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A comprehensive analysis of forest restoration practices across Europe: Ecological, economic, social and policy dimensions

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ABSTRACT

Scaling up ecosystem restoration is essential to halt and reverse land degradation and biodiversity loss and ensure future functionality and resilience. However, the implementation of concrete restoration initiatives will present many challenges, such as setting appropriate and realistic goals, selecting or developing the most effective and efficient restoration practices, as well as carrying out effective short- and long-term monitoring of success. Furthermore, there is a lack of information to facilitate the implementation of effective restoration interventions. To address this knowledge gap we gathered information on the ecological, economic, social and policy challenges faced by restoration practitioners across Europe using a widely distributed online survey.

Based on the 398 responses received from practitioners working in 31 countries we assessed how practical and scientific knowledge form an integral part of restoration initiatives. The focus of more than 40% of respondents from restoration projects was on increasing the population of species (plant species) and promoting their regeneration. Two common elements emerged across the wide diversity of responses: 1) a prevalent belief that restoration enhances multiple ecological aspects simultaneously, and subsequently, 2) the importance of developing monitoring frameworks that holistically evaluate restoration effectiveness, given the difficulty in defining a single, exclusive indicator of restoration success, as this could oversimplify the outcomes in complex ecosystems. Furthermore, respondents emphasized the importance of taking a holistic approach to restoration design, encompassing not only ecological aspects but also social, economic, and policy dimensions. The findings from the analysis of this survey provide, for the first time, a comprehensive view of the ecosystems and restoration activities that European countries are prioritizing, along with evaluation by the stakeholders involved.

1. Introduction

Despite the widespread consensus on the positive impact of ecological restoration initiatives (Suding et al., 2015a), there continues to be a significant gap in our knowledge with regard to the effectiveness of these projects, particularly their long-term effects on ecosystem service provision. To address this challenge, as also reflected in the Nature Restoration Law (NRL) provisions, there is a growing consensus on the

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need for enhanced long-term monitoring efforts over a period of up to several decades (Herrick et al., 2006), focusing not only on biodiversity but also on the outcomes related to ecosystem services (Rey Benayas et al., 2009). By improving our monitoring strategies and definition of restoration potential, the effectiveness of restoration initiatives can be better assessed and their long-term sustainability and economic viability ensured (Hanson et al., 2015).

In the European Union (EU), forest related policies with their associated funding have strongly influenced the type of forest restoration that has been undertaken in recent decades in Europe. These policies, together with other factors, have been instrumental in shifting the focus of forest restoration towards multifunctionality (Erdozain et al., 2024). In the absence of a legally binding EU forest policy (Winkel and Sotirov, 2016), forest management and restoration have largely been influenced by non-forest sector policies. Key drivers include the Common Agricultural Policy, particularly through the European Agricultural Fund for Rural Development (EAFRD); the Nature Directives, supported by the LIFE program for environment and climate initiatives; and the Water Framework Directive (Sotirov et al., 2021). Together, these policies shape forest management practices and restoration efforts across the EU. The EU Habitats Directive (CEC (Council of the European Communities), 1992) and Birds Directive (EU, 2009) with their regulations-based Natura 2000 instrument for area conservation, together with EU CAP funding for forestry measures, have probably been the most influential policies for forest restoration (Sotirov, 2017). Recently, the 2019 European Green Deal has set out the need to plant 3 billion trees while fully respecting ecological principles to help reach climate neutrality by 2050 (EC, 2019), while the EU 2030 Biodiversity Strategy (EC, 2020) calls for effective restoration of ecosystems including strengthening protection of at least a third of the EU's protected areas. The implementation of these EU forest related policies has been challenging (Sotirov, 2017). In the meantime, the conservation status of forest habitats and species in the EU's Natura 2000 Network continues to decline with 85 % being assessed as having an unfavorable conservation status (EEA (European Environmental Agency), 2020). This underscores the urgent need not only to strengthen the protection of European forests but also to restore them. This priority is increasingly reflected in both existing and new EU policy instruments designed to directly regulate or fund forest restoration efforts. The most important of these is the EU Nature Restoration Law proposed by the EU Commission in 2022, and approved by the Parliament and the Council in August 2024. The NRL, aims to restore at least 20 % of land and sea in need of restoration by 2030, including forest under the Natura 2000 initiative. In addition, in managed forest ecosystems, NRL seeks to encourage an increase in the trend for close-to-nature forest management. To achieve these goals, the NRL requests Member States to develop National Restoration Plans (EC, 2022). While supporting the conservation of biodiversity under the EU Nature Directives, this is the first comprehensive, EU law that establishes legally binding targets for the *restoration* of biodiversity in degraded ecosystems (EC, 2024). While the NRL does not provide direct funding, the EU LIFE funding instrument for the environment and climate action is one of the primary funding sources for ecological restoration projects (Andersen et al., 2017; Carvalho et al., 2019; Egoh et al., 2014; Hering et al., 2010). The LIFE instrument has funded initiatives that focus on rehabilitating endangered terrestrial and aquatic ecosystems, including in forest ecosystems, aligning with the guidelines outlined in the EU Nature Directive as well as the EU Water Framework Directive. Terrestrial ecosystems, particularly forests, grasslands, and wetlands, received the majority of project funding, with over 85 % of projects focusing on biodiversity conservation, while the remaining projects primarily targeted climate-change-related goals like mitigation and adaptation (UNEP-WCMC et al., 2020).

Furthermore, in recent decades, several national and regional strategies for ecological restoration have been developed, aiming to prioritize habitats or species for national restoration and conservation initiatives (Buisson et al., 2018; Cortina-Segarra et al., 2021; Hagen et al., 2013; Maes et al., 2020). The major barriers identified for restoration initiatives in Europe include economic, political, and governance challenges such as insufficient funding, conflicting interests among stakeholders, low political priority, and a lack of integrated land use planning (Cortina-Segarra et al., 2021; Halme et al., 2013; Erdozain et al., 2024).

Recent research initiatives have focused on learning directly from restoration actors around the world. These initiatives have employed methods such as (1) surveying individuals to understand their ongoing practices (e.g., Cole et al., 2024; Erdozain et al., 2024) and views on restoration dynamics (Nerfa et al., 2021); (2) systematically assessing freely available information on assisted forest restoration (Martin et al., 2021; Schubert et al., 2024); and (3) assessments of national and global restoration target setting (e.g., (Fagan et al., 2020) and progress (e.g., Forest Declaration Assessment Partners (2023). Moreover, emerging data platforms such as Restor (Crowther et al., 2022), the IUCN Restoration barometer (IUCN, 2022), and the Framework for Ecosystem Restoration Monitoring have made significant strides towards providing transparent web-based platforms that detail where restoration is taking place, what approaches are being used, and which communities are leading these efforts. However, restoration itself is a highly complex and regionally context-dependent socio-ecological process in which different direct (e.g., land use practices, climate change, ecological processes) and indirect (e.g., policy, economic, and social) drivers are at play (IPBES, 2019). Currently, the scientific and practical understanding of the main direct and indirect drivers of (forest) restoration in Europe (and beyond) remains limited or incomplete. As a result, there is a clear need in Europe for a more comprehensive study that not only examines the ecological factors traditionally explores in this field but also considers the social, policy, and economic drivers.

The main aim of this study is therefore to analyze and learn from the European forest restoration initiatives from a holistic perspective, by providing a comprehensive overview of the restoration activities being undertaken by European countries, and synthesizing practitioner perspectives on what drives the outcomes of their projects. Our specific objectives are: (1) to describe the goals of implemented, ongoing, or planned restoration initiatives; (2) to evaluate the compatibility of these goals; (3) to compile the indicators used to assess project outcomes; and (4) to analyze the benefits across ecological, economic, policy and social aspects of the initiatives. To achieve this, data was collected from practical experiences across Europe via cross-sectional stakeholder surveys, exploring the ecological, social, economic, and political drivers of restoration initiatives and how their outcomes are being assessed.

2. Material and methods

2.1. Research design and data collection approach

We designed an online questionnaire to collate knowledge and experience from past, ongoing and planned forest restoration and adaptation projects across Europe. This survey was designed as a multidisciplinary evaluation of the ecological, social, economic and political expertise in forest restoration in these countries.

We considered forest restoration as any action or project (hereinafter referred to as restoration action) that aims to improve the biodiversity, ecological integrity and provision of services in forest ecosystems. As such, actions such as rewilding, reforestation, afforestation, remediation, rehabilitation, prestoration (restoration that specifically includes climate change adaptation), or any shift in direction of a closer to nature forest management, can be included within the term restoration action. Similarly, restoration action could range from a passive approach, such as fencing an area to facilitate natural regeneration, to assisted restoration, such as creating habitat trees to promote biodiversity in forest management, to an active approach, such as enrichment planting to enhance resilience or planting after disturbances, including fires and wind storms. In summary, respondents were encouraged to think big when considering which initiatives fit under the forest restoration umbrella. The data of this survey were anonymised, synthesized and results made publicly available to support managers' decision-making and improve future restoration actions. This definition was included in the presentation of the online questionnaire.

The questionnaire was dynamically structured so that, based on the responses given, the questions became more specific, following a pre-established decision tree. In this way, not only did the type of stakeholder influence the path taken through the questionnaire, but the respondent's level of knowledge also determined the amount of detail required for the questions. The survey included a variety of multiple-choice and open answer questions depending on the topic (Supplementary Material 2 provides the complete questionnaire as it appears on the online webpage). Fig. 1 presents a general scheme of the questionnaire structure based on two levels of information detail: (1) general information, and (2) detailed information. The range of possible questions to be answered depended on the topic, with a maximum of around 200 questions for projects with three restoration objectives. Only the questions that were core to the decision tree were mandatory. Because of this, there may sometimes be a different number of answers for each question.

The online version of the questionnaire was officially available in six different languages (English, Spanish, French, German, Italian and Polish) on the 24th April 2023 at *https://www.tickstat.com/superbquestionnaire*. The questionnaire was sent via email to more than 1500 researchers or public/private institutes. At the same time, it was presented in several workshops (two in Spain, one in Italy) and some international (Sweden, Portugal and Estonia) and national congresses where practitioners, landowners and other potential initiative leaders were also engaged.

2.2. Data analysis

To explore potential patterns of the answers obtained across Europe, we first grouped all European countries following Forest Europe (2020) into five regions: i) Northern Europe, ii) Central-Western Europe, iii) Central-Eastern Europe, iv) Southwestern Europe, and v) Southeastern Europe. For each region we summarized the: 1) Restoration objective, 2) Pre-restoration land use, 3) Status of the restoration initiative, 4) Role of the respondents in the restoration initiative, 5) Respondents' experience with restoration, 6) Challenges encountered in engaging stakeholders in restoration initiatives, 7) Degree of stakeholder involvement, 8) Restoration phase involving stakeholders, and 9) Existence of conflicts among stakeholders. The Pearson Chi-squared test was utilized to assess aspects such as the proportional geographical distribution of respondents, or specific objectives for specific regions. If the significance associated with this statistic was lower than or equal to 0.05, we would reject the null hypothesis of independency. Additionally, Cramer's V statistic was computed to measure the degree of association between these aspects. This statistic is normalized and ranges from 0 (indicating no association between the aspects) to 1 (showing a strong association between the aspects). All the analyses conducted were subjectively reliant on the responses received to the online questionnaire and may not fully represent the reality of restoration initiatives across Europe.

We also conducted an assessment of the compatibility among restoration objectives based on the survey of respondents' perceptions and opinions. To facilitate the analysis of responses, three compatibility groups were established to classify them based on the frequency of responses: high compatibility was assigned when 75 % or more of the responses indicated this level, medium compatibility when the figure was 25 % to 75 % of responses, and low compatibility when the percentage was 25 % or fewer. In addition to the 21 possible main objectives of the restoration initiative, three additional aspects were included in the compatibility analysis: Social acceptance, Local acceptance, and Forest aesthetic attractiveness from a human perspective. These aspects could be considered as restoration objectives. However, they were not initially considered as such.

To address the ecological aspects related to restoration objectives, the use of ten ecological factors was assessed: distribution, abundance, and composition of species; structural diversity; presence of deadwood; functional groups; physical environment; ecosystem functions; ecosystem suitability; ecosystem health; ecosystem resilience; and ecosystem persistence. The level of agreement on the benefits of each of these 10 ecological factors, due to restoration initiatives, was evaluated

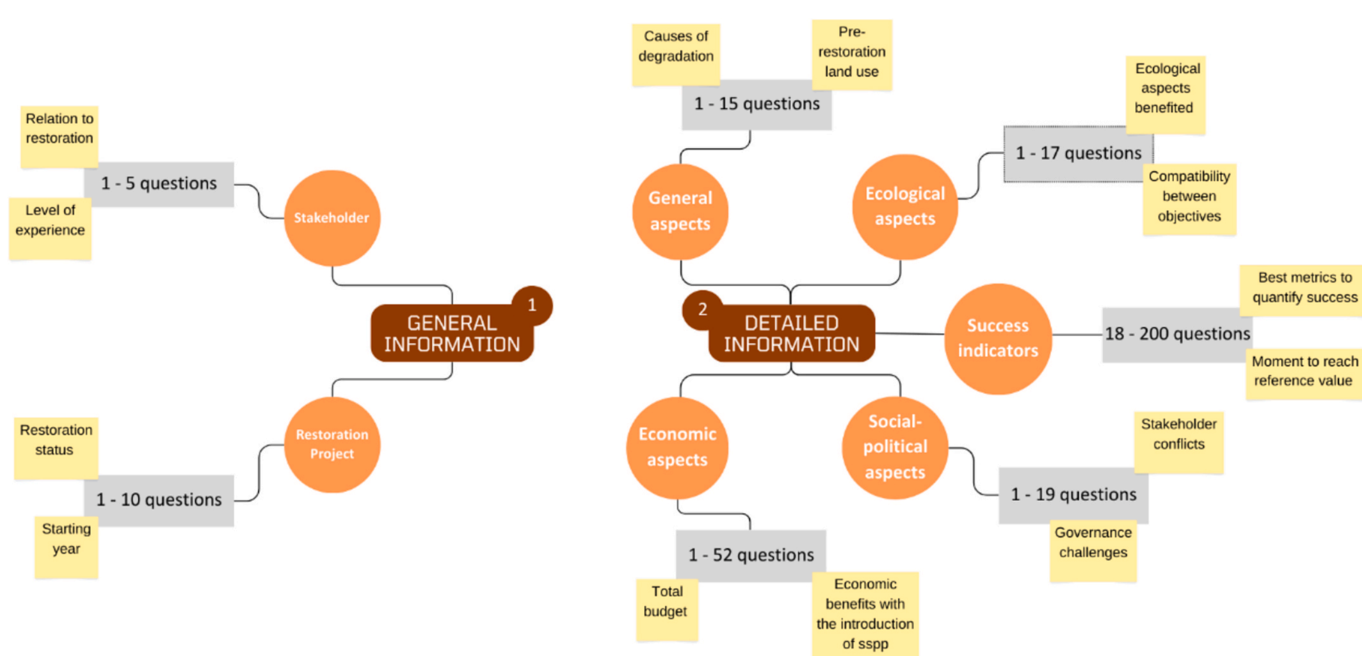

Fig. 1. Scheme of the online questionnaire structured into general or more detailed information (brown colour), with the various aspects considered (orange colour) to classify the topics of the questions, the range of possible questions, per aspect, in grey, and examples of addressed topics in light yellow. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

based on the type of objective. The same methodology was used as in the comparison between restoration objectives.

Finally, we assessed economic, social and political drivers of projects. Our survey also included questions related to the costs of restoration planning, implementation and monitoring, type of financing, and total budget (more details in Supplementary Material 2).

When analyzing social and policy drivers of restoration processes, the online survey focused on stakeholder identification, engagement and conflicts. Stakeholders play an important role in the success or failure of restoration projects as they can either have an effect on them or be affected by them. The main stakeholders in forest biodiversity conservation and restoration are public or private forest owners, conservation managers, consultants or scientists, businesses, policymakers, civil society groups and the general public (Sotirov, 2017). This part of the survey included assessing the level and timing of stakeholder engagement, as well as identifying any challenges or conflicts among stakeholders. Additionally, depending on the restoration objective, various indicators were proposed to analyse the success of the restoration initiatives implemented. An assessment of stakeholder agreement was implemented for the different indicators proposed based on the respondents' perception.

3. Results

3.1. Characterization of respondents

After one year from the launch of the survey, out of a total of 1000 requests, 398 valid responses were received, giving a response rate of 26.53 %. Most of the responses (30.4 %, 121 responses) were obtained from individuals professionally involved in the field of ecological restoration, and who have participated in the design, implementation or monitoring of one or more previous initiatives (Fig. 2A), followed by experts with extensive professional experience in the design, implementation or monitoring of the restorations (27.64 %, 110 responses) (Fig. 2A). As regards the role of the respondents in the restoration initiatives (Fig. 2B), the results indicate significant differences across the established geographical zones (Chi-Pearson squared = 0.001, Table 1). However, none of the aspects related to stakeholder involvement demonstrated any significant dependence on geographical zone (Chi-Pearson squared $\geq$ 0.05, Table 1). Similarly, there was no significant association between respondents' experience with restoration and geographical zones.

Responses were received from restoration projects spanning 31 different European and non-European countries, encompassing initiatives at national, transnational, regional, and local levels (Fig. 3). Almost half of the responses received were from Spain, Austria and Italy (42.49 %), while only one response was received from the Netherlands, Denmark, and Latvia.

Table 1
Results of Pearson Chi-Squared test and Cramer's V statistics for the aspects analysed in the five geographical zones.

ASPECT	PEARSON CHI-SQUARED	CRAMER'S V STATISTIC
Restoration objective	0.002	0.375
Pre-restoration land use	0.012	0.213
Status of the restoration initiative	0.037	0.161
Relationship of respondents to the restoration initiative	0.001	0.288
Respondents' experience with restoration	0.087	0.165
Challenges encountered in engaging stakeholders in restoration initiatives	0.725	0.177
Degree of stakeholder involvement in restoration initiatives	0.069	0.267
Restoration phase involving stakeholders	0.694	0.182
Existence of conflicts among stakeholders during restoration initiatives	0.050	0.248

3.2. Characterization of restoration initiatives

More than half of the responses corresponded to fully or partially completed restoration initiatives (52 %), followed by ongoing initiatives (31 %), and planned initiatives (17 %). Fig. 4 presents the distribution across Europe of the responses received based on the **status of the restoration** projects. The Chi-Pearson squared test indicated significant dependence between the status of the restoration initiative (planning, ongoing and fully or partially completed) and the five geographical zones established. However, the degree of dependence between the status of the restoration initiative and the five geographical zones shown by Cramer's V statistics was very low (Table 1). Responses from Southeastern Europe primarily focused on ongoing restoration initiatives. The highest level of dependence was observed between restoration objectives and geographical zones (0.375, Table 1).

The analysis of pre-restoration land use indicates that the plurality of restoration initiatives were carried out in forested areas (Fig. 4). In 36.6 % of the cases the restoration area contained 100 % forest cover prior to the implementation of the restoration initiative. At the other end of the

Fig. 2. Distribution of the level of experience of the respondents in the questionnaire (A), and role of the respondents in the restoration initiative (B). The type of relationship "*Other*" encompasses landowners and/or organizations that own land, private individuals and/or companies with economic interests in the restored land, residents of municipalities affected by the restoration, and private individuals with interest in the restoration initiative. Numbers next to each bar correspond to the exact number of responses received for each option.

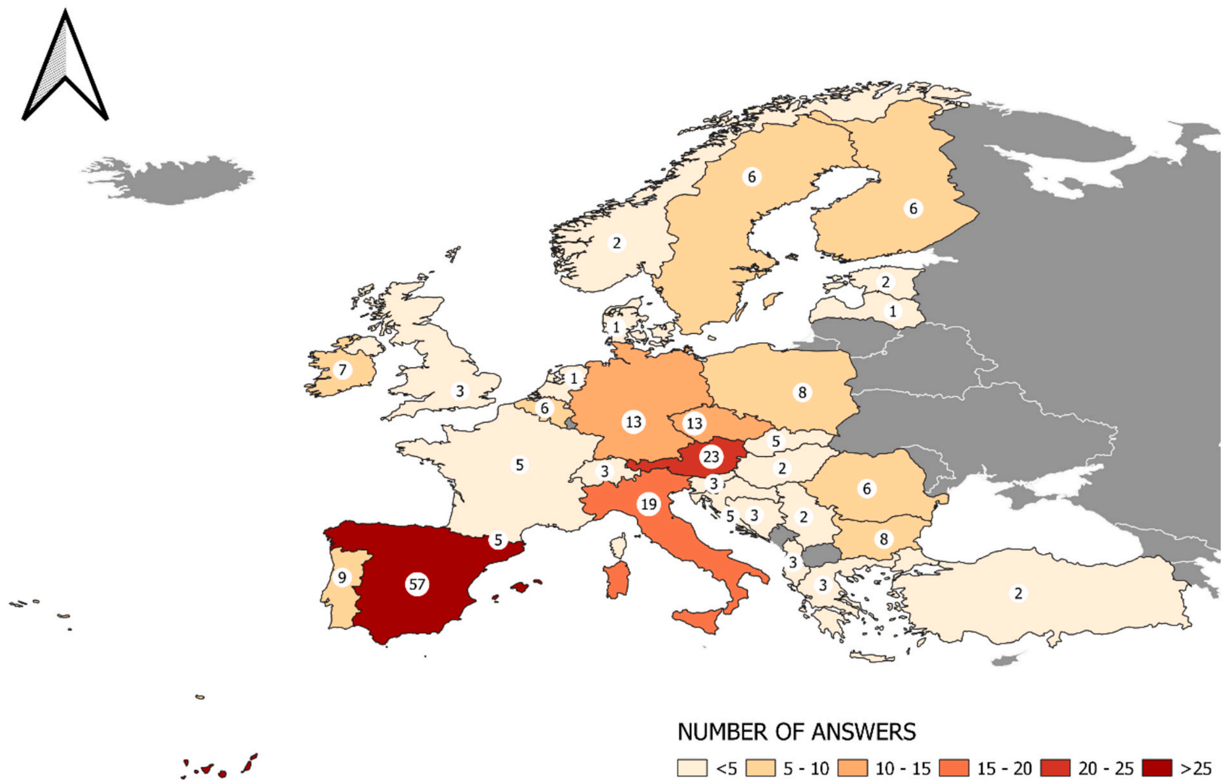

Fig. 3. Distribution of the number of answers collected through the questionnaire per European country. The colors indicate quantitative classes. The numbers indicate the total number of answers from each country.

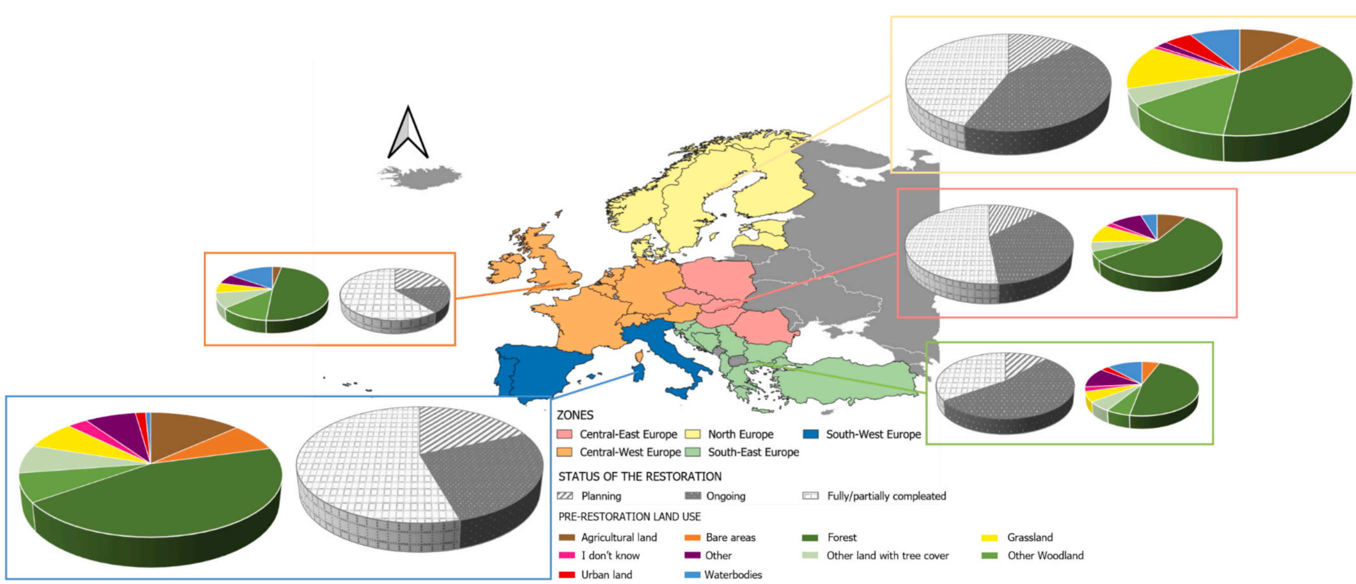

Fig. 4. European distribution of the responses received according to the status of the restoration initiative, and the pre-restoration land use, grouped by the five regions established following Forest Europe (2020). The size of the pie charts is proportional to the responses received.

spectrum, only 5.9 % of the responses indicated that there was no forest cover in the area prior to the restoration initiative. Responses coming from Northern, Southeastern, and Southwestern Europe considered all possible pre-restoration land uses. However, in Central Europe, neither Central-West nor Central-East took bare areas or urban lands into account as pre-restoration land use. The results of the Chi-Pearson squared test indicated significant dependence between the pre-restoration land use and the five geographical zones (Level of significance = 0.012, Table 1). Cramer's V statistics revealed a very low degree of dependence between both variables (0.213, Table 1), which was consistent with the analysis of the status of the restoration initiative.

Among the 21 **objectives for the restoration initiatives** considered (Table S1, Supplementary Material 1) (Menéndez-Miguélez et al., 2024), the most common primary objectives were *Increasing the population of species/expanding the distribution of the species*, *promoting tree/plant regeneration*, *increasing the resilience of the ecosystem*, *promoting habitats of interest*, and *protection against erosion*, with decreasing percentages of 19.70 %, 12.81 %, 12.32 %, 11.82 % and 10.34 % (Fig. 5). In this study

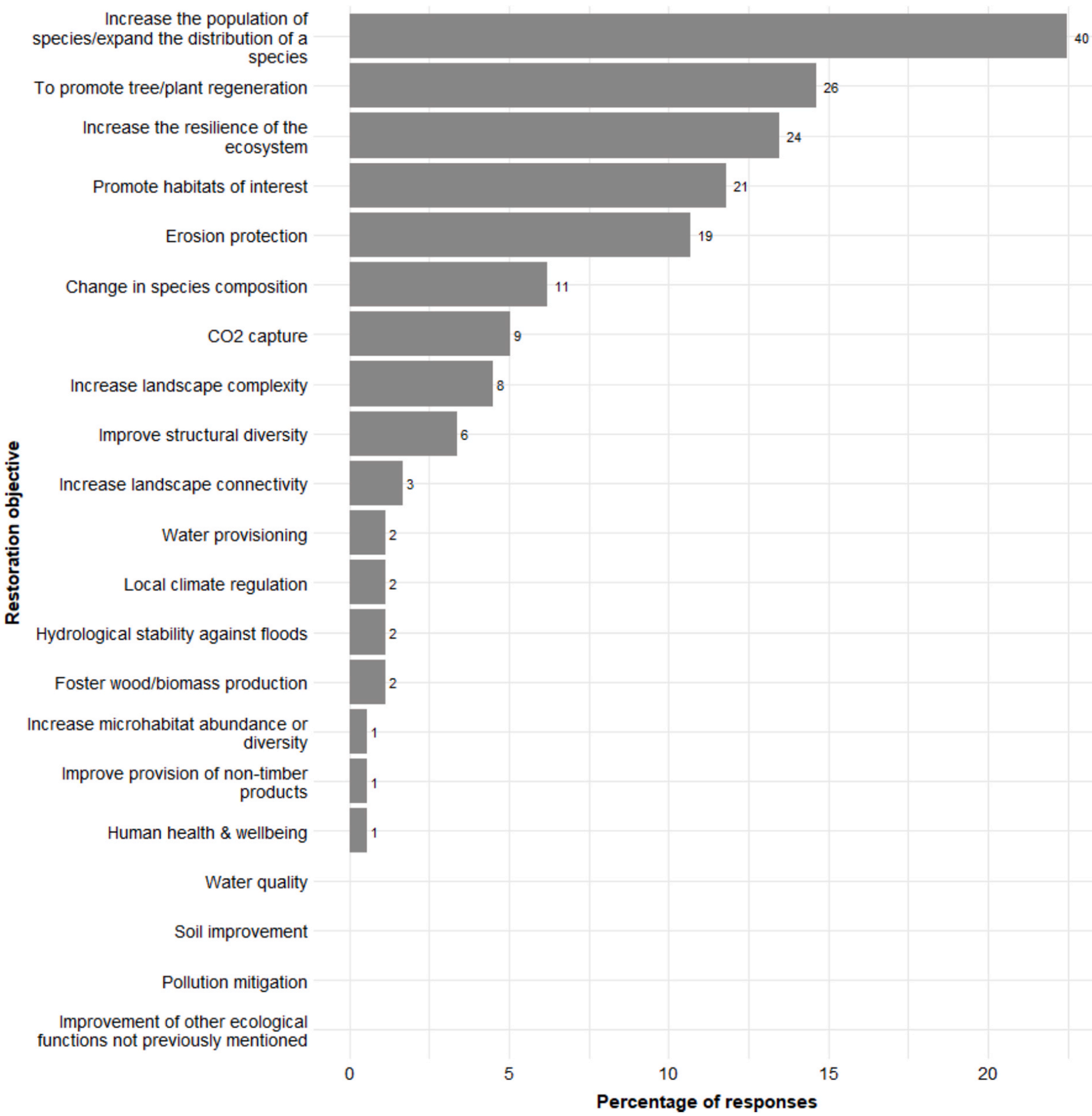

Fig. 5. Distribution of responses according to the restoration objective of the initiative. Numbers appearing on each bar correspond to the exact number of responses received for each option.

only the one identified as the main one was analyzed. The Chi-Pearson squared test revealed a significant dependence between restoration objective and geographical zones (0.002, Table 1) and Cramer's V statistics revealed that there was not a high degree of dependence between both variables (0.375 in the [0,1] interval), although it was the highest among all the comparisons analyzed. The analysis also revealed that responses from Southwestern Europe were more focused on *increasing the population of species/expanding the distribution of species*, *promoting plant/tree regeneration* and *protecting from erosion*. Responses from countries in Southeastern Europe focused primarily on *increasing the population of species*, while those from Central-Western Europe were aimed at *promoting habitats of interest*. However, there was no clearly predominant restoration objective when analyzing responses from countries in Northern Europe or Central-Eastern Europe.

3.3. Compatibility between objectives

Excluding the objectives for which no response was obtained (objectives 5, 9, 10, 12, 14, 15, 19, 20, and 21), the overall analysis of the responses (column % of responses, Fig. 6) revealed that a medium level of compatibility (medium brown) between objectives was the most observed in over half of the responses (68.7 %) (Fig. 6). This was followed by 19.1 % of responses indicating high compatibility (light brown) (75 % or more of the responses indicated this level) between objectives. Only 8.3 % of the received responses indicated low compatibility (25 % or fewer responses indicate low compatibility) between objectives (dark brown). Additionally, 3.8 % of the respondents either were not able to determine the compatibility, did not provide an answer, or considered it not applicable (white). Notably, the restoration objective of *water provisioning* (objective 13) presented a high level of compatibility in most instances.

3.4. Ecological aspects

A more in-depth analysis of the benefit of restoration objectives to certain ecological factors revealed that only 4.2 % of respondents (dark

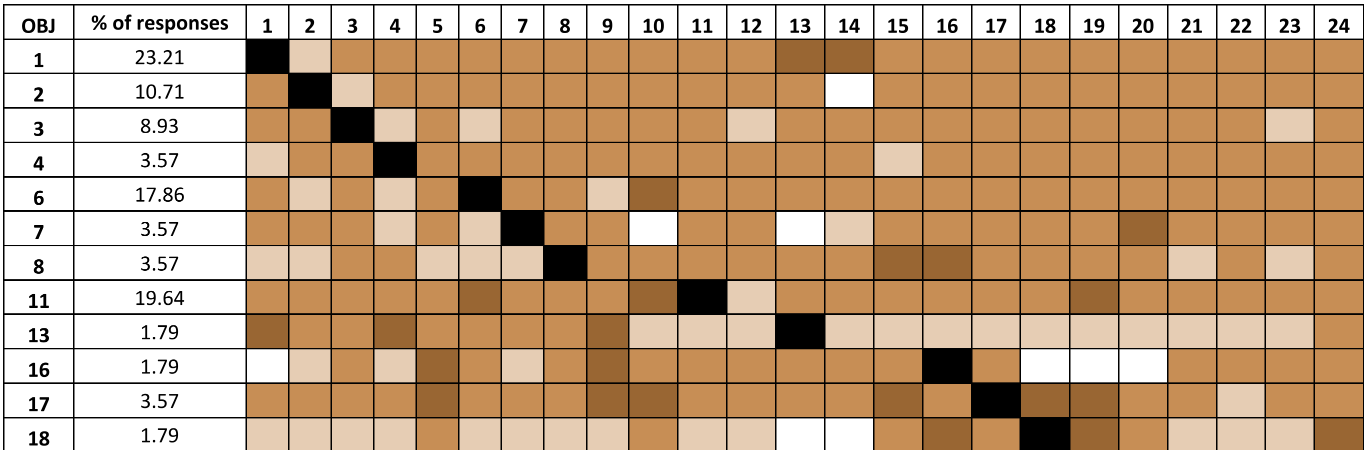

Fig. 6. Compatibility matrix between the main objective of the restoration initiative (first column) and all the possible objectives (heading). Black cells represent the main diagonal; Light brown cells represent high level of compatibility (≥75 %); Medium brown cells represent medium level of compatibility (25–50 %); Dark brown cells represent low level of compatibility (≤25 %); White cells correspond to the respondents either not knowing, did not answering or considering it was not applicable. The proposed objectives were as follow: (1) Increase the population of species/expand the distribution of species; (2) Change in species composition; (3) Promote tree species regeneration; (4) Improve structural diversity; (5) Increase microhabitat abundance or diversity; (6) Promote habitats of interest; (7) Increase the resilience of the ecosystem; (8) Increase landscape complexity; (9) Increase landscape connectivity; (10) Improve provision of non-timber products; (11) Erosion protection; (12) Soil improvement; (13) Water provisioning; (14) Water quality; (15) Hydrological stability against floods; (16) Forest wood/biomass production; (17) CO_2 capture; (18) Local climate regulation; (19) Pollution mitigation; (20) Improvement of other ecological functions not previously mentioned; (21) Human health & wellbeing. For this compatibility matrix three extra aspects were considered as objectives: (22) Social acceptance, (23) Local acceptance, and (24) Forest aesthetic attractiveness from a human perspective. Objectives (5), (9), (10), (12), (14), (15), (19), (20), and (21) do not appear in the first column because no responses were received.

brown color) perceived a low benefit of the proposed ecological aspect in relation to the main restoration objective (Fig. 7). Approximately three-quarters of respondents (70.0 %) expected ecological aspects to moderately benefit from the restoration objective (medium brown). A high level of benefit (light brown) from the restoration objective was reported in 23.3 % of the responses received. Additionally, only 2.5 % of the responses considered this benefit as not applicable, as respondents either did not answer or were unsure about the benefit (white). *Local climate regulation* (objective 18) was identified as providing the highest level of benefit among the proposed ecological aspects. In contrast, the lowest level of benefit was observed in restoration initiatives focused on *improving structural diversity* (objective 4). With regard to ecological aspects, “distribution, abundance, species composition”, “structural diversity”, and “ecosystem suitability” where considered the most benefited by restoration objectives. Conversely, “presence of deadwood”, and “ecosystem resilience” were identified as the least benefited aspects.

3.5. Economic aspects

Only a few respondents (14 %) provided information on economic aspects of the restoration initiatives, such as total costs, or the costs for

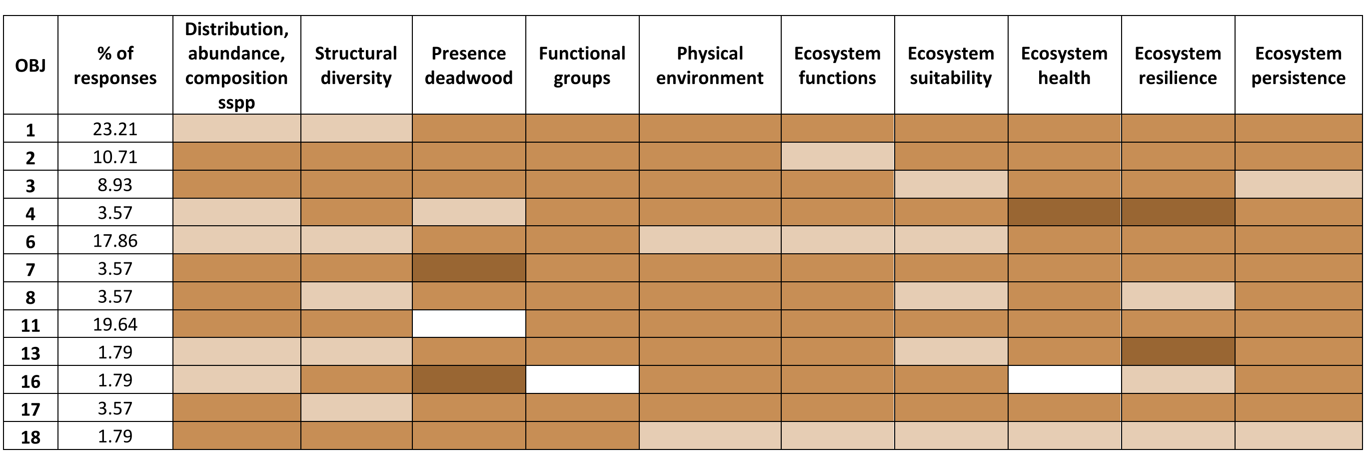

Fig. 7. Level of benefit of each ecological aspect (heading) proposed based on the restoration objectives (rows). Light brown cells represent high level of benefit (≥75 %); Medium brown cells represent medium level of benefit (25–50 %); Dark brown cells represent low level of benefit (≤25 %); White cells indicate that the respondents either did not know, did not answer or considered it was not applicable; Grey cells represent no responses received for these objectives. The proposed objectives were as follow: (1) Increase the population of species/expand the distribution of species; (2) Change in species composition; (3) Promote tree species regeneration; (4) Improve structural diversity; (5) Increase microhabitat abundance or diversity; (6) Promote habitats of interest; (7) Increase the resilience of the ecosystem; (8) Increase landscape complexity; (9) Increase landscape connectivity; (10) Improve provision of non-timber products; (11) Erosion protection; (12) Soil improvement; (13) Water provisioning; (14) Water quality; (15) Hydrological stability against floods; (16) Forest wood/biomass production; (17) CO_2 capture; (18) Local climate regulation; (19) Pollution mitigation; (20) Improvement of other ecological functions not previously mentioned; and (21) Human health & wellbeing. Objectives (5), (9), (10), (12), (14), (15), (19), (20), and (21) do not appear in the first column because no responses were received.

each stage of the restoration (planning, implementation and monitoring). Within the information provided, the total budget of the projects varied from 500 € to 7,000,000 € annually. It is important to consider that the investment commonly depends on the size of the restored area. Around 86 % of these restoration initiatives allocated 50 % or more of their budget to the implementation phase of the project, and almost 23 % allocated the total budget to the implementation phase. Only 9.1 % of the restoration initiatives dedicated at least half of their budget to the planning phase. This phase, along with the monitoring phase, had the lowest budget allocation in nearly three-quarters of the projects. In fact, 34.7 % of the projects allocated 5 % or less of their total budget to the monitoring phase. An overview of the total budget and its distribution for the projects between 100,000 and 1,000,000 €/year can be observed in Fig. 8A, while projects under 70,000 €/year are presented in Fig. 8B.

3.6. Social and policy aspects

In terms of the social and policy aspects of the restoration initiatives, the respondents who indicated no issues in stakeholder engagement (46 respondents) nearly doubled those who reported problems (28 respondents) (Fig. 9A). Regarding the level of stakeholder involvement in the restoration initiative, responses typically fell within the medium to high range (28.6 and 30.6 %, respectively) (Fig. 9B). However, despite this high level of involvement, it did not translate into fully active participation, as evidenced by the low value of the corresponding bar in Fig. 9B. The analysis of stakeholder involvement across project phases (Fig. 9C) revealed that over 75 % of respondents reported engagement primarily in a single phase, with the Design phase being the most common (33.8 %), followed closely by both the Implementation and Monitoring phases (23.9 and 18.3 %, respectively). By contrast, a smaller group (23.9 % of respondents) indicated that they employed active stakeholder involvement across all phases of the restoration initiative. Delving deeper into how this engagement was perceived across the five established geographical zones, no clear tendency was observed in responses from Southwestern Europe. However, responses from Southeastern Europe generally indicated that stakeholder engagement was not considered a difficult aspect when implementing a restoration project (in the compiled projects). By contrast, responses from restoration projects in Northern and Central-Western Europe generally agreed that engaging stakeholders is challenging in their

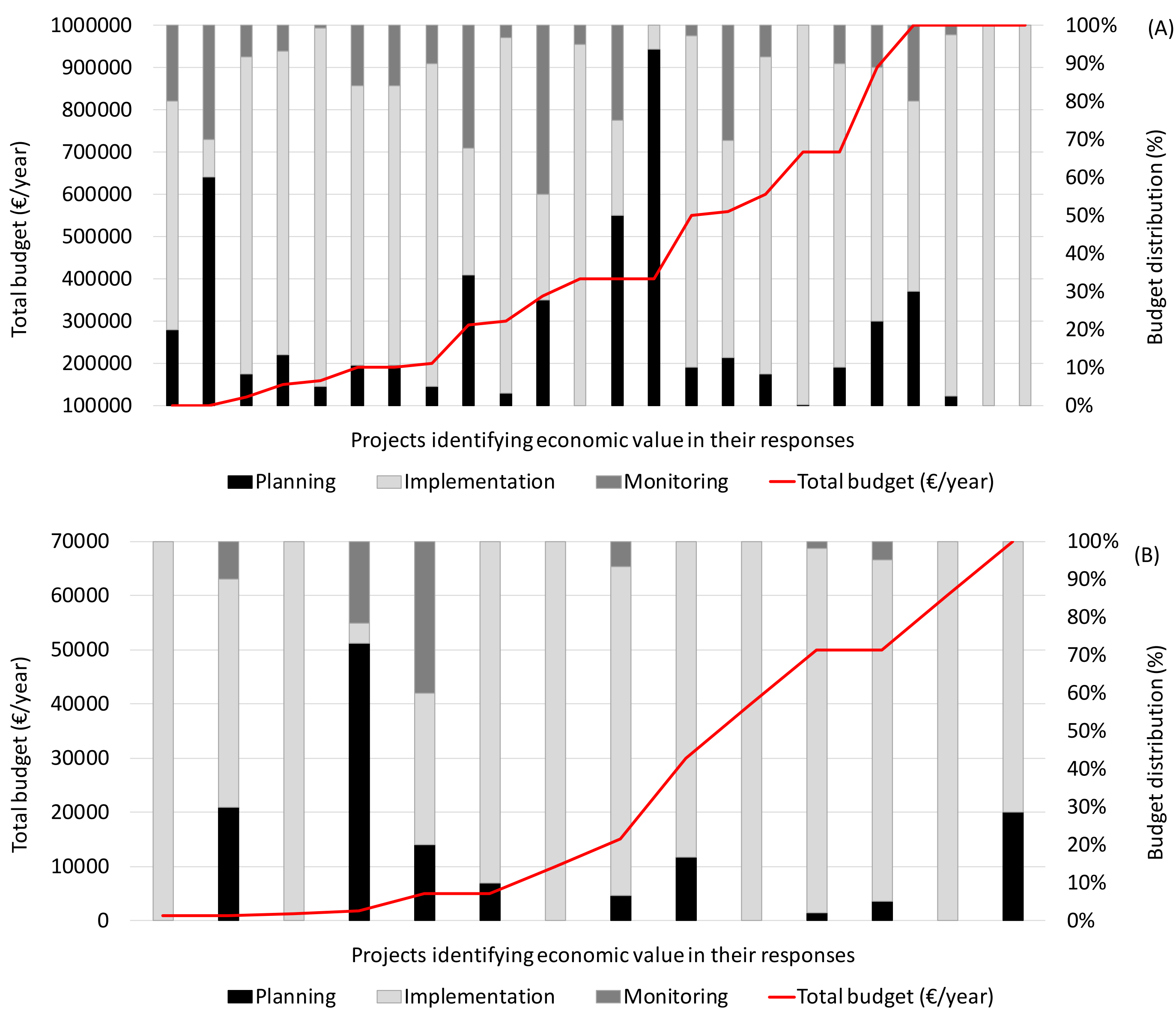

Fig. 8. Budget distribution by phase (Planning, Implementation, and Monitoring) for the identified projects between 100,000 €/year and 1,000,000 €/year (8A); and under 70,000 €/year (8B). Each bar indicates a project that provides this type of information.

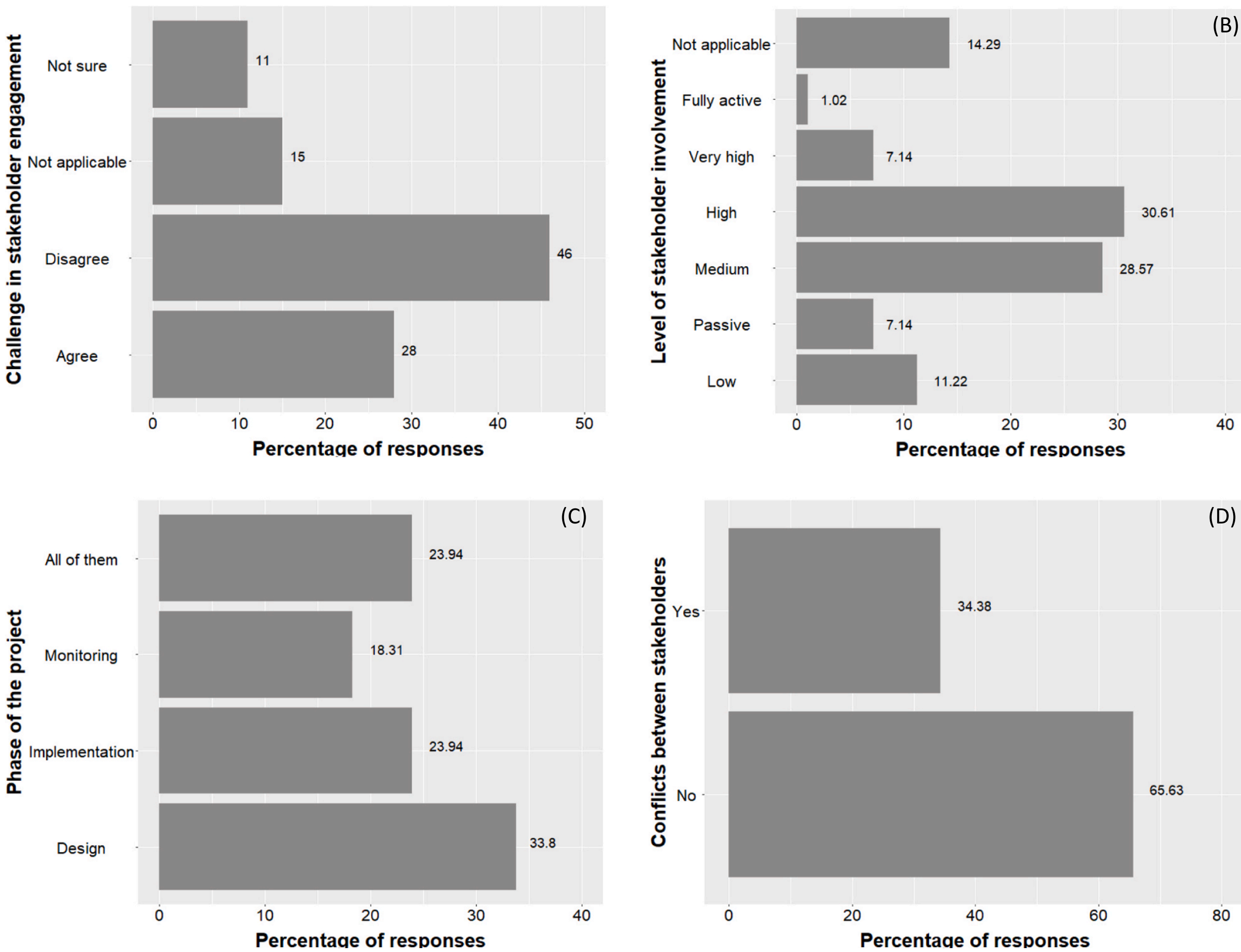

Fig. 9. Various aspects considered in the online questionnaire related to the degree of involvement of stakeholders in the restoration initiative. A) "Was it difficult to engage stakeholders in the restoration initiative?"; B) "Degree of stakeholder involvement in the restoration initiative"; C) "Phase of the project in which it was most difficult to engage stakeholders"; D) "Any conflict between stakeholders during the restoration initiative?". Numbers appearing on each bar correspond to the exact number of responses received for each option.

countries. Regarding the existence of conflicts between stakeholders, 66 % of the respondents stated that such conflicts did not affect their work, compared to 34 % who acknowledged their presence. However, as illustrated in Fig. 9D, the Chi-Pearson squared test only indicated significant dependence when analysing the existence or absence of conflicts between stakeholders across various geographical zones. None of the other aspects related to stakeholders showed significant dependence (Table 1). Similarly, Cramer's V statistics indicated a very low level of dependence or independence for these cases, mirroring the findings from the other analysed aspects.

3.7. Indicators of restoration outcomes

Little information was obtained about the indicators proposed to analyse the success of the restoration initiatives, either for concrete values before and after the restoration or for reference areas to estimate these indicators. However, there were enough responses to analyse the level of agreement of respondents with the proposed indicators. Significant difficulty was revealed by the respondents in selecting just one indicator to analyse the success of the restoration initiatives (Table 2). The variability of responses highlighted the subjectivity involved in choosing specific indicators to assess the success of a restoration initiative. On the one hand, respondents partially or strongly agreed with the proposed indicators to analyse the success or failure of restoration initiatives in 12 out of 21 possible restoration objectives. On the other hand, there were four proposed indicators (Quality of water for human consumption, quality of water for the ecosystem, biomass yield, and number of recreation visits) in which respondents were not sure at all on the feasibility of the proposed indicators to analyse the concrete objective of the restoration initiative. When examining initiatives focused on *erosion protection* (objective 11), a high level of agreement was observed in the first two proposed indicators (Soil loss, Ground vegetation cover). However, the last indicator (Area affected by soil erosion) was not as clearly supported by respondents. Similar trends were observed with the proposed indicators for analysing *foster wood/biomass production* (objective 16). Respondents considered Wood yield a suitable indicator in half of the cases, while 25 % completely disagreed and another 25 % were unsure about it. Additionally, half of the respondents were uncertain about the proposal of Biomass yield as an indicator for this main objective.

4. Discussion and conclusion

The importance of mitigating the impacts of climate change through ecosystem restoration and enhancing resilience has been emphasized by authors such as Evju et al. (2020) as a primary driver behind the increasing number of ecological restoration initiatives implemented globally. In addition, biodiversity-centered restoration has also been considered in forest restoration to increase biodiversity. In this study, the information gathered allowed us to enhance our understanding of

Table 2
Level of agreement of the respondents with the indicators proposed to analyse the success of each restoration objective.

ECOLOGICAL ATTRIBUTES	N	OBJECTIVES	INDICATOR PROPOSED	AGREEMENT (%)					
				Strongly agree	Partially agree	No agree no disagree	Partially disagree	Strongly disagree	Not sure
Species composition	1	Increase the population of species/expand the distribution of species	Abundance	18.18	**59.09**	9.09	9.09	0	4.55
	2	Change in species composition	Abundance	**50.00**	42.86	0	0	0	7.14
	3	Promote tree species regeneration	Regeneration cover	**57.14**	21.43	7.14	0	7.14	7.14
Structural diversity	4	Improve structural diversity	Volume of standing deadwood	11.11	22.22	22.22	11.11	33.33	0
			Volume of lying deadwood	11.11	22.22	22.22	11.11	33.33	0
			Structural diversity	22.22	44.44	22.22	0	11.11	0
	6	Promote habitats of interest	Area occupied	25.00	**56.25**	0	6.25	6.25	6.25
Ecosystem functioning	7	Increase the resilience of the ecosystem	Resilience of the system	8.33	33.33	25.00	25.00	0	8.33
	8	Increase landscape complexity	Landscape complexity	**50.55**	16.67	0	16.67	0	16.67
	9	Increase landscape connectivity	Number of connections/corridors	**60.00**	20.00	0	0	0	20.00
	20	Improvement of other ecological functions not previously mentioned	Ecological functionality	0	**100.00**	0	0	0	0
Physical conditions	11	Erosion protection	Soil loss/ha year	**50.00**	20.00	10.00	0	0	20.00
			Ground vegetation cover	**54.55**	18.18	0	0	9.09	18.18
			Area affected by soil erosion	45.45	18.18	0	9.09	0	27.27
	12	Soil improvement	Organic matter content	25.00	**50.00**	12.50	0	0	12.50
	13	Water provisioning	Annual average streamflow	0	**50.00**	25.00	0	25.00	0
	14	Water quality	Quality of water for human consumption	0	0	33.33	0	0	**66.67**
			Quality of water for the ecosystem	0	33.33	0	0	0	**66.67**
Products	16	Foster wood/Biomass production	Wood yield (m^3/ha year)	25.00	25.00	0	0	25.00	25.00
			Biomass yield (t/ha year)	0	25.00	25.00	0	0	**50.00**
	17	CO_2 capture	Aboveground biomass (kg/ha year)	44.44	33.33	0	0	22.22	0
	21	Human health & wellbeing	Number of recreational visits	**50.00**	0	0	0	0	**50.00**

Note. Numbers in bold denote more responses (or an equal number) agreeing with this category.

past, ongoing and planned forest restoration initiatives across Europe, compiled through a comprehensive survey which considered, for the first time, a wide number of aspects. However, we realize that due to the length of the questionnaire or excessive detail in the questions, the responses were sometimes not as extensive as initially expected (response rate 26.5 %). It must also be taken into account that some countries were scarcely represented. Despite these constraints, our approach could serve as a basis and provide a global overview of the types of activities and ecosystems on which European countries are currently focusing their restoration efforts.

The distribution of the main land uses in Europe, as obtained from the Land Use/Cover Area Frame Statistical Survey (LUCAS) conducted by Eurostat, showed that forestry covered 35.9 % of the EU area, while agricultural land accounted for 39.1 % of the total area in 2018 (Eurostat statistics web, last consulted 2024-07-01). Studies by the OECD/FAO (2024) predict a reduction of over 1,000 thousand hectares dedicated to crops and an increase of around 3,000 ha dedicated to forest in Western Europe over the period 2021 to 2033. Most restoration initiatives are being carried out on forested lands, primarily in degraded forests. Additionally, these initiatives are concentrated in countries with the largest areas of forested lands. Our results partially reflect this trend and align with those of (Vadell et al., 2016), which indicate that in countries such as the UK, Spain, Portugal or Ireland the restoration of agricultural land accounts for a substantial percentage of their total restoration initiatives. There is heightened interest in both Southwestern and Southeastern Europe with regard to restoring tree species, particularly by increasing their populations. In Southwestern Europe, there is also a strong focus on promoting tree and plant regeneration and protecting soil from erosion. These goals are probably related to the increased frequency of extreme wildfires in recent decades, mainly in southern Europe (Moura Batista dos Santos et al., 2023). In recent years, there has been a growing number of studies focused on post-fire restoration due to the current situation in Mediterranean countries (Kucuk and Kahveci, 2020; Lingua et al., 2023; Margiorou et al., 2022; Spatola et al., 2023). However, Central European countries appear to be more focused on restoring ecosystems by promoting habitats of interests and increasing system resilience in Central-Western and Eastern Europe, respectively, as evidenced by the growing emphasis on integrative forest management.

In the discussion surrounding restoration, it is essential to adopt a holistic understanding of the ecosystem, assessing not only ecological aspects but also social, economic and policy dimensions. Ecosystems comprise various abiotic and biotic factors and should be analyzed from multiple perspectives to address all influencing elements (Menéndez-Miguélez et al., 2024). This comprehensive view of ecosystems was evident in our study, as most individuals involved in restoration initiatives considered their objectives to be compatible with those proposed in the survey. This alignment was not only reflected in the compatibility of the objectives but also in the fact that most respondents saw their restoration initiatives as achieving multiple purposes rather than just one. This approach aligns with Krebs' (2014) definition of an ecosystem as the biotic community and its abiotic environment. The compiled information also captured the general perception that ecological initiatives are improving various ecological aspects of ecosystems. However, the presence of deadwood, ecosystem health, and ecosystem resilience were the most controversial ecological aspects benefiting from restoration initiatives, particularly those focused on *improving structural diversity*, *increasing the resilience of the ecosystem*, *water provisioning*, or *promoting wood/biomass production*. The presence of deadwood was not considered as beneficial in projects aimed at increasing resilience or promoting wood/biomass production. Although these ecological aspects are not considered contradictory to biomass/wood production, leaving deadwood is, and authors such as (Nikinmaa et al., 2020) found that deadwood was not a commonly used indicator for resilience. Deadwood plays a key role in various ecosystem services, such as regulating the carbon cycle, carbon storage (Moreno-Fernández et al., 2024; Shannon et al., 2022), facilitating regeneration patterns (Marcolin et al., 2019), serving as a biodiversity indicator (Larjavaara et al., 2023) and acting as biodiversity refugia (Sandström et al., 2019; Uhl et al., 2022). On many occasions, deadwood has been considered a risk for forest fires because it accounts for a large proportion of the available fuel in the forest. However, as stated by Larjavaara et al. (2023), pieces of deadwood burn slowly and contribute only minimally to fire intensity. In this regard it is the combination of various factors, such as the use or presence of invasive species or extensive areas of single-species plantations (Bowman et al., 2021; Ndalila et al., 2018), rather than just the higher or lower presence of deadwood. Resilience is a challenging concept to define, resulting in numerous definitions and approaches in the literature, with diverse methodologies for conducting analyses. Nikinmaa et al. (2020) discussed three broad conceptualizations of resilience: engineering, ecological, and social-ecological resilience. Krebs (2014) defined it as the magnitude of disturbance an ecosystem can absorb before changing the structure. Regardless of the approach to defining resilience, given the uncertain future we face, a mix of forest restoration objectives will be required to address this uncertainty. This global approach will facilitate the adaptability and resilience of ecosystems against unpredictable environmental changes.

Due to privacy issues, economic aspects are difficult to compile, which was reflected in the small number of answers received on the matter. Of those responding, the implementation phase was the only one in which the entire budget was allocated, while the monitoring phase, in particular, appeared to be neglected in terms of budget. In fact, monitoring and evaluation are often regarded as the most costly phases in the implementation of a restoration project (Menéndez-Miguélez, et al., 2024). Based on the data we received, the focus of funding tends to be on implementation rather than long-term planning such as monitoring, which threatens the outcomes of projects. This finding was also reported by Cole et al. (2024). Budget constraints and other factors usually result in the inability to carry out monitoring and evaluation, even though these provide the necessary data from attribute and indicator measurements to appropriately assess the success or failure of a restoration initiative (Nilsson et al., 2016).

Despite the numerous challenges faced when implementing restoration initiatives – ranging from environmental, policy and financial to social –, the general perception as regards stakeholder involvement was positive, and the potential for conflicts among stakeholder interests was perceived as low by our respondents. This may be due to the context-specific nature we observed (i.e. some countries highlighted conflicts and others not). In many countries, stakeholder conflicts are still very present, mainly in more pluralistic countries or those with less available land (leading to land-use conflicts). Only in countries with hierarchical political cultures like in Eastern Europe (and France), and which have substantial rural areas and a less organized pluralistic society, do we see less stakeholder conflicts. In addition to these challenges, it is also important to consider the various motivations of the different actors involved in the restoration initiatives, especially given the need to scale-up restoration initiatives to meet international biodiversity commitments (Suding et al., 2015b). Therefore, the perceptions and the general absence of conflicts we observed are even more significant, since differences in motivations can lead to divergent outcomes and social conflicts in many instances (Colvin et al., 2015; Fielding and Hornsey, 2016; Hagger et al., 2017).

When analyzing restoration initiatives, the focus is commonly on how best to plan, monitor, and evaluate them (Hagger et al., 2017). It is essential to adequately evaluate and document the impacts and progress of these restoration initiatives, as highlighted by Kurth and Schirmer (2014), Palmer et al. (2005), and Wortley et al. (2013). However, it is unclear how many projects define measurable objectives with their corresponding indicators or directly monitor these indicators (Bernhardt et al., 2007; Burton and Ellen Macdonald, 2011; Murcia et al., 2016). On the one hand, Menéndez-Miguélez et al. (2024) highlighted substantial heterogeneity in the indicators used for restoration initiatives across various pre-restoration land-cover types. On the other hand, studies such as Hagger et al. (2017) reported that fewer respondents in their studies monitored restoration using predefined indicators or directly measured restoration success, with only 35 % of respondents doing so. Both of these patterns were evident in our analysis, as shown by the high variability in agreement levels regarding the proposed indicators for different restoration objectives. This is due to several factors, such as analyzing the complexity of describing the diverse ecosystems from a holistic perspective to encompass all aspects affecting and evolving within them, or the absence of agreement of a set of indicators to determine whether restoration initiatives can be considered successful or unsuccessful.

In conclusion, effective forest restoration requires a holistic approach that considers not only ecological factors but also social, economic, and governance dimensions. This comprehensive view is essential for building resilient ecosystems that can adapt to future uncertainties. Deadwood plays a critical role in biodiversity conservation, carbon storage, and ecosystem regeneration, yet it is often misunderstood as a significant fire risk. Research indicates that while deadwood contributes minimally to fire intensity, fire risk is more influenced by factors like invasive species and monocultures. Resilience is a complex concept with various interpretations, including engineering, ecological, and social-ecological resilience. To enhance ecosystem adaptability, a blend of restoration objectives is necessary to manage the unpredictable environmental changes ahead. Budget limitations frequently restrict the monitoring and evaluation phases of restoration projects, even though these stages are crucial for measuring success. Without dedicated funding for long-term monitoring, it becomes difficult to assess the full impact of restoration efforts and make data-driven improvements. Despite financial, environmental, and social challenges, stakeholders generally showed positive engagement in restoration initiatives, with low conflict potential. Understanding stakeholder motivations is critical as restoration efforts scale up to meet global biodiversity goals, as alignment among actors can reduce risks of social conflict.

This is the first time such an extensive survey has been conducted for this purpose. We recommend further research to continue collecting data on the variability across Europe, adopting a holistic approach to learn from the experiences of all types of stakeholders.

CRediT authorship contribution statement

M. Menéndez-Miguélez: Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **A. Rubio-Cuadrado:** Writing – review & editing. **J. Bauhus:** Writing – review & editing. **I. Cañellas:** Writing – review & editing, Funding acquisition, Conceptualization. **T. Crowther:** Writing – review & editing. **S. de-Miguel:** Writing – review & editing. **M. Erdozain:** Writing – review & editing. **J. Hoffmann:** Writing – review & editing. **K. Kremer:**

Writing – review & editing. **M. Sotirov:** Writing – review & editing. **K. Lapin:** Writing – review & editing. **T. Lundhede:** Writing – review & editing. **S. Jacobs:** Writing – review & editing. **E. Schatzdorfer:** Writing – review & editing. **L. Werden:** Writing – review & editing. **I. Alberdi:** Writing – review & editing, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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Data availability

Data will be made available on request.

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