motorized recreational traffic,
- to facilitate forest protection and, in particular, rapid and effective forest fire-fighting, as well as
- to enable rescue operations.

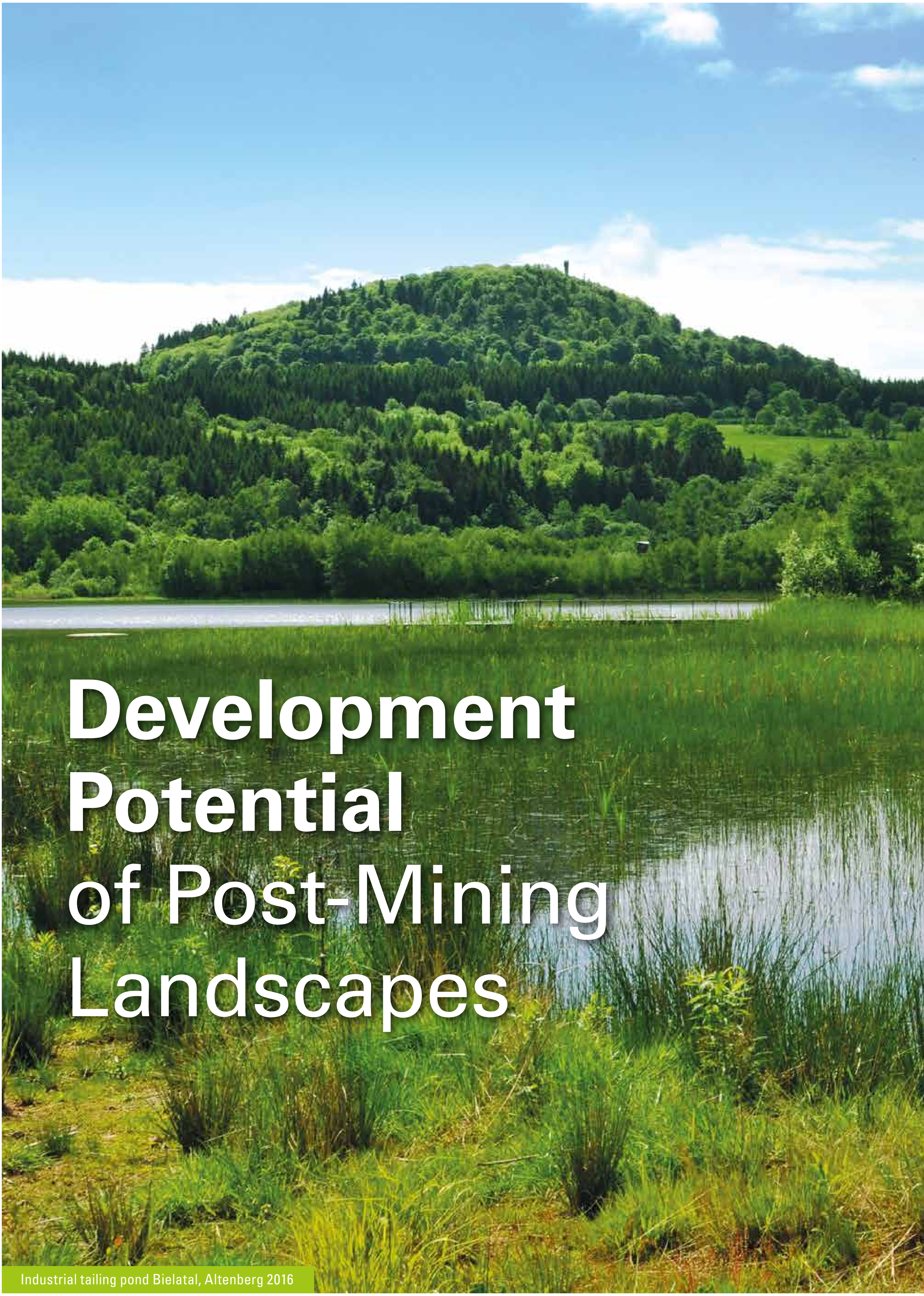
Preliminary development is carried out via paved, truck-accessible, main agricultural roads, with connections to the existing road network. The existing road network is then further extended over the course of ongoing recultivation. The aim is to achieve a high degree of development using the shortest possible transport distance. A travel distance density of 15 linear meters per hectare is considered sufficient for the mostly flat to slightly inclined dumping site areas. Taking into account the respective forms of land management and landscape conditions, transit route layout is implemented as parallel as possible. This ensures optimal site development. For example, prominent points of terrain or premining circumstances, such as former settlement areas, can thus be integrated into the route layout. Roadway width is usually 3.0 or 3.5 meters, with passing lanes at sufficient distances. This amounts to a total width of 4.5 to 5.5 meters, taking non-trafficable hard shoulders into account. In the case of highly cohesive soil substrates with a tendency towards water-logging, substrate stabilization must be carried out using liners, fiber mats or binding material. The superstructure consists of base, coating and wearing layers. A standard construction method with a base layer consisting of a mixture of gravel, crushed stone and sand has proven to be optimal for dumping site areas. Drainage is achieved by a corresponding transverse slope of 5 percent in the top or gradient profile, and trapezoidal, troughed or V-shaped ditches on both sides. The ditches are interrupted approximately every 50 meters to allow for water seepage.

This construction method is designed for land management with low-traffic loads. It is best suited to a multifunctional use of roadways, while at the same time being ecologically compatible. Maintenance of roadways is limited, under normal use, to the leveling of road surfaces every one to two years.

ROAD CONSTRUCTIONS



Development Potential of Post-Mining Landscapes



Industrial tailing pond Bielatal, Altenberg 2016

LAND RESTORATION AREAS

In the rehabilitation plans of the federal states, "renaturation areas" are designated as nature conservation priority areas, alongside traditional agriculture and forestry, as a separate type of land use. This creates a crucial foundation for rehabilitation.

The areas left over after open-cast lignite mining are usually very spacious, unfragmented and quiet, due to the extensive use of land by the large mines and the associated infrastructural changes.

The mostly nutrient-poor dumping site substrates are contrasted by those of the areas surrounding the mine, which are characterized by ongoing landscape fragmentation and extensive eutrophication processes. This also applies to large areas of Germany and Central Europe. In young post-mining ecosystems, in particular, the lowering of groundwater levels and/or the sometimes extremely low pH values of Tertiary substrates have a selective effect on species composition. Due to these unique location factors, dumping sites and stockpiles represent ecosystems with low competitive pressure during the irst phases of colonization, which are primarily settled by specialists.

Coincidence and so-called "first comer effects" are important colonization factors in this process. The heterogeneous nature of dumping site substrates and the operationally determined large and small-scale structures of land rehabilitation, e.g. ridges of rubble, stockpile heaps, depressions and erosion channels, mean that post-mining areas, with their changing landscapes, have a high developmental potential for rich biological diversity, as well as a distinctive character and bizarre beauty. The development of young ecosystems is highly dynamic, at locations with ongoing geomorphological processes, and continues to be so over long periods of time.

Grasses in nature reserve Grünhaus

Wall of deadwood in the recultivated area of the Nochten opencast mine

VALUABLE BIOTOPES

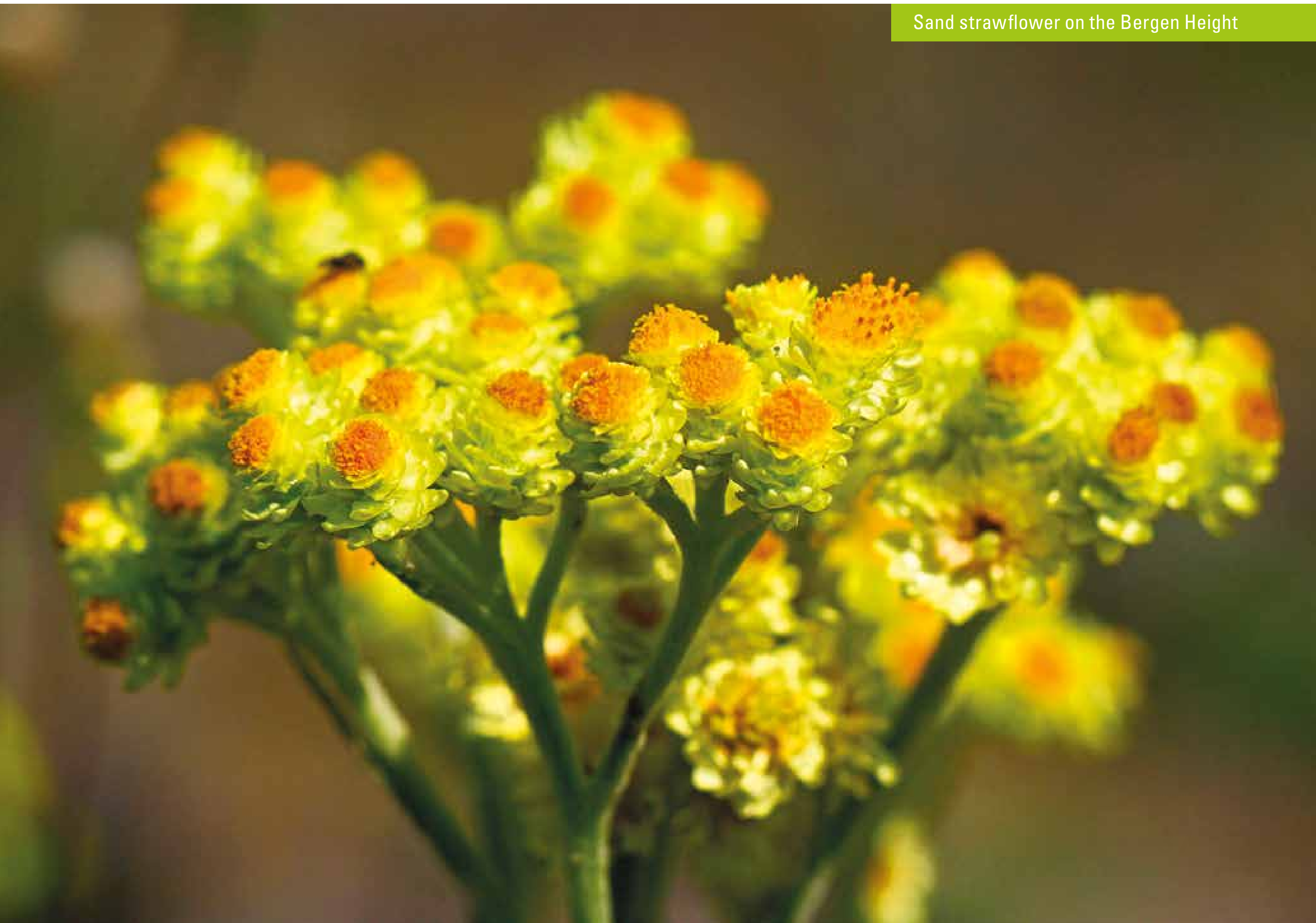
Biotopes in the post-mining landscape that are valuable for nature conservation were created under special geomorphological conditions. Steep banks, drop-offs, raw soil areas or pond-like bodies of water are coincidental biproducts of former mining activities.

Over the course of natural succession, gray hair-grass pioneer meadows and sandy dry grasslands, initial chalk heaths, reed beds, willow bushes and pioneer forests can form very quickly at suitable sites and in the presence of supplier biotopes from the surrounding areas. In the medium to long term, the development of swamps, fens and sedge marshes is possible, as well as heaths and mixed hardwood forests.

At special locations, for example, dwarf rush communities can develop with changing water levels, or, in the case of geologically-determined high salinity levels, inland salt deposits.

In Central Germany, macrophyte-rich bodies of water, some with distinctive stonewort mats, are also not uncommon. Lower Lusatia, in contrast, is dominated by extremely acidic waters, with populations of bulbous rush and reeds. The particular features of biotope development are reflected in the biotope type designations that have been specifically developed for post-mining landscapes.


Sand martin colony


Sand strawflower on the Bergen Height

BIODIVERSITY

Potentials for species are not only linked to the development of their corresponding living environments in the narrower sense (habitats), but also to development potentials at the level of landscape ecology. It is only those properties of being "spacious" and "unfragmented" that guarantee these newly created post-mining ecosystems a low level of disturbance, which many animal species require for their reproduction (e.g. ground and reed bed breeders).

Low-nutrient fens and swamps provide habitats for orchid species and other bog specialists over a longer period of time, mainly because the adjacent areas are also very low in nutrients and thus act as an effective buffer to the surrounding area. These and other weakly-competitive plant species are particularly sensitive to competition for light.

The possibilities for germination and establishment are improved for species whose seeds have little or no nutritive tissue due to low biomass production, and the resulting light-rich locations. In addition, they usually exhibit poor growing habits, so that even as mature plants, they enjoy better development opportunities than in the surrounding landscape, which is often characterized by eutrophication. These species also have very

Female Yellowhammer in former opencast Zeißholz

Chicory with a hoverfly

well-flying diaspores. The large surface areas of the open-cast mines and the wind permeability of the open landscapes, in turn, increase the probability that these species actually reach open-cast mining areas. LMBV allows geomorphological processes to occur, such as fracturing and erosion processes, after geotechnical analyses and in consultation with mining authorities.

As a result, new raw-soil sites are constantly being created for specialists, such as the striped earwig or the blue-winged grasshopper. For their entire life and reproduction cycle, many animal species require diversely structured habitats (hunting grounds, breeding grounds, wintering grounds, etc.), which are created over the course of the natural succession of post-mining sites, due to substrate and site heterogeneity, as well as chance events during the colonization process.

If these biotope mosaics are made up of open-land, shrubland and pre-forest phases, or diversely structured shore areas with slope movement in appropriate proportions, numerous animal species that have become rare in the surrounding cultural landscape can establish stable populations here.

Water frog in former opencast Seese-West

Italian locust in former opencast Schlabendorf-Süd, Wanninchen

Succession in former opencast Seese-Ost, 2006

MIGRATION OF ANIMAL SPECIES

Older succession areas are accumulation sites for plant species that are gradually introduced into the mining areas from a distance, via long-distance propagation and exceptional events. These species more quickly. The process of successive settlement is promoted by a mosaic of sites with differing colonization capability. Dumping site substrates or substrate mixtures from different geological time periods make a significant contribution to this process. Simultaneously, a high diversity of landscapes can further promote the development of mosaic-like vegetation structures. Easily colonizable sites, such as depressions or Quaternary substrates, act as accumulation areas and supplier biotopes for further settlement processes at border locations, such as very dry areas (e.g. southern slopes) or very acidic Tertiary substrates. The immigration of animal species depends to a large extent on how interconnected the post-mining landscape is with supplier biotopes from the surrounding area. Consequently, in the medium term, open-cast mines often exhibit only a partial spectrum of species from the surrounding, undisturbed landscape, especially in the case of not-so-mobile groups of animal species.

PRIORITY AREAS FOR NATURE CONSERVATION

Priority areas for nature conservation should, above all, have the highest possible proportion of primary succession areas, with the pronounced structural diversity that is typical of mining. In contrast to forest areas, renaturation areas are usually neither treated with lime, nor fertilized. Upon termination of mining supervision, according to the federal states' forest laws, no economic uses or characteristics may be present in these areas. As long as there are no dust emissions coming from the site into surrounding residential

Red kite in post-mining area

areas, greening is also dispensed with, in favor of primary succession processes. For this reason, wherever possible, such sites are not designated in the immediate vicinity of settlements or tourist destinations. If greening is nevertheless necessary, a grass composition of clump-forming fescue species with a maximum seeding of 2 to 5 grams per square meter is introduced, in order to not accelerate or even impair succession processes.

For this purpose, however, the pH of the top-soil (approx. 20 centimeters) must be increased to at least 4.0 by the light use of lime treatment. In large-scale field trials, sandy dry grasslands, heaths, chalk heaths and fresh meadows have been successfully developed during the course of rehabilitation work in nature conservation priority areas. These open-land biotopes can be established by using the methods of sod dumping, sod transplantation, the spreading of mowed material, as well as mulch-cover seeding. For the longterm preservation of the landscape ecology features of being “unfragmented”, “lacking in disturbance” and “nutrient poor”, and in order to minimize transboundary effects, priority areas for nature conservation require sufficiently large, contiguous spaces of at least 400 hectares, and preferably over 2,000 hectares. In addition, areas of refuge for weakly-competitive species can only be continuously maintained if sufficiently large areas are available, with locations that can be colonized in different ways. These large-scale biotope mosaics are also important habitats for many animal species with larger areas of activity and differentiated demands on habitat structures (e.g. structurally differentiated feeding and breeding habitats for birds of prey).

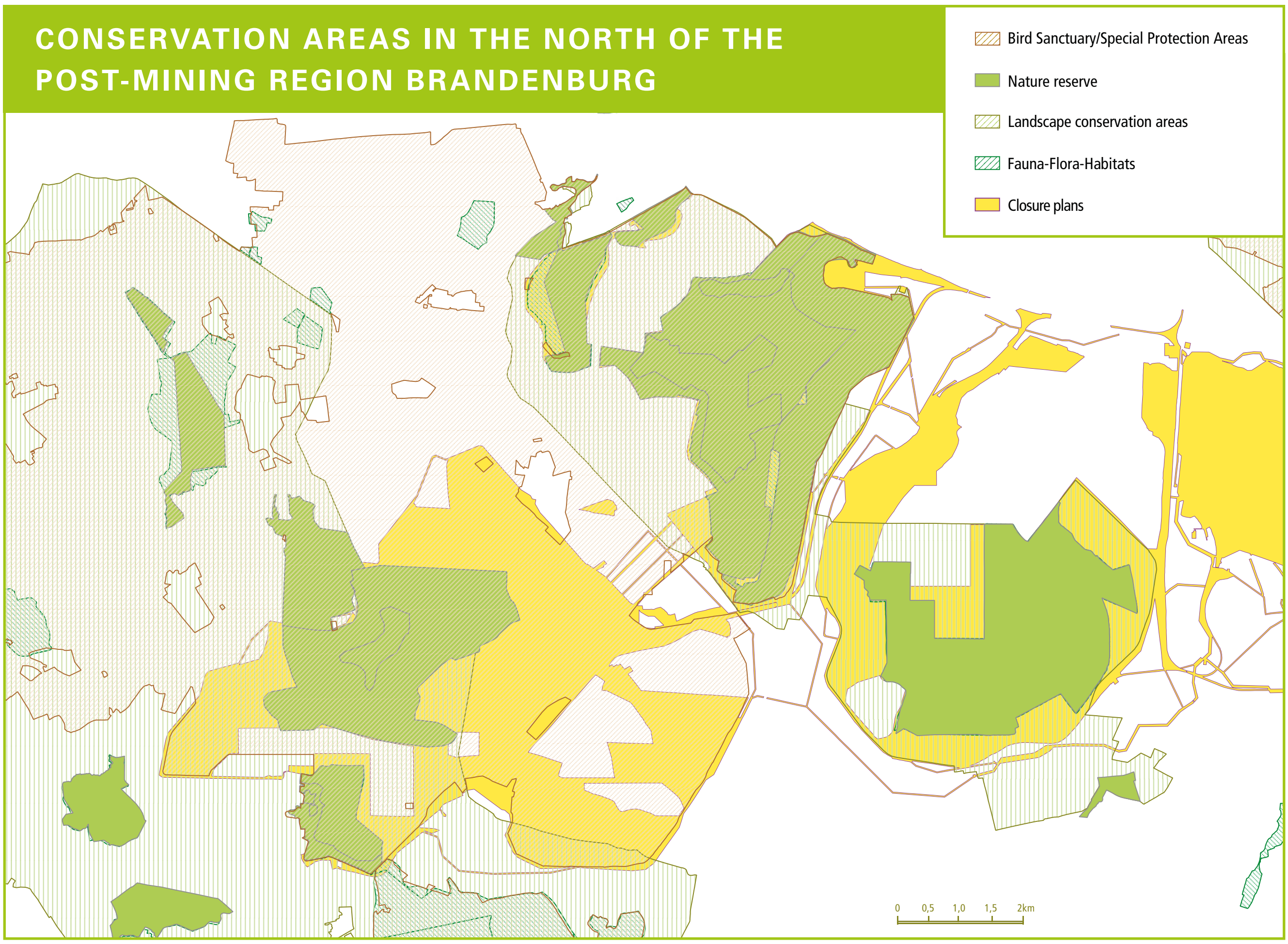
Populations in larger protected areas are also generally subject to a lower risk of being exterminated by chance events. If smaller areas are to be designated, concepts must be developed for buffering the area against nutrient input and disturbances, as well as well-founded management concepts for the conservation of the species, since habitats can be lost via progressive succession and, due to the small size of the area, there would not be many alternative sites. If the areas are also to be used for sustainable tourism, strategic visitor management is of great importance.

ESTABLISHMENT OF A CONSERVATION AREA SYSTEM

In cooperation with nature conservation authorities, associations and scientific institutions, LMBV has developed site proposals for areas that are valuable in terms of nature conservation, known as "Core Areas for Nature Conservation". Former open-cast mines owned by LMBV that had not yet been or were incompletely rehabilitated played an important role in the selection process. Through the sale and transfer of ownership to nature conservation institutions, the natural potential of the post-mining landscape can be secured for the long term. The terrestrial core area amounts to 14,454 hectares (LMBV survey, 2005). On average, a 15 percent share of the post-mining area has been reached in the respective federal states.

EXPERIENCING NATURE IN CONSERVATION PRIORITY AREAS

In addition to their function as abiotic and biotic resources, the naturally developed succession landscapes also have a fundamental socio-geographical significance. This is because the spacious, unfragmented post-mining areas represent an important landscape-aesthetic resource for nature-related recreational use. Positive synergistic effects, in terms of the possibilities for local recreation and regional economic impulses, can be utilized more intensively within the framework of a sustainable form of tourism.



CONSERVATION AREAS IN THE NORTH OF THE POST-MINING REGION BRANDENBURG

Lausitzer und Mitteldeutsche
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Front: Afforested wood on a former Lusatian mining dumpsite (photo by Lennert Piltz)

Back: European nightjar with a chick (photo by Lennert Piltz)