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Ecological restoration and dike relocation on the river Elbe, Germany

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ABSTRACT. Floodplain restoration has been successfully initiated on a 420 hectare area on the Middle Elbe River in the German Federal State of Brandenburg. Within a federally funded "Large Scale Conservation Project", grassland dominated agricultural landscape was converted into a natural floodplain area between 2002 and 2011. The relocation of a dike was essential to re-establish natural flooding conditions as a prerequisite for the rehabilitation of floodplain specific animal and plant communities. At the same time the dike relocation proved to be of great benefit to flood protection, restoring retention capacity, broadening a narrow of dikes and eliminating a hydraulic bottleneck situation in a dangerous river bent. Alluvial forest was initiated by scattered plantations of autochthonous woody species leaving much of the area subject to spontaneous succession. Excavation of alluvial water bodies and maintenance of a extensively grazed horse pasture area add to a diversity of landscape elements with the aim to restore a broad range of floodplain habitats with a high level of biodiversity. The initiated landscape change quickly set off successional processes, mostly related to the altered hydrological conditions among which extended periods of inundation are of major importance. Severe changes in vegetation communities, birdlife and fish communities could be assessed by evaluation investigations and prove the success of the restoration project. Research activities and public environmental education continue to play an important role in the management of the project.

Key words: Elbe, Lenzen, floodplain restoration, alluvial forest, dike relocation

INTRODUCTION

The need for space for our rivers has been largely agreed on by water managers, politicians and the general public as well. Slowly but steadily does the notion win recognition, that integrated approaches to river management, acknowledging the multifunctional character of floodplains, are essential and the only way to reduce the negative effects of single-interest focussed management practices of the past.

Nevertheless are activities for the implementation of such policies, namely increasing the size of active floodplains far from being a commonly implemented management option. Despite numerous traumatic experiences with flood catastrophes over the past decades and a growing awareness for the ecological and economical losses of floodplain destruction, a trend towards resource oriented, integrated management practices cannot be asserted on a large scale concerning Europe and beyond. However, best practice examples of individual projects are to be found, a collection of which has been published by Damm et al. (2012) [4] The present article intends to share and distribute some of the experience which has been made in a successful dike relocation project that has been realized between 2002 and 2011 on the Elbe River in Germany.

The combination of nature conservation objectives on the one hand and flood protection goals on the other hand make this project an example for an efficient and integrated approach. The need to restore floodplains on a larger scale is targeted and perfectly matches the requirements of the European Water Framework Directive [13] as well as those of the EU-Flora-Fauna-Habitats and Birds Directives ([12]; [16]).

Even though the scheme started as a nature conservation project, it developed into an integration of additional landscape uses, an increasingly important one being flood protection. The mitigation of a locally unfavourable hydraulic situation on a large river and the restoration of retention capacity became strong arguments, mainly after the experience of the large flood of 2002 on the Elbe River, which strongly supported this integration, even though the project proposal had long been submitted before that event. In this regard the EU-Flood Risk Management Directive [14] became also relevant for the project.

PROJECT HISTORY AND LOCAL SITUATION

The project area is located on the lower Middle Elbe section halfway between the metropolis regions of Berlin and Hamburg in the formerly East German state of Brandenburg. The gently meandering lowland river with a mean discharge of about 680 m³/s runs through the northern German plain, formerly paralleled by extensive alluvial forests which long since have been turned into dominating pasture land throughout the morphological floodplain area. Within the project region, the river has been the borderline between East and West Germany, leaving behind a region with little infrastructural development, a very low population density but some very important remnant areas of nature conservation interest. It was the fall of the iron curtain that urged local actors to discuss the future development of this disadvantaged region. New ways needed to be explored anyhow – which triggered an unforeseen process of public and administrative discussion. During this exciting period, the director of the quickly established regional nature park and the director of the former agricultural cooperative, who later became executive of the local agricultural holding, were important actors in this regional process. Developing the region's future with a combination of pronounced nature conservation goals and largely continued adapted agricultural use was the main idea. Tourism was considered a new source to explore and conditions for this attempt seemed favorable given the fact that river tourism started a career on many other rivers those days.

It took more than a decade of discussion, persistence in persuading considerable, mainly locally based skepticism among politicians, administration and the public. A number of strategically placed smaller and larger projects, among which an EU-Life project and a federally funded interdisciplinary research program are the most prominent predecessors, have been instrumental in paving the way for the project [3]. Financial support was a last obstacle which could be overcome by the engagement of the federal government, providing support through its "Large Scale Conservation Projects-program" issued by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

A number of particular circumstances have been instrumental for implementation of this project [2]. The political and structural changes of the early nineties have already been mentioned. Furthermore the large structured agricultural landscape of former East Germany greatly reduced the number of land users to deal with, down to mainly one large farming enterprise. Since this unit was entirely supportive to the project being one of its main promoters from the beginning, a very favorable situation was given.

The administrative responsibility for flood protection and all the respective structures is centralized within the administration of the Federal State of Brandenburg. Continuous support of the state administration over years was important for the implementation. This is much different in other Federal States, where local and regional entities are taking many of the responsibilities and/or governmental support is not asserted. These articulate structures are usually far less interested in large scale measures – a well-known problem for the management of rivers which ought to be looked at on a large, usually catchment-oriented scale.

Within the ongoing attempts to modernize the flood protection facilities along the Elbe River, this section was due for reconstruction in any case. Thus a window of opportunity was given to rebuild the dike with an entirely new alignment. Even though flood protection authorities of the state would have implemented a much smaller dike relocation without significant gains for conservation, but the initiative in this case was coming from the conservation side and the state government agreed to combine a much larger relocation scenario in order to meet conservation and flood protection objectives in a joint project.

Further tailwinds for a dike relocation in this location derived from a dangerous and unfavorable hydraulic situation that had been known for more than a century [10]: the old dike line was almost immediately on the riverbank on the outer perimeter of an extremely tight river bent, thus presenting a very dangerous situation for dike safety. It even resulted in the local name "Bad Place" (German: "Böser Ort") for this locality. The dike relocation could entirely solve this problem.

Another favorable condition was the location of the project area as part of the Biosphere Reserve Elbe River within a nationally protected conservation area and being a site of community importance according to the European Flora-Fauna-Habitats – and Birds Directives ([11]; [12]; [16]).

Last but not least is the personal involvement with competent and continuous engagement of individual people a most important factor for the advancement of such projects. The above mentioned protagonists deserve greatest credit in this regard.

THE PROJECT – STRUCTURE AND OBJECTIVES

The dike relocation and the floodplain restoration have been realized within the Large Scale Conservation Project-program of the Federal Ministry for Environment, Nature Conservation and Nuclear Safety. Even though nature conservation is within the responsibility of the Federal States in Germany, the federal government has one budget to support the Federal States for selected, nationally representative conservation projects, providing 75% of the project budget in the above mentioned program. In the present case, another 18% were provided by the Federal State of Brandenburg, the remaining 7% being an obligatory contribution of a private institution which has to take the task of implementing the project. An alliance of Conservation organizations led by Friends of the Earth (Bund für Umwelt und Naturschutz Deutschland – BUND) together with the local municipality and the farming enterprise provided this private partnership. This alliance, called "Trägerverbund Burg Lenzen e.V." also runs the BUND-owned historical castle of Lenzen, where a nature education center as well as a visitor center for the biosphere reserve are appropriately located on the edge of the Elbe river valley.

The Large Scale Conservation Project comprises of a 1500 hectare area, 420 hectares of which are the area of the dike relocation (Fig. 1). The latter is the core area of the project, the measure providing the hydrological conditions needed to achieve the ecological objectives of the project. The relocation area will in the future be subject to natural processes and spontaneous development only.

The major goal of the project is the re-establishment of a functional, hydrologically active floodplain. Along this part of the Elbe River 80 - 90% of the floodplains are nowadays situated behind the dike [15] and disconnected from direct hydrological regime of the river, there is a great need to improve not only the quality of the recent floodplain but also to enlarge its acreage by taking back the existing dike lines in suitable situations. Since the re-establishment of floodplain forest was a main subject of the project idea from the beginning and federal support had been facilitated by the idea of restoring the strongly endangered Natura 2000 habitat types of hardwood and softwood forests. The restoration of suitable grounds inevitably required the hydrological restoration of former floodplain areas, since the active floodplain in the area was greatly reduced by historical dikes situated close to the river banks. Thus dike relocation was needed in order to provide significant acreage for the intended reforestation. By construction of a new dike, 420 ha of historical floodplain terrain were restored as a new retention area with greatly optimized habitat quality (Fig. 2).

The planting of about 80 hectares of hardwood and softwood forest by creating a network of forest patches as initial cells for a long term spontaneous regeneration of the historical alluvial forest was a main goal.

Targeting at the re-establishment of a natural floodplain landscape, other landscape elements with their floodplain specific diverse mosaic structure were also among the project goals. 45 hectares of water bodies were dug out, providing construction material for the new dike and at the same time aquatic floodplain habitat of considerable extent. Semi-aquatic habitat, periodically inundated grasslands, Bidentetea and Nanocyperion communities, reeds and a diversity of grasslands from moist to sandy and dry stands are

target habitats to be preserved and restored in the area. An extensively horse-grazed pasture landscape has been established on 70 hectares of the dike relocation area. Also the development of the seepage zone inland the new dike with moist and wet grassland providing habitat for amphibians and rare crustaceans of ephemeral pools is part of the target list. Besides the conservation goals, environmental education of the public has been and continues to be an important objective.

MEASURES AND METHODS

Dike relocation

The construction of a 6.1km long new dike up to 1.3km inland the old dike provided 420 ha of hydrologically rehabilitated floodplain. Acceptance for this measure was greatly enhanced by the fact that water managers had to deal with a hydrological bottleneck situation in this place anyhow and reconstruction of this dike section was due on the state wide flood protection agenda. The extent of the measure was nevertheless determined by the much larger spatial requirements of the conservation objectives - balanced against the far reaching but not endless flexibility of the land user. A land consolidation scheme had been implemented since the year 2000, jointly initiated by the regional agricultural and the Biosphere Reserve in order to merge public lands purchased to a large extent by the preceding EU-LIFE-project for the proposed dike relocation. Planning and permission procedures for the dike construction were executed by the state authorities for flood protection (LUGV, Landesamt für Umwelt, Gesundheit und Verbraucherschutz) between 2003 and 2005. The same entity implemented the construction of the new dike (2005-2008) and the opening of the old dike (2009), with some residual works until 2011. Soil material for the new dike could to a large extent be gathered locally by the excavation of about 40 hectares of flood channels and other waterbodies restoring some of the alluvial topography – providing another win-win effect of flood protection works and nature conservation. The old dike was opened by six breaches each 200 to 500 m wide, removing 20% of the dike's former 7.4km in length. Material was deposited on the back side of the remaining old dike fragments in order to minimize transportation effort and remobilization of contaminated soil particles.

The beneficial hydraulic effects predicted by extensive modeling conducted by the Federal Waterways Engineering and Research Institute (BAW) were instantly proven by a series of flood waves in early 2010 and 2011 when the area was flooded for the first times. Peak levels sank by 25cm at the 3km upstream gauge at Schnackenburg, while the following gauges along the river downstream recorded higher water levels compared to similar flood waves of 2002 and 2006 [1].

Restoration of floodplain forest

Land use history of the Elbe valley changed the landscape from the natural floodplain forest to pasture dominated grasslands. Only small remnants remain of the formerly extensive floodplain habitat types consisting mainly of hardwood forest (FFH-Code 91F0). Softwood forest (FFH-Code 91E0*) with its indispensable precondition of riparian dynamics has been reduced largely with river training measures, eliminating natural hydromorphological processes of site rejuvenation at large. Restoring some of this historical hardwood forest was a main reason for the federal funding of the project. Building on some preceding works of floodplain restoration, namely a EU-LIFE-project conducted in the same location [8], another 80 hectares of alluvial forest were planted using local genetic material raised in a local nursery. The idea was to establish a larger number of scattered initial forest cells from which the surrounding successional areas should be colonized later by spontaneous spread. Thus a large number of locally adapted species were used not in order to plant an anticipated stand structure, but to provide an initial genetic source to facilitate natural succession over a nearly treeless agricultural landscape. As can be taken from several sites in the region, such support is needed if successional processes are to be expected within a moderate time frame on these very dense and productive grasslands. The long term goal is to establish a 350 hectare floodplain forest complex which will be adding to the only two other appreciable floodplain forest stands (180 and 100 hectares) in the region.

Pasture landscape

In order to maintain a large diversity of floodplain typical landscape structures within the relocation area, open grasslands are considered another landscape element. Most of the formerly cultivated grassland are currently in a rapid development towards hardwood (and partly softwood) forest, sedge-meadows, reeds and other types of abandoned alluvial plains. By low intensity horse grazing it is intended to add another element of short grass wetlands, which according to their relative elevation and proximity to the waterbodies reveal a range of additional habitat types, presumably supporting another set of adapted species and thus contributing to the areas biodiversity. The horses employed for this purpose are a re-breed to the European Wild Horse ("Tarpan") which emerged from a set of Norwegian Fjord horses and the Polish Konik. The race is called "Liebenthaler Wildlinge" and reveals ideal traits for a horse to be kept without much human contact under very natural conditions. An area of 70 hectares is currently grazed by about 20 horses through much of the year. Due to the floodplain situation and the flat terrain the herd has to be kept behind the dike on other grasslands during flooding times.

Supporting endangered floodplain meadow species

Floodplain meadows are known to be among the most species rich types of meadows. They are of high conservation interest in Germany, particularly those belonging to the Cnidion alliance (FFH-habitat type 6440). Many species of these meadows are suffering from large population declines, mainly due to intensified agricultural practices. In an experimental approach developed by another R&D project on the River Rhine [6], 12 hectares of species-impoverished grassland have been treated with hay seeding using species-rich hay harvested on the few remaining rich stands of the region. The seedbed was prepared by multiple treatments with a disc harrow and subsequently with a rotary harrow. Ploughing was not an option even with the heaviest machinery due to the heavy alluvial clay soil. The freshly cut material was transported with a self-loading forage wagon or in round bales and applied to the seedbed the same day to avoid spontaneous heating of the seed-material. The success of the measure so far remains behind the expectations and more time might be needed for the establishment of the transferred target species.

Seepage water management

Within the project area - but outside the dike relocation area - most of the grassland remains agriculturally used with different intensities. The pastureland immediately adjacent to the new dike on landwards side receives additional seepage water due to the relocated dike. The parcels of land affected have been purchased by the project in order to mitigate the economic damage inferred by the altered water conditions. Furthermore a drainage ditch paralleling the dike 50 m inland was built with the intention to divide a wetter part of grassland along the dike from the more intensively used pasture lands further inland. In order to not drain the seepage dominated grasslands immediately along the dike completely, four vertical lifting gates have been installed in the drainage ditches. This is due to the conservation requirements for this area, which replaces the ecologically important seepage zone lost by the dike opening along the old dike, affecting a number of endangered species, mainly amphibians and other organisms of ephemeral waterbodies. Water level control is subject to permanent consultation between biosphere reserve administration, flood management authorities, state water managers and the local stock farmer.

The tenant of these impacted grasslands received financial compensation for lost profits.

Visitor guidance and education

The project holder "Trägerverein Burg Lenzen e.V." with its Biosphere Reserve visitor center and its Center for Floodplain Ecology has a strong background in environmental education. The large scale conservation project provides an ideal facility to practically demonstrate a new approach to safeguard riparian landscapes. Visitor facilities like hiking- and bicycle trails have been established to open the restored floodplain area for controlled accessibility with the aim to provide outdoor experience and a real insight into the developing floodplain landscape. Information tables, a viewpoint-shelter on the edge of the main inlet structure on the Elbe River and a large number of excursions provide comprehensive visitor information, adding in-the-field information to the respective expositions in the visitor center (Fig. 3).

Project evaluation and results

Despite the broad consensus that floodplain restoration and the enlargement of active floodplains are urgently needed on a large scale, the experience with such projects is still quite limited. In order to gather experience and share it for future projects, the present project included a number of evaluation measures to check for the success of the implemented actions and give the opportunity for alterations of the planned measures already within the project period. The fields of evaluation included the dike relocation, evaluated by indirect parameters like species abundance/occurrence of birds and fish species, changes in soil parameters and water level and socio-economic investigations. Direct evaluation was applied to concrete measures like forest plantations, floodplain meadow improvements and extensive grazing. The following table lists the evaluation parameters, methods applied and the data needed for the appraisal of the respective measures (Table 1).

Evaluation measures

Table 1.

Evaluation parameter	Methods and data expected
Avifauna	Regular observation routine; population trends, species composition
Fish fauna	Repeated population sampling; colonization of new waterbodies
Alluvial Soils	ground water levels, standard soil parameters, heavy metal content, soil moisture, soil redox potential, sediment quantity and -quality
Local Water level	Installation of dike gauges, local effects, verification of numeric models
Forest plantations	Stand investigations; mortality, species survival, practical experience
Floodplain meadows	Floristical species-abundance sampling; success of seed transfer
Pasture area	Floristical species-abundance sampling; effects of grazing
Socio-economy	Stakeholder interviews; regional economic and social effects

The tremendous change in landscape structure within the dike relocation area, following the abandoning of the grasslands and the altered water conditions immediately after decommissioning the drainage system of the area, started in 2005 right after the dike construction works began. Local birdlife proved to be a strong indicator for the ongoing successional processes. Extended periods of inundation followed by far reaching structural changes of plant communities resulted in ideal conditions for various kinds of waterfowl such as ducks, waders, geese and others which so far had been present in marginal numbers only on the former agricultural land. The number of resting migratory birds as well as breeding birds increased remarkably [5], making the site the most densely populated bird sanctuary far beyond the region. The four year investigations reflect the changes in habitat quality being influenced also by the annually very different inundation situation and some impact by ongoing construction works. Some waterfowl and wader species proved to benefit temporarily from the open conditions provided by the excavation works on more than 45 hectares and decreased with the regrowing vegetation layer. Nevertheless did the overall quality of the area as bird habitat improve greatly. Expected trends following the continued vegetational succession can be recognized in the development of functional bird guilds: while open grassland guild species are decreasing, wetland, shrubland and forest guild representatives are increasing in abundance.

Fish faunistic data also shows the ongoing successional processes: two newly created waterbodies were quickly colonized even before the reconnection with the main river by some species which are likely to be descendents of individuals which lived in the former system of ditches. Pike (*Esox lucius*), Sunbleak (*Leucaspis delineatus*) and Tench (*Tinca tinca*) have been caught in the first sampling before the re-connection. In 2010, three month after the first flooding, eight new species were sampled (Bleak / *Alburnus alburnus*, Catfish / *Silurus glanis*, European perch / *Perca fluviatilis*, Freshwater bream / *Abramis brama*), White bream / *Abramis björkna*, Common dace / *Leuciscus leuciscus*, Roach / *Rutilus rutilus* and Pope / *Gymnocephalus cernuus*), proving the importance of the newly created waterbodies for the river fish populations [7].

Besides these organismic investigations, the hydraulics of the dike relocation have been intensively studied for more than a decade by the BAW (see above), providing its technical design as result of a number of numeric and physical models and following the actual results by field measurements during the first flooding events. Four water level gauges installed along the new dike helped recording the exact local water levels in the new retention area during the flood events, being important for the verification of the numeric models.

The other evaluation parameters documented the ongoing landscape change with their respective results in a similar way.

DISCUSSION AND CONCLUSIONS

As laid out in the previous paragraphs, the project's evaluation measures proved the significant effects of the dike relocation project. Investigations on the avian and fish fauna documented the rapid developments within animal communities. Detailed vegetation investigations including repeated mapping of the whole dike relocation area within a Ph.D. program added a comprehensive documentation of changing plant communities. Further ongoing research activities coordinated by the project holder and the administration of the Biosphere Reserve support these results. Thus ample evidence is given for the greatly improved ecological status of the project area (Fig. 4). The complete change from a culturally dominated landscape to an area influenced entirely by natural processes will take a long time before a new state of equilibrium can even be approached. Thus the collected data so far documents early stages of a continuous successional development, making this project a very unusual and interesting research object to be continuously pursued.

Lessons to be learnt are being used far beyond the project region as can be seen by the great demand for information which the project management and the administration of the biosphere received. Being the largest dike relocation project completed so far in Germany, the project still receives much attention even on an international scale and continues to be quoted frequently by water managers, politicians, conservationists and other expert groups. Public environmental education efforts have reached numerous people and conveyed knowledge on floodplain ecology and appreciation for riparian landscapes in general.

It needs to be stated that the project was initially called a pilot project. Given the broad success of the implemented measures, the need for follow up projects is now very urgent but remains largely behind expectations. Putting into practice the experiences made in this project is the task to be accomplished elsewhere.

Research on the site, documenting and evaluating the continuing processes is also deeply needed beyond the activities being currently carried out with limited resources. The need for more project monitoring is being stated in many studies evaluating similar projects ([4]; [9]) and pertains particularly to an exemplary project like the one presented here. Long-term monitoring efforts need to be supported meeting scientific standards and ensuring a wide dispersal of the knowledge.

Rethinking particular aspects of the project and its layout might be another task to be approached. Taking the experiences made here and elsewhere and recent year's progress of restoration ecology, certain details could most likely be handled differently today. One detail concerns the hydraulic connection to the river. During the planning phase the situation on a federal navigation waterway led to a very cautious treatment of this aspect. No impact on the waterway was a prerequisite for the waterway administrations consent and the guideline for the model-based optimization process. Despite a discharge of about 30% of the total rivers discharge passing through the dike relocation area [1], erosional processes are very limited. Sediment deposition on the other hand is likely to occur due to the widening of the discharge channel, increasing the decoupling of the already eroded river bed and the rising floodplain surface. This adverse effect will slowly reduce the inundations of the floodplain, counteracting the goal to revitalize the floodplain and its ecosystems. The Elbe River in the project area is known for its ongoing bed erosion, making floodplain rehabilitation in the area even more challenging. Re-activation of erosional processes should be investigated as a sustainable tool to minimize the detrimental effects and even reduce the present distance between floodplain and river bed level.

SUMMARY IN ROMANIAN LANGUAGE - REZUMAT

Pe cursul mijlociu al râului Elbe în statul Federal Brandenburg al Republicii Federale Germania a fost inițiată și implementată cu succes pe o suprafață de 420 ha o măsură de reconstrucție ecologică. Astfel, în cadrul unui „Proiect de Conservare de mare amvergură”, finanțat din fonduri federale, un peisaj agricol dominat de pajiști a fost transformat între anii 2002 și 2011 într-o zonă de luncă naturală. Relocarea unui dig a fost esențială pentru a reface condițiile naturale de inundare care la rândul lor constituie premiza pentru reabilitarea unor comunități de animale și plante tipice luncilor inundabile. În același timp relocarea digului s-a dovedit a fi deosebit de importantă și benefică pentru protecția contra viiturilor, refăcându-se capacitatea de retenție prin lărgirea unei suprafețe inundabile foarte înguste și eliminându-se astfel o piedică hidrolică într-o cotitură periculoasă a râului. O pădure aluvială a fost inițiată prin plantare răzleață de specii lemnoase autohtone, lăsându-se însă cea mai mare parte a suprafeței liberă pentru succesiunea naturală a vegetației. Excavarea și adâncirea unor zone depresionare pentru crearea, respectiv în unele cazuri pentru refacerea de foste lucii de apă în luncă și menținerea unei pajiști extensive pentru cai a fost adăugată ca plusvaloare unei diversități de elemente peisagistice cu scopul de a reface un spectru larg de habitate de luncă cu un înalt nivel de biodiversitate. Schimbarea peisajului inițiată a intrat repede în procesul de succesiune, condiționat preponderent de regimul hidrologic în care perioade lungi de inundații au jucat un rol important. Semnificative schimbări în comunitățile de plante, a păsărilor și a peștilor au

putut fi documentate și evaluate, acestea servind drept exemplu și constituind o dovadă a succesului proiectului de reconstrucție ecologică cu toate măsurile luate. Activități de cercetare și educative continuă să joace un rol important în managementul proiectului.

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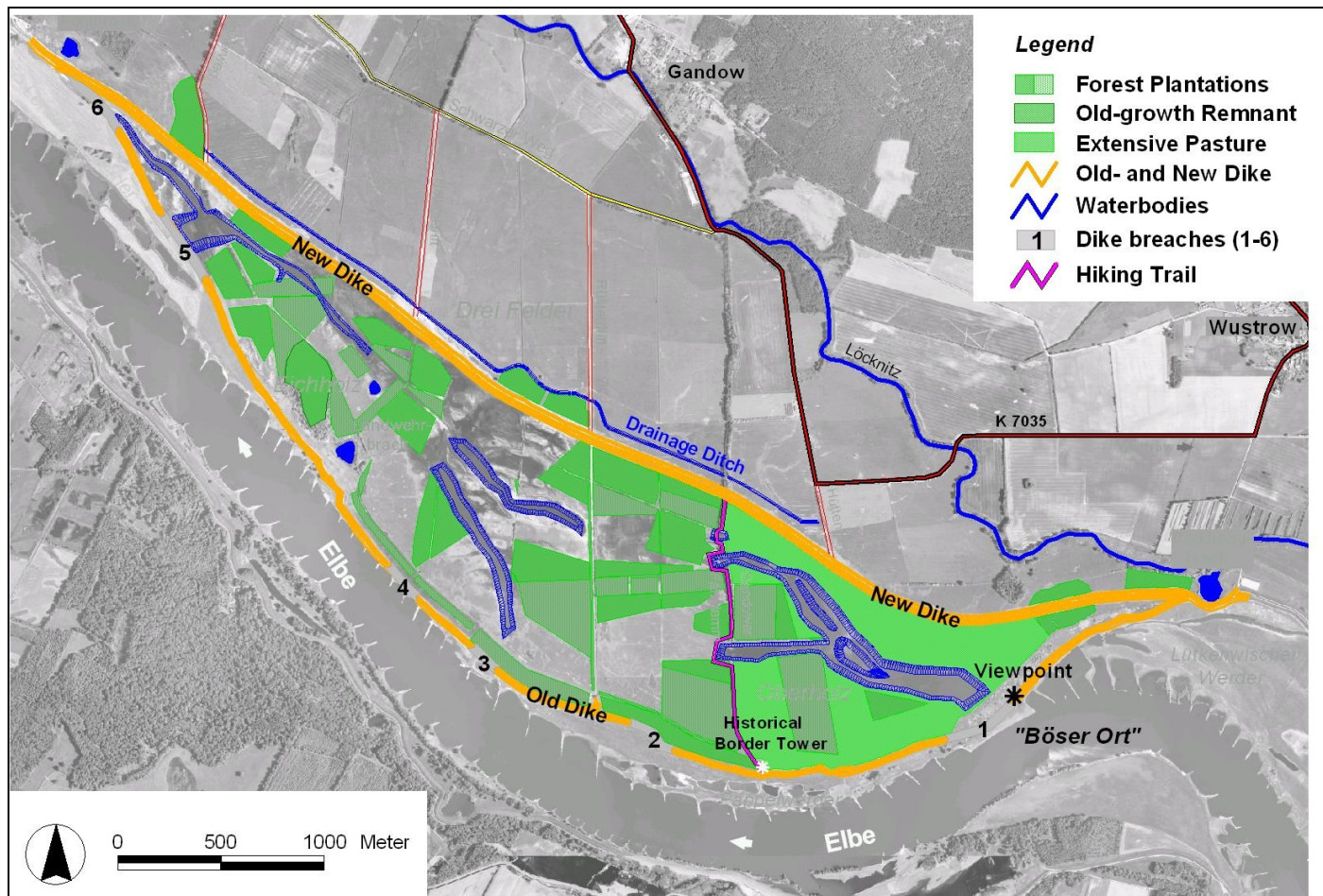


Fig. 1. Map of the 420 hectare dike relocation area on the Elbe River



Fig. 2. 420 hectares of rich-structured floodplain habitat developing on former pasture land.

Note. photo credit: K. Nabel.



Fig. 3. Excursions and information displays and a viewpoint shelter play an important role to convey the message of the project.



Fig. 4. Natural succession on former pasture land creates a diversity of habitats on an excavated flood channel