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Meeting Aichi Target 15: Efforts and further needs of ecological restoration in Hungary.

Abstract

Aichi Target 15 aims to enhance the resilience of ecosystems through the restoration of 15 % of degraded land by 2020. Compliance with the target is still insufficient, partly due to the lack of appropriate baselines and knowledge of restoration efforts. The four-level model of ecosystem condition was suggested to set the baseline and support the estimation of progress. This study is the first to assess the condition of MAES ecosystem types at a country scale, using the suggested approach. Altogether 613 000 ha of land is in close to natural condition (Level 1), 893 000 ha in a slightly degraded state (Level 2), 1 907 000 ha in moderately degraded condition (Level 3), and 5 890 000 ha of land is in highly modified category (Level 4). An inventory of ecological restoration interventions was created based on the reports of the national park directorates and EU LIFE projects. The findings of the restoration database of 634 interventions were compared to the need for restoration of nine habitat types. Restoration efforts were focused at habitat types with the most extended degraded area, except for dry forest restoration and the fight against invasive species in all three forest types. This study provides a more reliable estimate of habitats in natural state than Habitat Directive reporting can achieve, therefore better suited for estimating compliance with the 15 % target. Only 1 % of degraded land was the target for restoration in the period of 2002-2016. The details of the survey regarding habitat and degradation types can support further restoration planning.

Keywords: four-level approach; habitat condition; LIFE Nature projects; MAES ecosystem typology; restorable surface; restoration prioritization

1. Introduction

Ecological restoration as a means of enhancing biodiversity and improving the provision of diverse ecosystem services has been acknowledged at high international political levels by now (Aronson and Alexander 2013; Jorgensen 2015; Suding et al. 2015). The Aichi Biodiversity Targets of the Convention on Biological Diversity (CBD 2010) and the EU Biodiversity Strategy 2020 (European Commission 2011) both define 15% of degraded land to be restored by 2020. The implementation of this goal seems to be behind progress in many European countries (Cortina-Segarra et al. 2016; Tolvanen and Aronson 2016), and only few member states or regions have carried out restoration prioritization to guide the process (Aradóttir et al. 2013; Hagen et al. 2013; Kotiaho et al. 2016). However, many authors agree that the process should be accelerated to reverse biodiversity loss (Aronson and Alexander 2013; Tittensor et al. 2014; Tolvanen and Aronson 2016).

Several issues slow the compliance with the target, among others, the lack of systematic information on restoration activities (Aradóttir et al. 2013; Tobón et al. 2017). The selection of baseline is a critical step. The four-level approach developed by the "Green Infrastructure and Restoration Prioritization Working Group" (Lammerant et al. 2013) provides means for estimating the baseline and the progress towards the 15 % target. The concept classifies land cover to four levels of ecosystem condition from poor to excellent. Level 1 condition is close to natural, whereas Level 4 represents highly modified, severely degraded ecosystems. The idea is that any raise on this ladder of ecosystem condition can be considered restoration. Ecosystem condition can be evaluated with the help of different descriptors (i.e. indicators characterising ecosystem condition) and transition thresholds. The specific descriptors and transition thresholds have to be carefully identified to confirm the restoration. Priority is given to descriptors that have been collected at the EU level to enable between country comparisons (Annex 2. in Lammerant et al. 2013) and to ensure the update of data, but national databases should be used to complement these.

It is essential to test the feasibility of the evaluation of 15 % restoration accomplishment based on the four-level approach in real situations in order to comply with the targets. To date, only one attempt has been made at national level to classify degraded land according to the four-level model and identify proportion of land for each level as a baseline state for the Nordic countries (Estonia, Finland, Iceland, Norway, Sweden; Hagen et al. 2015). The five countries are different regarding how the four levels can be identified depending on the existing databases. A bias regarding the comparison between countries was perceived as the same percentage of degradation level might represent very different states as a result of different approaches used for data gathering and interpreting. This example demonstrates the difficulties rising from the task and calls for further surveys.

Another prerequisite to measure progress towards the 15 % restoration target is the availability of data on restoration activities (Aradóttir et al. 2013). Data can be derived from national censuses and statistics and from individual projects. Individual projects are diverse (Hagen et al. 2013), and even in the rare cases when databases are available (Halldórsson et al. 2012), several constraints may arise, worth investigating to help further restoration planning.

In this study we estimated ecosystem condition for the total area of Hungary based on the methodology suggested by Lammerant et al. (2013). We also gathered a database of terrestrial restoration interventions carried out by natural park directorates and NGOs in Hungary between 2002 and 2016, and evaluated restoration efforts towards the 15 % restoration target.

The following specific questions were investigated:

1) What is the baseline of ecosystem condition levels in Hungary according to the four-level approach of Lammerant et al. (2013)?
2) What was the extent of terrestrial ecological restoration in Hungary for the period 2002-2016?
3) What is the relationship between the spatial extent of degradation types and the type of restoration interventions in natural and semi-natural habitats?
4) What was the progress towards the 15 % Aichi target in Hungary between 2002 and 2016?

2. Material and Methods

2.1. Study area

Hungary lies in the Pannonian biogeographic region (Fig. 1) and its biodiversity is still rich in species and habitats (Mihók et al. 2017). This richness is indicated by the high proportion of area in conservation status: altogether 22.2 % of its territory is under EU or national protection (EU 21.4 %; 9.1 % national; NBS 2016). The biodiversity of the Pannonian biogeographic region greatly contributes to the natural wealth of the European Union as its territory only covers 3 %, but it is home to 17 % of plant and 36 % of bird species of Community importance.

2.2. Assessment of ecosystem condition levels for the territory of Hungary

Following Maes et al. (2013, 2014) and Lammerant et al. (2013) we adopted the recent MAES (Mapping and Assessment of Ecosystems and their Services) typology for terrestrial and fresh water ecosystems (Maes et al. 2013, Annex 2). We estimated the share of ecosystem condition levels defined by Lammerant et al. (2013) for each of the MAES ecosystem types by using the following databases. The MÉTA Landscape Ecological Vegetation Database (Horváth et al. 2008) was used primarily to inventory the natural and semi-natural ecosystems of Hungary. The MÉTA Programme was carried out at the beginning of the Millennium to survey the actual state of the vegetation heritage of Hungary (Molnár et al. 2007), and covered about 19 % of the country where natural and semi-natural habitats occurred. The estimated spatial extent of altogether 85 habitat categories (Bölöni et al. 2011) and other information, including the level of habitat naturalness (Bölöni et al. 2008) and causes of degradation (Botta-Dukát 2008; Molnár et al. 2008) were surveyed in the field in hexagon units of 35 hectares (Fig. 1).

The naturalness in the MÉTA database was estimated along a 1-5 gradient, 5 being the natural state (Molnár and Horváth 2008). The estimation for nature conservation purpose was based on the naturalness of species composition and vegetation structure of the habitat. Habitats in the highest naturalness (5) category have a high number of specialist and accompanying species, the structure is characteristic to the habitat type and there are no weeds and invasive species. These habitats are typically nature sanctuaries. Habitats in good natural condition (4) are less species rich, or their structure might be degraded. Naturalness 3 is dedicated to habitats in moderately degraded state with disturbance tolerant species, while heavily degraded habitats received 2 and totally degraded 1, that is, the habitat cannot be recognized and assigned to any natural or semi-natural habitats anymore (Bölöni et al. 2008). For example a closed steppe loess grassland is in naturalness 4 if the dominant grass species (*Festuca rupicola*) is underrepresented, other grass species dominate and accompanying dicots are less species rich (Bölöni et al. 2011). The naturalness categories of habitat types and their spatial extent were used in this study to estimate levels of ecosystem condition according to the four-level approach of Lammerant et al. (2013) for natural habitats. We assigned MÉTA naturalness 5 and 4 (natural, semi-natural) to Level 1, MÉTA naturalness 3 to Level 2 and MÉTA naturalness 2 to Level 3 ecosystem state. MÉTA naturalness 1 refers to Level 4. The description of characteristics of ecosystem condition levels is described in the online Appendix (Table A1).

As much of the human affected and controlled ecosystems, like settlements or intensively cultivated agricultural areas, part of forests, plantations and extended water bodies were not covered by the MÉTA database (Molnár et al. 2007), evaluation of additional data had to be considered to reach a full accounting of MAES ecosystem types. The Hungarian Water Management Plan (report to the Water Framework Directive) was used in relation to rivers and lakes (VGT 2010). Whereas summary statistics from the National Forest Inventory (NFI, Kolozs and Szepesi 2010) and the Forest Monitoring and Observation System (FMOS, Kolozs et al. 2009) were applied to extend data on all forested habitats. We used data from the CORINE Land Cover database (CLC, Heymann et al. 1994; Bossard et al. 2000) to complement the other databases and to cover urban and agricultural habitats. The summary of CLC 2006 database version 17 (EEA 2013) was applied that provided a ‘snapshot’ of the same period as the MÉTA Programme and various summary statistics of NFI and FMOS.

A detailed typology of MAES ecosystem types and a crosswalk among the used databases are demonstrated in the online Appendix Table A2. The concept of the decision process is demonstrated in Fig 2. A set of decision rules and threshold values were established to assign the appropriate extent of MAES ecosystem types to each condition level (for more detail see Table A3 in the online Appendix). According to this classification, we considered all states of ecosystems degraded that are not in Level 1, that is Level 2-4 categories.

2.3. Data gathering on restoration interventions

The data on terrestrial restoration interventions originated from two main sources: the documentation of EU LIFE Nature projects carried out in Hungary and the yearly reports of the ten Hungarian national park directorates, made available through their websites, dating between 2002 and 2016. The LIFE projects were found via the search engine of the EU Environment Life Programme and further information was gathered from the particular websites of the projects. We collected data on the location (at least at the settlement level), the year of the implementation, the target habitat types, the area and the type of the intervention. Interventions where these data were not available, were omitted from the analysis.

The types of restoration interventions were classified to the following categories: management of invasive species, wetland restoration, grassland restoration, and forest restoration. The control of invasive species was given at the species level. Data collected on restoration interventions were more detailed on targeted habitat types than the MAES ecosystem typology but frequently less specified than the MÉTA typology. Therefore, a meanly detailed classification of target semi-natural habitat types were used: Marshes (W_mar); Bogs and mires (W_bog); Aquatic habitats (W_aqu); Dry grasslands (G_dry); Meadows (G_mea); Salt grasslands (G_sal); Dry forests (F_dry); Mesic forests (F_mes); Riparian forests (F_rip). The assignment details of habitat groups are given in the online Appendix (Table A4).

2.4. Comparison of the reason of degradation and types of restoration interventions

Systematic information on habitat degradation was available only for natural and semi-natural habitats surveyed in the MÉTA database. Furthermore, restoration interventions focused on these target habitats. Therefore, the knowledge on the types of degradation was gathered from the MÉTA database covering 19% of the country. All habitats not in natural, or semi-natural state (naturalness categories 4 and 5, Bölöni et al. 2008) were considered degraded and the information on the reason of degradation and the total area of degraded habitat were retrieved from the MÉTA database for each of the nine habitat types, listed above. The reasons for degradation were grouped as the following: invasion by the 15 most dangerous alien species (or groups of species in the same genera), adverse water, grassland or forest management. Management not supporting the sustainability of the given habitat type and thus resulting degradation of biodiversity is called adverse management. It has to be noted that different types of adverse management can occur at the same site, so there can be an overlap among the areas degraded by different factors. The area and the type of restoration interventions carried out in the nine target habitat groups were compared to the area and reason for degradation of those habitat groups. Invasive species presence and restoration efforts were compared at a national level also by species.

2.5. Estimation of restoration achievement

In order to assess progress towards the 15 % target, the coarse scale (Level 1-4) ecosystem condition. Level 1 MAES ecosystem types, as a result of their good condition, are not target for restoration, so the restorable surface of Hungary is the total area minus the area of Level 1 MAES ecosystem types in accordance with Lammerant et al. (2013). The total area of restoration interventions is compared to the restorable surface. In this estimate we presumed that any restoration intervention increases the condition to the next, better level as there were no systematic information available on the effectiveness of each restoration project. This way, our calculation probably overestimates the progress towards the 15 % target.

3. Results

3.1. Area of the four ecosystem condition levels in Hungary

Area estimates for the MAES ecosystem types and the share of the different ecosystem state levels are shown in Fig. 3. Altogether 613 000 hectares (7 % of the country) can be considered close to natural (Level 1), not target to restoration efforts in Hungary. The largest areas of natural state ecosystems in decreasing order are found among woodlands and forests, grasslands, and rivers and lakes. Level 2 ecosystem condition extends over larger area (893 000 ha, 9.6 % of the country), whereas Level 3 ecosystems cover approximately 20 % of Hungary (1.9 million hectares). In the latter category, a fraction of cropland and urban area with some remnant biodiversity appears. More than 60 % of the country (5.89 million hectares) is highly modified (Level 4) due mainly to arable cultivation.

Rivers and lakes are in the best natural state with more than 64 % in Level 1 and 25 % in Level 2 condition. Wetlands are also categorized mostly to Level 1 and 2 conditions (47 % and 46 %, respectively). The majority of grasslands are considered Level 2 (35 %) and Level 3 (46 %). Despite the largest area of natural state forests among ecosystem types, the ratio of Level 1 forests is only 15 %, compared to the 58 % in Level 3 condition (mostly plantations, Fig.3). A small fraction, 1 % of tree plantations are assigned, according to expert estimation to Level 4 forests together with 4 % of heath and shrubs that represent young clear-cut areas.

3.2. Restoration interventions in Hungary

Our survey resulted in a database of 634 terrestrial restoration interventions for the period of 2002-2016. The map with the locations of activities at settlement precision can be found in Fig. 1. Mesic forests, grasslands (all three types) and marshes were restored at the largest total area. Data are demonstrated with the degraded area of the relevant habitat group based on the MÉTA naturalness estimates (Fig. 4). Degraded habitats refer to the areas in the MÉTA database that are not assigned to naturalness 5 or 4, these natural, semi-natural areas are not demonstrated in the Figure. High treated / degraded area ratio was found for wetland marshes and dry and meadow grasslands (18, 13, 12 % respectively). Forested habitats seem to be less treated (between 1 and 6 %) in relation to their degraded area. In case of aquatic wetlands the restored area exceeds the degraded area as a result of the low representation of freshwater habitats in the MÉTA database.

3.3. Comparison of degradation type and restoration interventions

Adverse water management, not supporting the sustainability of the habitat, and resulting in degradation was found primarily in salt grasslands and meadows, marshes and riparian forests (Fig. 5a). Water regulation as a means of restoration was mainly carried out in marshes, aquatic habitats, salt grasslands and meadows. Adverse grassland management affects the largest areas in meadows and grasslands, and grassland restoration was carried out focusing on these habitat types (Fig. 5b). Adverse forest management affected mainly mesic and dry forest, and restoration focused on the mesic type (Fig. 5c). Degradation due to invasion was abundant in all habitat groups, whereas elimination programmes aimed primarily at dry grasslands, grassland meadows and dry forests (Fig. 5d). At the species level, the most widespread were woody invasives, primarily black locust (*Robinia pseudoacacia,* at 463 833 ha) and Russian olive (*Elaeagnus angustifolia,* at 115 107 ha) (online Appendix Fig. A1). From the herbaceous species, *Solidago spp*. (237 942 ha) invaded mostly wetter and *Asclepias syriaca* (59 420 ha) drier areas. Restoration interventions targeted a very limited area of the infected sites (5 397 ha for *R. pseudoacacia*, 3 710 ha for *E. angustifolia,* 5 658 ha for *Solidago spp,* and 3 721 ha for *A. syriaca),* however, interventions concentrated on the most problematic species (Fig. A1).

3.4. Estimation of restoration achievements

By deducting Level 1 ecosystem condition area (613 000 ha; Table 1) from the total area of Hungary (9 303 000 ha) the restorable surface is estimated 8 690 000 ha, that is about 93 % of the country. The total area of restoration interventions is 92 057 ha based on the restoration survey. As we consider the restoration interventions to be successful in raising one level up the ecosystem condition hierarchy, this means the restoration of 1.06 % of the degraded area for the period of 2002-2016, according to the method of Lammerant et al. (2013). In case we follow the approach of Egoh et al. (2014) and deduct Level 4 urban areas (536 000 ha; Table 1) from the restorable surface (equals 88 % of the country), the studied restoration interventions cover in total 1.13 % of degraded areas. If croplands in Level 4 are also deducted from the restorable surface (31 % of the country), the restored area is 3.24 %. The most permissive way to count the level of achievement could be to only take the degraded area in the MÉTA database into account as restorable surface (note that it only covers the 19 % of the country), this way the restored area would reach 5.29 %.

4. Discussion

The present study is the first estimate of the compliance with the Aichi restoration target for Hungary by using field based ecosystem condition and degradation assessments and data on ecological restoration carried out in the period 2002-2016. The survey revealed a remarkable delay in reaching the target by 2020. According to the four-level approach (Lammerant et al. 2013), in 14 years less than the tenth of the aim (1.06 %) was achieved regarding ecological restoration that calls for a significant acceleration and scaling up of activities.

The approach followed provided a precise and scientifically sound assessment for natural and semi-natural terrestrial habitats, but the ecological restoration interventions only represent a partial inventory of activities. However, these interventions, with focus on biodiversity have a reliable potential to increase naturalness of ecosystems along the ecosystem condition level by one step, especially at Level 2 or 3. The collection of standard data and the construction of the database during this study is a major step forward, as there is a general lack of information for the purpose of Aichi Target 15 (Tittensor et al. 2014; Vanhove et al. 2017). However, there are some uncertainties regarding the estimation of restoration results. In the absence of systematic information on the outcome of restoration interventions, we assumed that the naturalness increased at least one level in each case. This probably resulted in an overestimation of restoration progress. The exclusion of data-poor projects (28 %) from the survey added to the underestimation of the restoration activities. A third source of uncertainty emerges from the investments carried out in the studied period causing degradation, but there was no data available to include them in our survey. With all these uncertainties, however, we can state that the 15 % restoration target will most probably not be achieved by 2020 in Hungary, like elsewhere (Leadley et al. 2014). This is in line with the mid-term report of the Convention of Biological Diversity at a global scale (CBD 2016). The study raises the question whether the methodology for estimating the restorable surface should consider the trade-offs emerging with urban areas and croplands to be completely part of the restoration target.

4.1. Assessment of ecosystem condition levels (Level 1-4)

To comply with the Aichi restoration target, inventorying the condition of ecosystems and assembling data on restoration interventions is necessary (EEA 2015, Box 5.2). By only using data of different reporting obligations, like that of the CBD or the EU Habitat Directive, the level of achievements towards the target cannot be estimated. The Nordic countries made efforts to use the existing databases and report for five countries to assign ecosystem condition to the four levels (Hagen et al. 2015), but results are rough estimates and call for further inventories.

This study provides the first assessment of ecosystem condition levels for the MAES ecosystem types for the complete territory of Hungary using the suggested approach (Lammerant et al. 2013). Uncertainties exist regarding precision and reliability of data, as several databases were used in parallel. Decision rules and threshold values provided by the Restoration Prioritization Framework are rather vague, therefore expert judgement was involved. This might represent a bias when comparing ecosystem condition levels between countries (Hagen et al. 2015). However, by using best available knowledge sources and precise descriptions of the estimation methodology the outcome can be a major basis for the monitoring of restoration achievements.

Following the four-level approach and the estimates gathered for MAES ecosystem types, 7 % of Hungary (613 000 ha) is in close to natural state (Level 1). Natura 2000 ecosystems in favourable conservation status cover 371 000 ha (19 % of designated area), as reported in 2013 (NBS 2016). The difference (1.6 fold) of area demonstrates that a thorough inventory of ecosystem condition is necessary for providing a more precise assessment of the extent of Level 1, 2 and 3 ecosystem conditions, with the help of other national databases to complement Natura 2000 reporting. We cannot compare the resulting state levels to other countries, as even the Nordic country survey only provides percentages of ecosystem types assigned to the levels (Hagen et al. 2015). Therefore, the degraded area and target for restoration that should be the basis against which to count the 15 % restoration target is not defined so far in the literature (Tittensor et al. 2014). Egoh et al. (2014) tried to estimate efforts to reach the target by using only Natura 2000 habitat data and considers all EU Member States as one unit, however, the targets should be achieved by country, preferably including all major habitat types (Lammerant et al. 2013).

4.2. Status of ecological restoration in Hungary

By using the best available data on the restoration activities gathered by a standard methodology we provide the first estimate of the status of ecological restoration for Hungary. The data acquired this way has uncertainties. First, only data on restoration carried out by natural park directorates and NGOs was gathered, but other interventions, like rehabilitation of industrial areas or large water bodies, and other activities to lower adverse impacts are not included in the lack of data. Efforts were made for extending our database with rivers and lakes at national level by using the reports to the Water Framework Directive (VGT 2010; 2016), however, the change in the methodology during the period prevented a reliable estimate of ecological state and improvements. Another uncertainty of the study is that no information was gained on the success or failure of the restoration interventions; we only know that the efforts were made. The lack of knowledge on the outcome of the interventions draws attention to the need of monitoring, evaluation and the publication of the results (Lammerant et al. 2013; Navarro et al 2017). In this context, our study provides measure descriptors in the sense of Lammerant et al. (2013) as initiated restoration actions. To summarize, the database underestimates the area of restoration interventions, but might over-estimate their success by assuming the raise of one ecosystem state level as an outcome.

We have limited information to compare the restoration efforts in Hungary to other countries. Published data exists on the area restored for particular ecosystem types for a few countries (Hagen et al. 2015), e.g. Finland restored 200 km^2 of forests and woodlands, but in the lack of other data, no summary can be made for the whole country and all ecosystem types. The Global Restoration Network has a database on restoration projects, but its geographical bias and low number of entries avoid its use as a source for national estimates (Navarro et al. 2017).

4.3. Comparison of the type of degradation and restoration aims

This is the first comparison of restoration interventions and degradation types for habitat groups that can assist in further restoration planning. Restoration interventions analysed in this study were initiated mainly at habitat groups where degradation problems occurred, however at a very limited area. Most effort was put in improving the state of degraded grasslands, marshes and mesic forests. Further effort was invested in the fight against invasive species. Hungary lies in the gateway of species invasion and is especially threatened by plants and animals as well (Lukács et al. 2016; Takács et al. 2017). Therefore, restoration efforts are important for their control, but the area should be greatly increased to cope with the problem.

4.4. Planning further restoration

The mid-term review of the EU Biodiversity Strategy (European Commission 2015) states that no significant overall progress was made, the same is true for the Aichi targets (RSPB 2016). There is a general opinion of the failure of reaching Aichi targets in the required time frame (Leadley et al. 2014; Tittensor et al. 2014; Cortina-Segarra et al. 2016; Tolvanen and Aronson 2016; Teh et al. 2017). Despite of probable non-compliance, the targets should not be given up (Simberloff and Vitule 2014; Tolvanen and Aronson 2016; Ruete et al. 2018).

We demonstrated that a remarkable amount of effort is still needed to meet the 15 % target. Different approaches to estimate restorable surface result in different percentages of restored area, however, only expanding from 1.06 % to 5.29 %, far from the 15 %. In the most permissive version of estimation, when the restorable surface is only based on semi-natural degraded area estimated by the MÉTA database (describing only 19 % of Hungary) instead of the total of L2-4 level of area (with or without urban and cropland), more than 84 000 hectares have to be restored in the two upcoming years to meet the target of 15 % by 2020, by taking into account of the area already restored (92 000 ha). It is rather unlikely that the target will be met in the remaining period. The utmost benefit of this survey is to provide numerical estimate for the target by using best available, site-based data and rigorous, repeatable methodology.

Our methodology in pointing out the major degradation causes and threatened habitat groups in comparison to past restoration efforts at a fine scale can be a major contribution to guide restoration prioritization at a national level. We quantified the need for further restoration in forests, especially in dry forests. The low forest restoration activity is a sign of forest management being largely economic and less conservation targeted, however, recently new, more sustainable concepts emerged in forest management (Stanturf et al. 2014; Csépányi 2017). Restoration to counteract problems caused by invasive species is another area to be strengthened and harmonized at the EU level (Hulme et al. 2009). The results of the study can contribute at a national level to the planning of the Post-2020 Biodiversity Framework (CBD 2018) and can support to specify the targets. The need to "rocket" (Perring et al. 2018) ecological restoration is recognized by the United Nations General Assembly, declaring 2021 – 2030 the UN Decade on Ecosystem Restoration. In the lack of other examples, our survey is a minor, but necessary contribution to this goal at a national level, and could influence other countries to follow the methodology, by using best available field based knowledge.

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Supplementary data (Online Appendix)

Characteristics of ecosystem condition levels (Level 1-4) based on the habitat naturalness indicators, extracted from the MÉTA database are demonstrated in Table A1. A detailed typology of MAES ecosystem types and a crosswalk among the used databases is demonstrated (Table A2). A set of decision rules and threshold values were established to assign the appropriate extent of MAES ecosystem types to each condition level (Table A3). A table on the nine habitat groups and their relevant ÁNÉR and Habitat Directive categories helps to compare the groups to European level habitat types (Table A4). Area invaded by the 15 most abundant invasive species and the area of interventions aiming to eradicate them can be found in Fig. A1.

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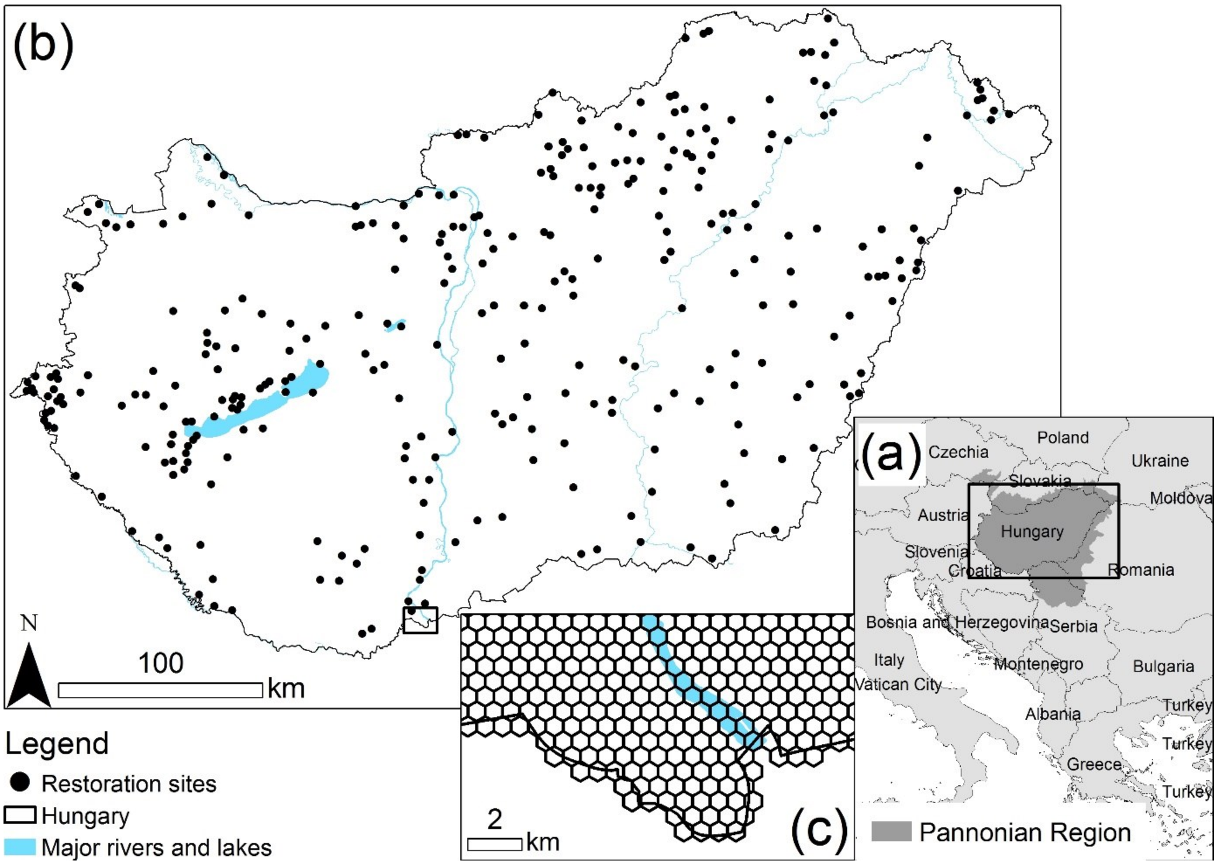


Fig. 1. Map of the study area. a) The Pannonian biogeographic region; b) Map of Hungary with the points of analysed restoration interventions; c) Sample of the MÉTA database hexagons, units from where the naturalness and reason for degradation data were retrieved.

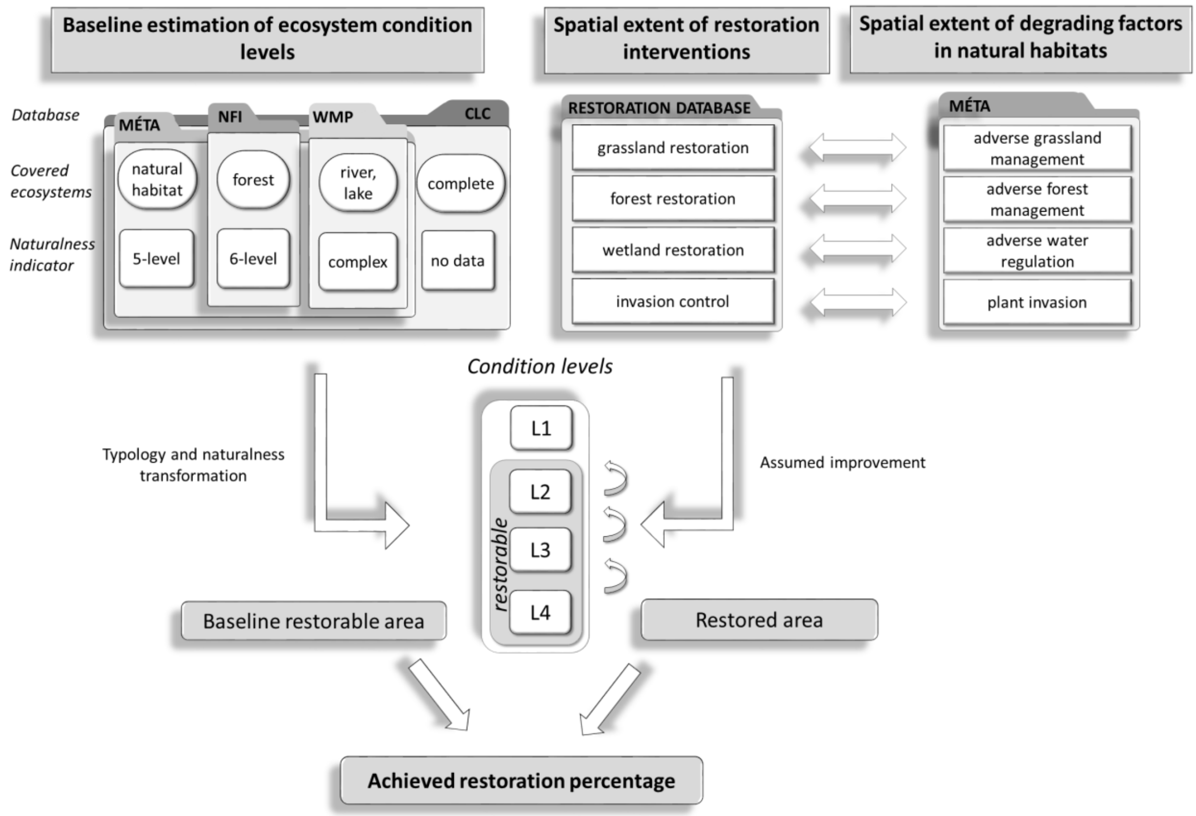
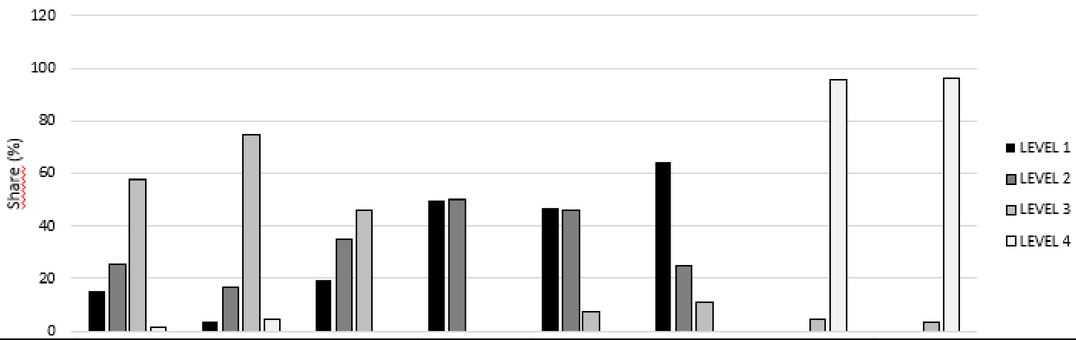


Figure 2. Conceptual diagram of the decision tree of the assignment of ecosystems to condition levels Level 1 – 4 according to Lammerant et al. 2013. Ecosystem types refer to MAES ecosystem types (Maes et al. 2013). Data sources are: MÉTA, National Habitat Classification System (ÁNÉR – Bölöni et al. 2011); CORINE Land Cover types (Bossard et al. 2000) for Hungary; NFI, forest type categories of National Forest Inventory (NFI – Kolozs & Szepesi 2010); WMP, Water Management Plan (WMP – VGT 2010, 2016). The restorable area is considered as all condition levels except Level 1 (natural, semi-natural). Detailed description of the process is added in the Supplementary Material, Table A3.



MAJOR ECOSYSTEMS	WOODLAND & FOREST	(HEATHLAND) & SHRUB	GRASSLAND	SPARSLY VEGETATED	WETLANDS	RIVERS & LAKES	CROPLAND	URBAN	**TOTAL**
LEVEL 1 (ha)	270 000	10 000	170 000	1 000	49 000	113 000	0	0	**613 000**
LEVEL 2 (ha)	450 000	45 000	305 000	1 000	48 000	44 000	0	0	**893 000**
LEVEL 3 (ha)	1 010 000	200 000	400 000	0	8 000	19 000	250 000	20 000	**1 907 000**
LEVEL 4 (ha)	25 000	12 000	0	0	0	0	5 317 000	536 000	**5 890 000**
TOTAL (ha)	**1 755 000**	**267 000**	**875 000**	**2 000**	**105 000**	**176 000**	**5 567 000**	**556 000**	**9 303 000**

Figure 3. Classification of the area (ha) and share (%) of ecosystem condition according to the four-level approach (Lammerant et al. 2013) for Hungary, based on the decision rules indicated in the online Appendix (Table A3) and the conceptual diagram, Fig. 2. Level 1 ecosystems are in close to natural condition, Level 2 are in slightly degraded state, Level 3 ecosystems are in moderately degraded condition and Level 4 are in severely degraded or highly modified state. Ecosystem types are given according to MAES categories (Maes et al. 2013).

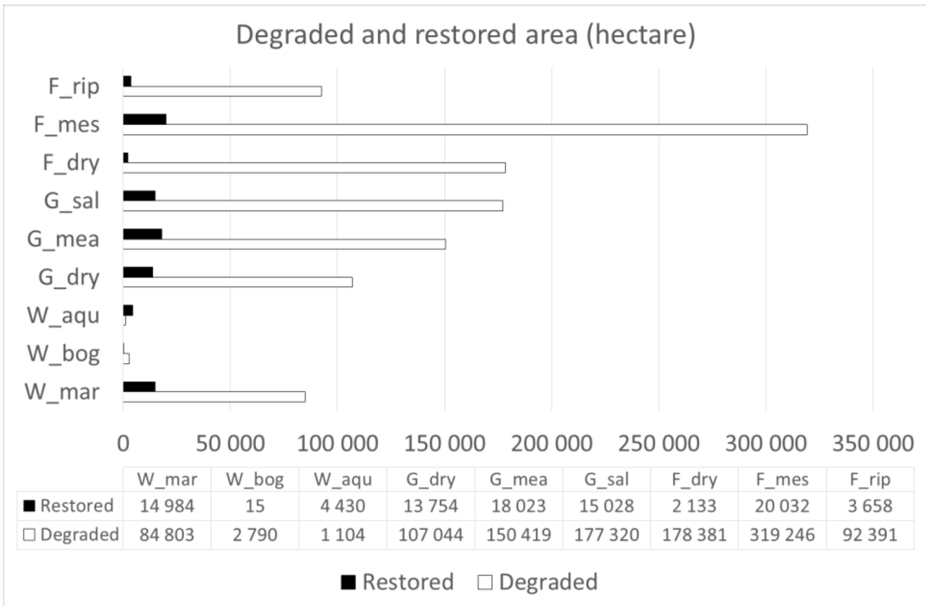


Fig. 4. Total area (ha) of degraded habitats (not in natural, semi-natural state; naturalness 5 and 4 excluded; Bölöni et al. 2008) within the MÉTA database (1 739 025 ha) and that of total restored area (92 057 ha) for the nine habitat groups. Codes of the groups: Wetland / marshes (W_mar); Wetland / bogs/mires (W_bog); Wetland / aquatic (W_aqu); Grassland / dry (G_dry); Grassland / meadows (G_mea); Greassland / salt (G_sal); Forest / dry (F_dry);

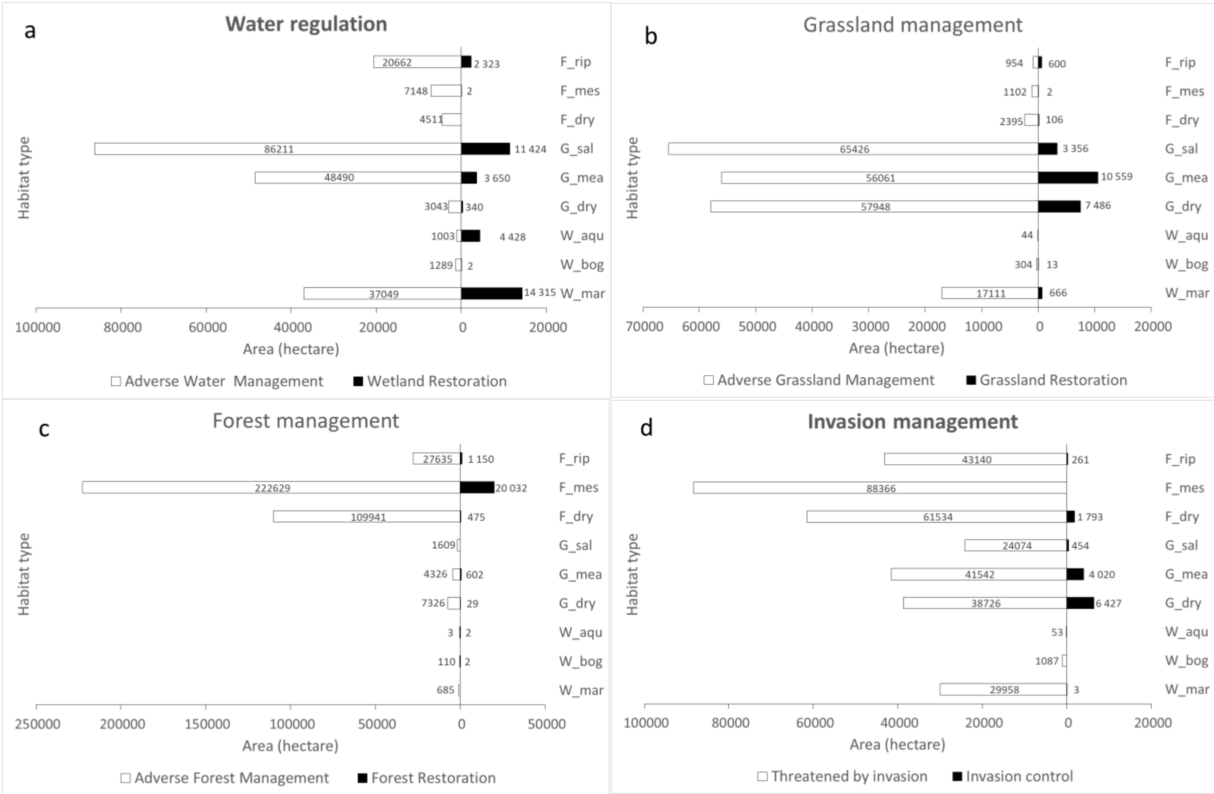


Fig. 5. Area of degraded habitat types based on the MÉTA database and that of restoration intervention types. a) Adverse water management and restoration area by water regulation; b) adverse grassland management and grassland restoration area; c) adverse forest management and forest restoration and d) invaded areas and invasion treatment for the nine habitat types in hectares. For codes of the habitat groups see Fig. 4.