Assessment methodologies and mitigation measures for the impacts of road projects on soils – ROADSOIL

Expert survey and workshop on best practices for soil protection

Deliverable D5.1/5.2

27. October 2022

Norwegian Institute for Bioeconomy Research NIBIO
Swiss Federal Institute for Forest, Snow and Landscape Research WSL
Swedish University for Agricultural Sciences SLU

CEDR Call 2019: Soils

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Due date of deliverable: 31/08/2022

Actual submission date: 27/10/2022

Start date of project: 01/03/2021 End date of project: 28/02/2023

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Version: 1

Executive summary

Soil is defined as a biologically active mixture of organic matter, minerals, liquids, and gases built up from horizons consisting of different proportions of these components. It is the result of a long weathering process driven by biological, climatic, geological and topographic influences. Road construction entails soil sealing, compaction, pollution, and disposal of surplus material which compromise the soil functions with direct and indirect negative impact on people and their environment. Damage on soil must be avoided, mitigated, or compensated for. Therefore, we assessed guidelines, soil information and best-practice examples of soil protection that relate to the planning and construction phase of a road construction project in the previous work package 4 of the RoadSoil project (Deliverable 4.1, 4.2). We concluded that although a considerable number of guidelines and other information is available in the investigated countries, there are still difficulties in implementation. For this reason, we suggested to further investigate which measures are known and implemented among European experts in the field of soil protection and road construction. Further, to what extent these measures are considered effective and feasible by the experts. And finally, which problems prevent the implementation and what are potential solutions to solve them.

We carried out an expert survey using an online survey tool to distribute the questionnaire which we provided in nine different languages. We addressed the experts through organisations and associations related to the topic as well as through the already existing network of the project consortium. We collected a total of 156 completed questionnaires from 17 different countries of Europe. 56 of the respondents had an environmental professional background, 18 were experts from civil engineering and infrastructure construction, another 48 had a mixed professional background including environmental and engineering knowledge.

Following the results of the survey, we conducted three online workshops. The aim of the workshops was to have the results of the survey evaluated by experts, to identify additional challenges and then to jointly develop new ideas for improving soil protection in road construction in Europe. We invited experts from authorities, the private sector and research in the fields of soil protection, nature conservation, road construction as well as engineering and planning. A total of 21 experts from nine different European countries took part in our workshops.

The survey results show that the experts acknowledged the damages on soils by road construction independent of their professional background. However, it was often stated that the situation had improved in the recent past, particularly by experts with a mixed background. The lack of knowledge about and no legal obligation for correct soil handling were mentioned as the main reasons for damages on soil due to road construction. Conversely, these two points were stated as the most important success factors to reduce damage on soil in the context of road construction.

The lack of knowledge and obligation were mentioned as obstacles in other aspects as well, particularly as reasons why polluted soils were not reused or soils infested with invasive species were not treated separately. Considering the reuse of surplus soil in general, the experts additionally stated conflicts with other legislations as impediments. However, the majority of the respondents stated that surplus soil from road construction sites was usually reused, in most cases for the restoration and upgrading of agricultural land. This was also mentioned as part of the measures to compensate for the impacts of road construction to the environment, required by spatial planning legislation. However, the restoration of natural habitats was by far the most frequent compensation measure mentioned.

The countries' guidelines for soil protection in road construction were mostly assessed as partly useful, though the statements strongly differed between the countries. In some countries, no guidelines seem to be available. On the other hand, about half of the respondents said that

they did not know about guidelines provided by the EU. This is surprising because many experts stated that the EU EIA directive had a considerable influence on how the environmental impact assessment (EIA) was carried out in their respective countries. Supra-national guidelines about soil protection in road construction and stricter requirements by the EU EIA directive might improve the situation in countries where such guidelines are missing.

Soil information is available in most countries, mainly as soil maps. They are, however, not commonly used in road planning and construction because they do not provide the appropriate resolution or the necessary contents or do not cover the entire area of a road project. Consequently, most experts stated that field investigations of the soils were carried out before a road construction site was established. These field investigations usually include detailed soil mapping with soil profiles, followed by soil samples for chemical and physical laboratory analyses. Although the soil properties are usually ascertained at the beginning of a road construction project, the quality of the restored soil after termination of the construction work is rather rarely checked. Damage on soil due to road construction could probably be further reduced, if a final check of soil quality was prescribed by the EIA.

A number of soil protection measures are already, at least partially, implemented on road construction sites. Most applied are the separate treatment of topsoil and subsoil as well as soil restoration for agricultural land-use. The Swiss system of assigning a soil protection expert to supervise the construction process is not yet widespread. As this measure strongly contributes to increased knowledge about soil protection in road construction, it would be worthwhile to find ways to adopt this system in other countries.

In the workshops, the exchange among experts from the different countries was very much appreciated. This kind or exchange was mentioned as an important approach to improve the application of soil protection practices. The participants expressed the need for such meeting places in order to learn about new practices and how to implement them.

Not only the exchange among professional, but also communication with politicians and society was stressed as important to improve soil protection in road construction. The participants brought up specific suggestions such as “soil ambassadors” and a “soil advocacy plan” to raise awareness among the politicians about the challenges in soil protection. They referred to various specific training courses for authorities and construction and planning companies.

The workshop participants complained that surplus soil is treated as waste in many national legislations, and the policies should change towards the principles of circular economy for better reuse of surplus soil. However, the participants also expressed problems with the handling surplus soil, such as the fact that supply and demand not always match and the soil quality at the destination is hardly known. Soil banks that enable the trade of surplus material could be a solution, participants mentioned some good examples from European countries. In order to increase the demand for surplus soil, some regional authorities provide maps of areas with soils suited for upgrading. The participants mentioned with strong emphasise that the management of surplus soil must already be integrated into the planning phase of a road construction project, to reserve enough space and time for proper soil handling.

The experts pointed out that compensation measures should also be taken into account already in the planning phase. These measures must be elaborated in a comprehensive way, i.e. all ecological aspects, and adapted to the local conditions. Compensation measures should enhance soils that have been damaged in the past, they must not affect other local ecosystems (e.g. water bodies). The environmental authorities should define areas of degraded soils suited for compensation measures on open access maps.

The participants concluded that the EIA is a powerful tool to commit the constructors to soil protection measures. The EIA should include the elaboration of a soil management plan and

the comprehensive planning of compensation measures. In addition, soil quality should be assessed not only before the start of construction, but also after soil restoration. Particularly the latter should be prescribed in the EIA. The participants suggested to add specifications in this sense to the EU EIA Directive because this document has an impact on the way the EIA is conducted in the single countries.

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1 Introduction

In the RoadSoil project, we aim to develop methods and tools to assess the impact of road construction on soils by combining knowledge syntheses with novel approaches of data mining and modelling; to evaluate measures and best practices to mitigate and compensate for the impacts of roads by analysing expert knowledge and practical experiences; and to develop feasible practices that are effective in soil protection. We will pursue these objectives in a set of work packages (WP). In this work package (WP5), we conduct a survey to evaluate the situation of soil protection in road construction by experts from different sectors and different countries in Europe as well as to locate widespread conflicts of the implementation of soil protection measures in road construction.

Results of further work packages showed the that availability of guidelines and soil maps within Europe is rather heterogenic (Deliverable 4.1, 4.2). Although various best-practice examples were found, there is no uniform solution for soil protection in road construction so far and it was pointed out that individual approaches are needed and that there is a lack of implementation of known methods. From this, it was concluded that the following issues should be investigated:

i. How far the documents and soil protection measures are known and implemented in the investigated countries;
ii. How the experts assess the soil protection measures and best practices in terms of effectiveness for soil protection as well as legal, technical and political feasibility;
iii. The most relevant problems in implementation and potential solutions to approach them.

We approached these questions with a survey and three workshops among experts of all sectors related to soil protection and road construction from a number of different European countries. As already mentioned in the previous WPs, we divide road construction into different phases; mainly the planning phase and the construction phase and partly the operating phase. In these phases, stakeholders of different sectors are involved in the implementation of soil protection measures:

- *Authorities*: They review and approve construction projects and are responsible for implementing the applicable law. They ensure that soil protection aspects are considered accordingly in planning and financing.
- *Planning and Engineering offices:* They are responsible for planning the construction projects to be approved and for monitoring the projects. This includes the development of environmental impact assessments and soil protection measures. Such offices are, for example, responsible of: planning the road alignment, local pre-investigations, construction supervision, elaboration of compensation measures, organisation of follow-up soil management.
- *Road construction companies:* They carry out the actual construction work and are responsible for handling the soil. These companies do the following work: establishing driveways for construction machines on soils, earthwork, transportation of surplus, and sometimes contaminated, soils, etc.

2 Methods

2.1 Survey

2.1.1 Concept and Background

The survey was designed on the basis of the findings of the previous work package 4 (Deliverable 4.1, 4.2) and the knowledge of the RoadSoil project team. Based on this we designed a conceptual framework for the questionnaire. A conceptual framework defines the main topics to be addressed and the guiding questions to be answered with the survey (Chirk et al., 2006; Pew Research Center, n.d.). It can then be used as a tool to ensure that all the questions asked within the survey provide exploitable data for the analysis followed.

We defined three topics and, based on these, nine guiding questions as the conceptual framework for our survey (Figure 1). Each question of the survey was assigned to at least one of the guiding questions. In addition to the thematic questions, we defined a series of questions about the respondents' professional background. According to these, the thematic questions are later grouped and evaluated.

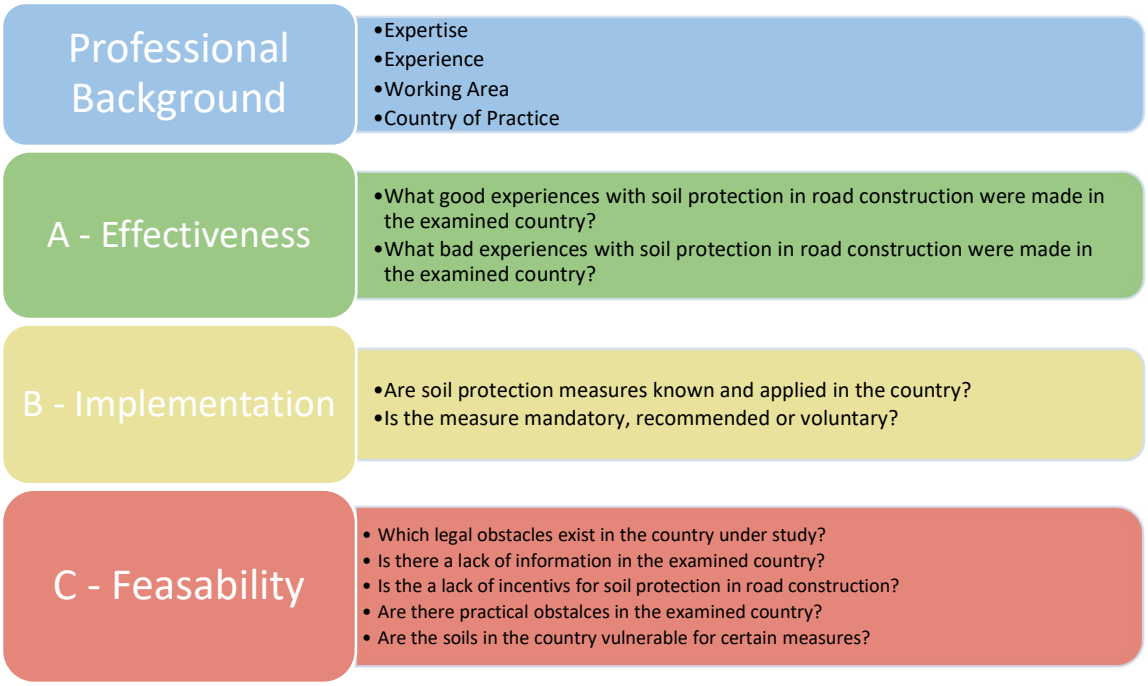

Figure 1: Conceptual Framework with three topics (effectiveness, implementation, and feasibility) with nine guiding questions and personal information about the expertise and location.

In the first set “Professional Background” we asked the respondents about their:

- Expertise: on which thematic area they work.
- Experience: number of years they are working on their professions.
- Working Area: classification of their work in professional disciplines.

- Country of practice: we asked specifically about where they practice their professions and not where they or their knowledge is from.

Based on this information, the results of the thematic questions were grouped to be analysed and compared among each other. We did not ask for any other personal information and we did not collect IP-addresses or any other information from the respondents.

We divided the thematic questions into three topics: effectiveness, implementation, and feasibility of soil protection measures in road construction. The questions on effectiveness allowed us to identify good and bad examples, and to assess the experts' experiences whether the implemented measures were effective. With the questions about implementation, we asked the experts whether soil protection measures in road construction were known and implemented and their legal and structural bases. And with the feasibility questions, we identified specific problems and approaches to solutions from the experts' experience.

2.1.2 Language and Translations

The survey was worked out parallel in German and English and then translated in seven other languages: Danish, Dutch, French, Italian, Norwegian, Spanish and Swedish. We decided to translate the survey into the national languages for which we have the linguistic competence in the team and from which we expected a sufficient number of responses from these countries based on the experiences from WP4. All of the translations, expect the Norwegian, were machine translated with Deepl Pro (DeepL SE, 2022) and then checked by colleagues with very good language skills from the respective languages. This was done by people from the project team, their working environment or private environment who have knowledge in the field of soil science or related topics. Since Deepl Pro does not provide the option of Norwegian translations, this work was completed by the Norwegian project members. The reason for the initial machine translation was to minimise the workload for the interpreters and to keep the documents as consistent as possible for further processing.

2.1.3 Survey Software

As we did not collect complex forms of data, we were able to focus on simplicity and user-friendliness as the main criteria for selecting survey software. Especially for the respondents the software should be appealing, self-explanatory and easy to use to motivate experts to fill in our survey. Additionally, the software needed to be able create multilingual surveys and have the option to add skip logics to the questions. Following these criteria, we went with the Advantage Plan of SurveyMonkey (Momentive Inc., 2022).

In the SurveyMonkey application questions can be added to the questionnaire as single- or multiple-choice questions, dropdown menus, text boxes etc. In some cases, element's logics can be added so that the follow-up question depends on the previous response. With all these tools SurveyMonkey allows a flexible use although the elements in themselves can only be adapted to a very limited extent. Crucial settings, such as the exclusion of participants who do not agree with the conditions of participation, are very easy to integrate.

For the translations, the SurveyMonkey application provides the survey in either a .csv or .po file to download and then to be edited with a respective application. We have decided to use the .po file, as it is not the less time-consuming, but the less error-prone variant. We edited the .po files with the free version of the Poedit application (Slavík, 2021). Within the Poedit application, the files are displayed as two columns. One for the original language in which the survey was created and one for the language to be filled in with the translation. Each row represents an item from the SurveyMonkey application, which consists of the designed questions and response options. For our survey, there were 362 lines, which had to be filled in mainly manually, separately for each language. The edited file could then simply be

uploaded again into the SurveyMonkey software.

2.1.4 Recruitment of participants

In order to address the experts, we contacted organisations and associations that aggregate a target group of experts and asked them to distribute the link to the questionnaire within their organisation. These included soil science societies, associations for geosciences, national and regional road agencies as well as environmental protection agencies, associations of engineers and planning offices. In addition, some experts were contacted personally. For this purpose, the networks of the people involved in the RoadSoil project (Consortium & Program Executive Board) were used. In total, 127 organizations and individuals from 17 different countries as well as from the European Commission were contacted.

2.1.5 Analysis of the responses

First cleaning of the data and structural adjustments were made in Excel. This included removing data that could not be analysed and responses from non-European countries. The further processing of the data and the graphical representations were carried out with RStudio (Version 3.5.1) running R (R Core Team, 2021). The professional background was re-categorised into three levels: "Green" for professionals from environmental science & conservation disciplines, "Grey" for professionals from construction or planning, and "Mixed" for a professional background from both of the previously listed disciplines. The questions were evaluated by country if the number of answers per country was sufficiently large and the question required such an evaluation. Countries with less than 3 answers were not listed. Questions with scaled answer options were additionally evaluated according to the three categories of professional background to allow for an extended interpretation. All of the asked questions were evaluated. However, if the number of responses was particularly low, for example in the case of response-dependent follow-up questions that might only be asked a very small number of respondents, the results were not graphically processed, but mentioned in the text.

2.2 Workshops

2.2.1 Organisation, objectives and method

We conducted three online-workshops of ca. three hours with the platform *zoom.us* and pursued the following objectives:

- Have the experts evaluate and reframe the challenges and potential solutions for soil protection in road construction;
- Jointly find ways to implement soil protection measures in road construction in all European countries;
- Jointly develop ideas to improve soil protection in road construction in the experts' home countries.

The workshops were structured according to the "Design Thinking" method (Pierce, 2020) which is a collaborative approach to jointly develop prototypes of solutions for a problem. The method consists of five steps from getting familiar with a problem (empathizing) to developing and testing prototypes of solutions. Table 1 explains the steps of design thinking and our implementation in the workshops. The steps 3 (ideate) and 4 (prototype) were conducted as group work in break-out rooms, whereas the other points were elaborated in plenum discussions.

Table 1: Implementing the Design Thinking method in the workshops with international experts.

Step of design thinking	Workshop topic
1) Empathize: the group gathers insights about the problem	• Presentation of the main results from survey with a focus on contradictory statements and open questions; • Short discussion of the presentation; have participants formulate problem statements
2) Define: the group identifies and agrees on the most relevant insights	• Have participants prioritize problem statements; • Participants agree on 3 problems for further work
3) Ideate: the group brainstorms ideas of solutions for the problem statements	• Quick brainstorming in small groups; generate many ideas for potential solutions; • Participants score the ideas
4) Prototype: the group transform the ideas to prototypes of solutions	• Develop prototype for the 1–2 ideas with highest scores of each group; • Prototypes = policy scenarios for transferring best-practices from one country to others
5) Test: the prototypes are presented to the others for their feedback	• Present the prototypes of each group; • Gather feedback

2.2.2 Workshop participants and recruitment

We selected the participants so that the groups of each workshop represented a broad spectrum of practical knowledge about soil protection in road construction (Table 2). In addition, they should represent different European countries.

Table 2: Selection of workshop participants.

	Practitioners	**Authorities**
Soil protection	e.g. soil protection experts on construction sites, consultants for EIA reports	Environmental agencies (national, regional)
Road construction	e.g. construction companies, traffic planning consultants	National, regional road administrations

For recruitment, we primarily used the professional network of the project team. We further invited experts who had been interviewed for work package 4 and work package 5. Finally, contacts recommended by the Programme Executive Board (PEB) members and the PEB members themselves were invited. In the course of the invitation, the experts could choose among three available workshop dates in September 2022. Based on this information, the experts were assigned to the three workshops. Attention was first paid to the priority of the experts, then to the mix of countries and the mix of expertise.

3 Results

3.1 Survey

3.1.1 Survey participants

228 people started the survey. Of these, two were not from Europe and another 70 quit the questionnaire at the questions about their background and expertise and before the topic-related questions were asked. These questionnaires could not be analysed and were removed. Hence, we could analyse 156 completed questionnaires. The respondents practice their profession in the following countries (Figure 2): Switzerland, Italy, Germany and Spain, with about 20 responses each. This was followed by Austria, Norway, France, Sweden and Belgium with about 10 responses each. We received 6 responses from experts working in the UK and 3 or fewer responses each from the Netherlands, Ireland, Denmark, Poland, the Czech Republic, Romania and Luxembourg. 56 of the respondents had a professional background in a soil protection or environmental/nature conservation discipline (later on called “green” experts), and 48 had an interdisciplinary background, i.e. knowledge from environmental disciplines, urban planning, construction industry or similar (later called “mixed”). Only 18 of the respondents came exclusively from urban planning, architecture, construction industry or similar (later called “grey”), who worked in Germany, Austria and Norway. The experts had 22 years of professional experience in average. The minimum experience was 2 years and the maximum 51 years.

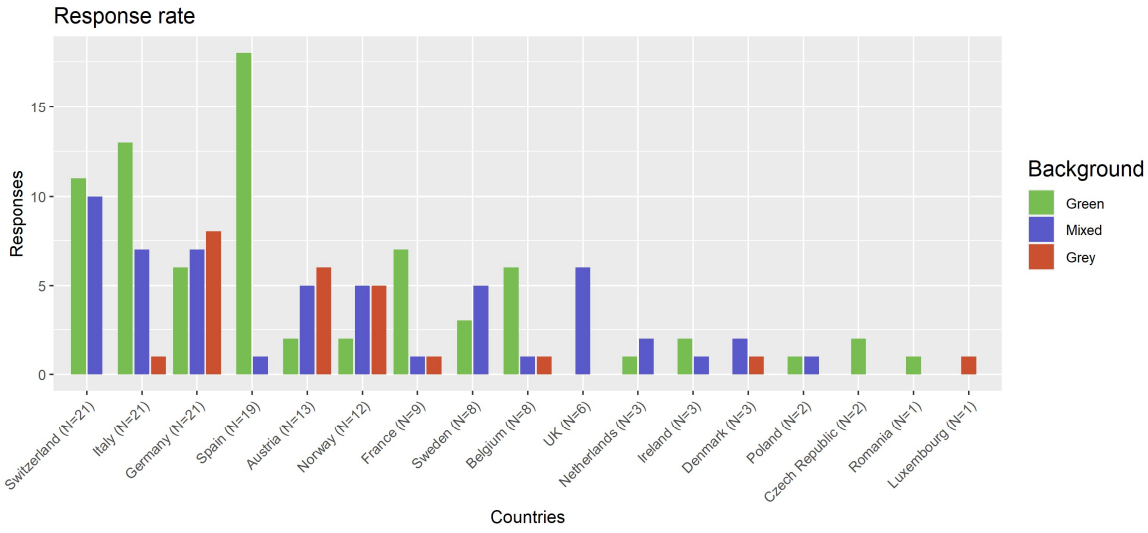

Figure 2: Number of completed questionnaires listed by country and professional background. “Green”: soil protection, environmental or nature conservation background; “grey”: road construction, civil engineering, urban planning background; “mixed”: both environmental and engineering background.

3.1.2 Success factors and obstacles of soil protection in road construction

The impact of road construction on soils is largely acknowledged by all experts from all sectors (Figure 3). However, a considerable part of the expert, particularly with “grey” and “mixed” background stated that the situation had improved in the recent past. Only a few experts with a construction and planning background or with a “mixed” background said that road construction did not damage soil in their countries.

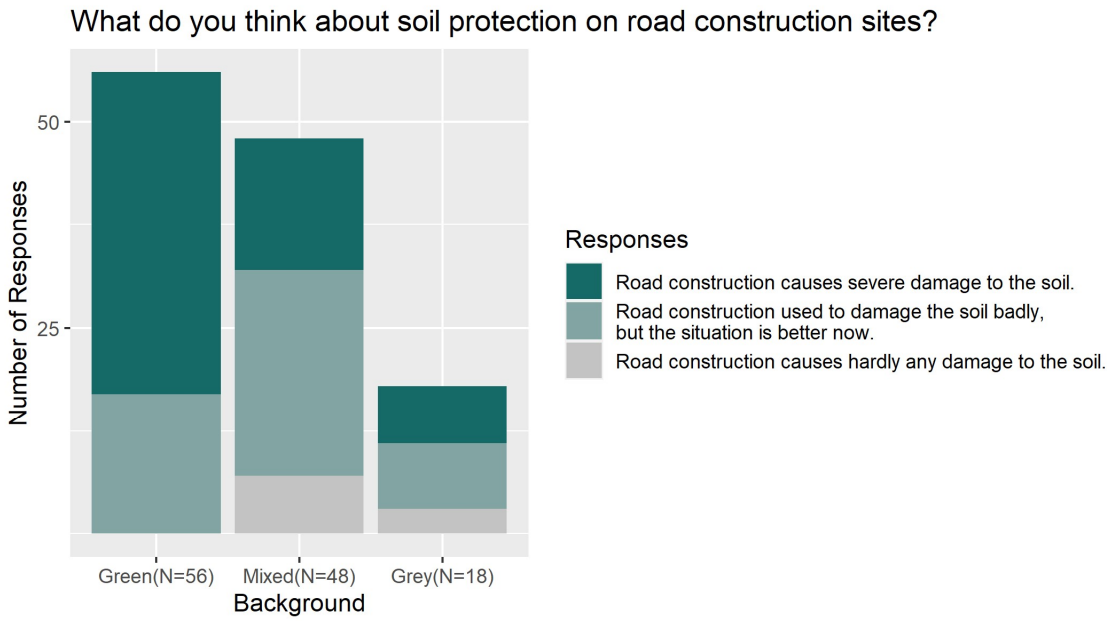

Figure 3: Results of the assessment of the situation of soil protection in road construction, according to the experts' professional background (N=122).

We asked the experts who stated that road construction severely damages the soil about the reasons (Figure 4). The experts mostly mentioned a lack of knowledge about the correct handling of soil among the people doing the earth work. Further reasons mentioned were a lack of incentives for the correct use of soil, insufficient communication between experts from road construction and soil protection, lack of penalties for careless soil handling, and practical obstacles such as lack of time, space, etc. Too heavy machinery or particularly vulnerable soils were mentioned with the lowest frequencies.

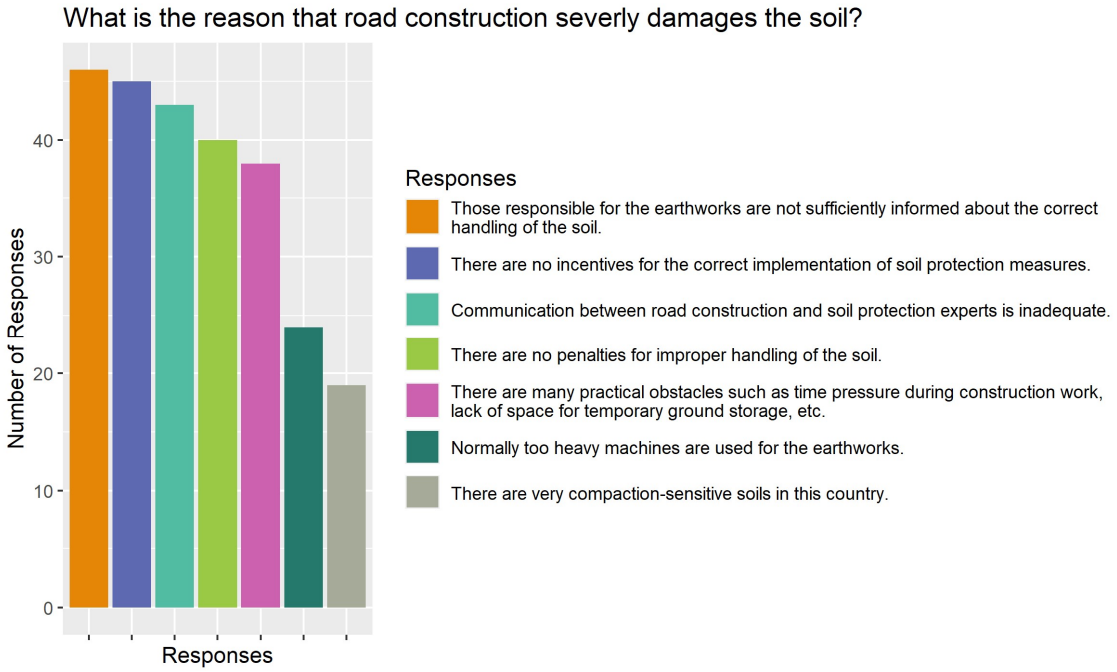

Figure 4: Answers to the question about the reasons for damages on soils due to road construction. Evaluated according to all responses from all experts. Respondents were those who stated in the previous question that road construction (still) causes strong damage on soil; multiple answers were possible (N = 255).

Figure 5 shows the answers of the experts who stated that the soil protection in road construction had improved. The most important success factor seems to be better information and training of the staff doing the earth work. This might be a consequence of new guidelines for the correct handling of soil and the supervision of construction sites by soil experts, which were both mentioned as strong success factors. New regulations at national level were deemed far more effective than new regulations at the EU level. Penalties for careless handling of soil and the preferential treatment of companies known to be particularly good at implementing soil protection measures were rarely mentioned as reasons for improved soil protection in road construction. This result probably means that these measures are seldom implemented, as the lack of penalties or incentives were mentioned as reasons for damage on soil (Figure 4).

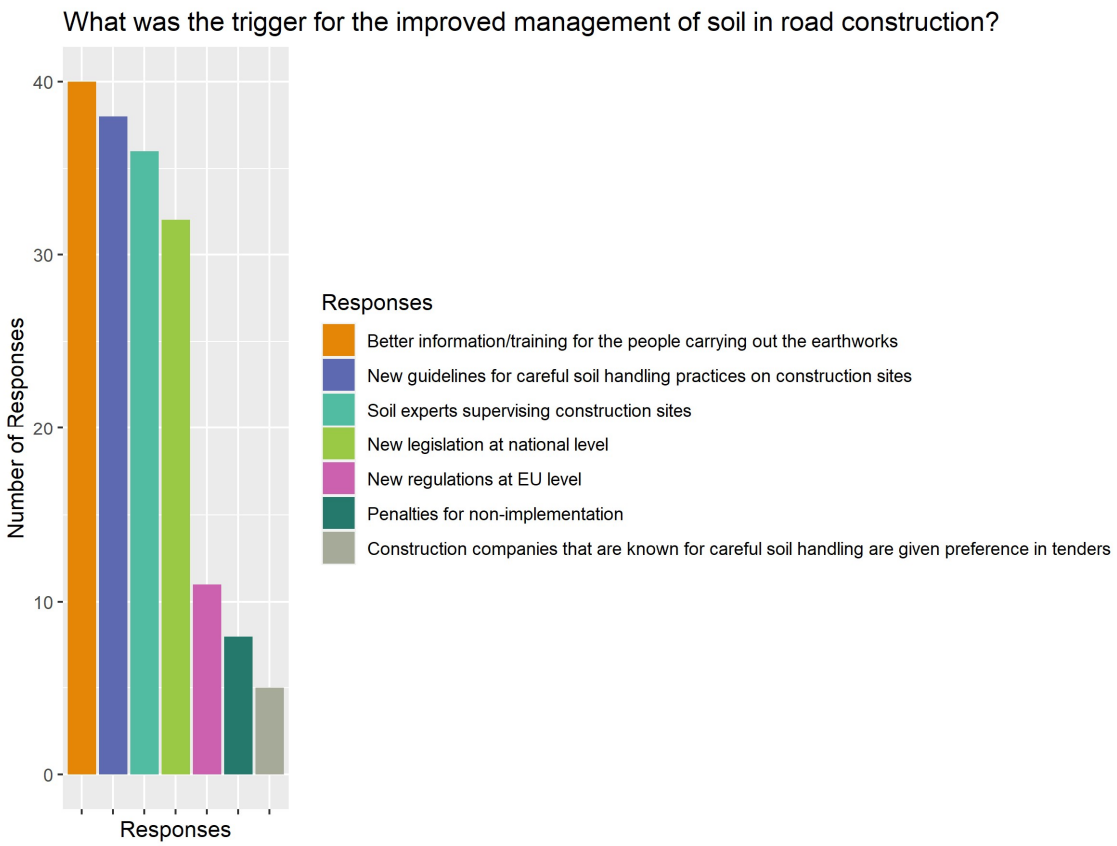

Figure 5: Success factors that improved soil protection in road construction. Respondents were those who stated that road construction used to cause severe damage to soil, but the situation has improved. Multiple answers were possible (N = 170).

The few experts who stated that road construction did not cause any damage to the soil said that, on the one hand, the soils in their countries were not particularly susceptible to compaction and could easily be restored, and, on the other hand, soil protection was required by law.

3.1.3 Guidelines and environmental impact assessment (EIA)

The experts assessed the soil protection guidelines of their countries very differently (Figure 6a). In the German-speaking countries, there is a larger group of experts who find the national guidelines helpful. In the contrary, experts from Spain perceive the guidelines as not helpful or unavailable. The most frequent answer was that the national guidelines were "sometimes" helpful. This might indicate a need for more specific guidelines.

Guidelines provided by the EU, on the other hand, were hardly perceived as helpful by the experts (Figure 6b). A large proportion of experts, including EU countries, answered the question with “I do not know”. This might indicate that soil protection guidelines at EU level are not well-known among professionals in road construction. The remaining experts mostly stated that the available EU guidelines were not helpful or only sometimes helpful. Only for Italy a larger group of experts considered the EU guidelines to be partly helpful or helpful (Figure 6b).

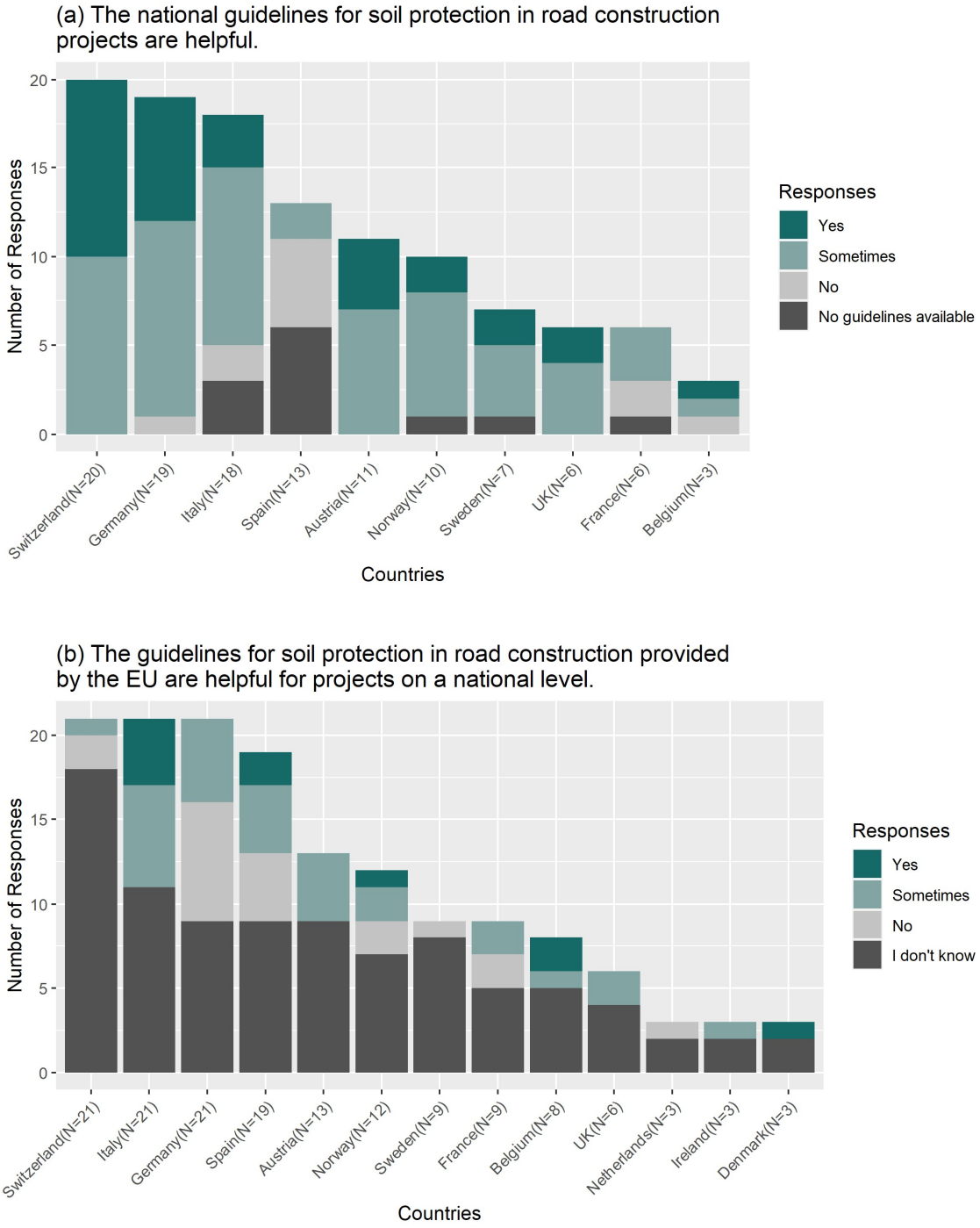

Figure 6: The use of soil protection guidelines assessed by the experts: the countries' guidelines (6a; N =113); guidelines provided by the EU (6b; N =148).

With regard to the Environmental Impact Assessment (EIA), most experts, independent of their professional background, stated that the EIA required detailed planning of soil protection measures, at least sometimes (Figure 7). Experts with a professional background in the

"green" category were more sceptical than those with a professional background in the "grey" category. Experts with "mixed" professional backgrounds were between the other two groups in their response rates to this question.

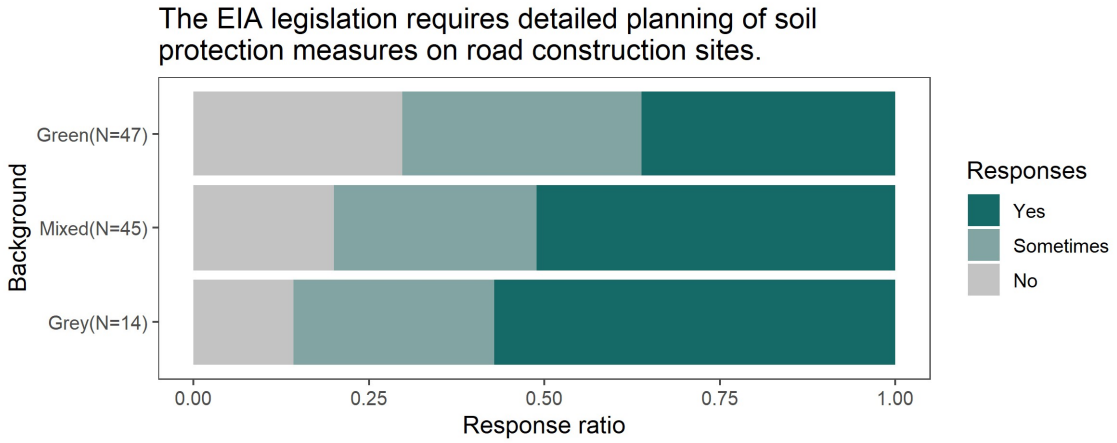

Figure 7: Requirements of the national EIA legislation in the planning phase of road construction projects (N=106).

The results are similar for the question about the influence of the EU EIA directive on the EIA at national level (Figure 8). Most experts answered “yes” or “sometimes” independent of their professional background. However, a considerable number of experts answered this question again with “I do not know”.

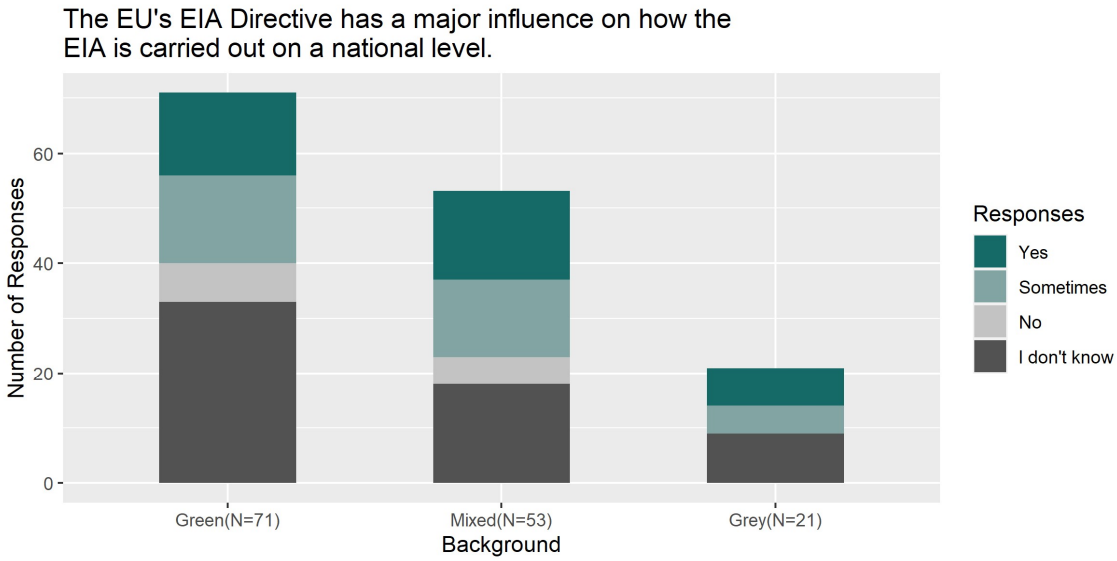

Figure 8: Influence of the EU's EIA Directive on the implementation of the national EIA (N=145).

When asking the experts whether the measures prescribed in the EIA were sufficient or too weak or too strong, we observe different perceptions related to the professional backgrounds

(Figure 9). While the majority of experts with a "green" professional background said that the EIA instructions were too weak, the majority of experts from the "grey" category deemed them sufficient.

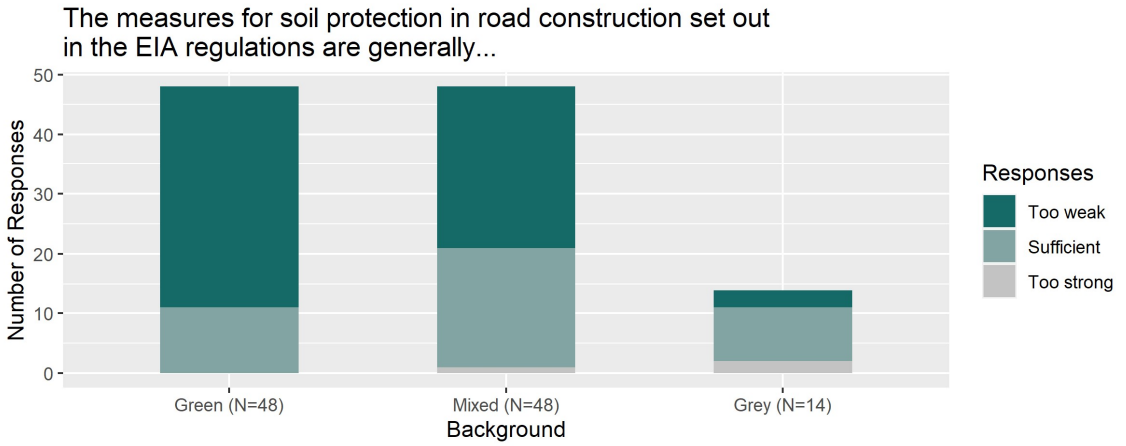

Figure 9: Assessment of the soil protection measures in road construction set out by the EIA regulations depending on the professional background of the respondents (N=110).

3.1.4 Planning phase

In the planning phase of a road project, spatial planning requirements usually have to be considered, whereas most planning prescriptions apply to natural habitats (Figure 10). Agricultural land and forests have to be conserved in road planning as well. The road planning phase includes the planning of measures to compensate for damage on soil caused by road construction. Again, in most cases natural habitats are restored (Figure 11). Upgrading of agricultural soils is a less frequent measure. It has to be mentioned, though, that compensation measures also include unsealing of road sections, mostly to re-establish natural habitats, but also to create urban green spaces.

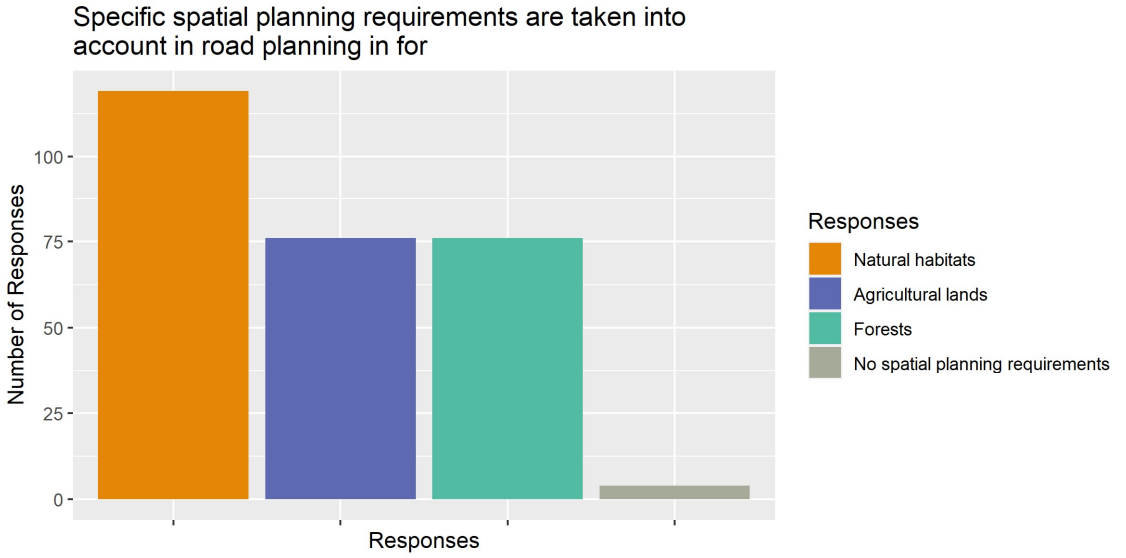

Figure 10: Land uses for which spatial planning sets up requirements (N=275).

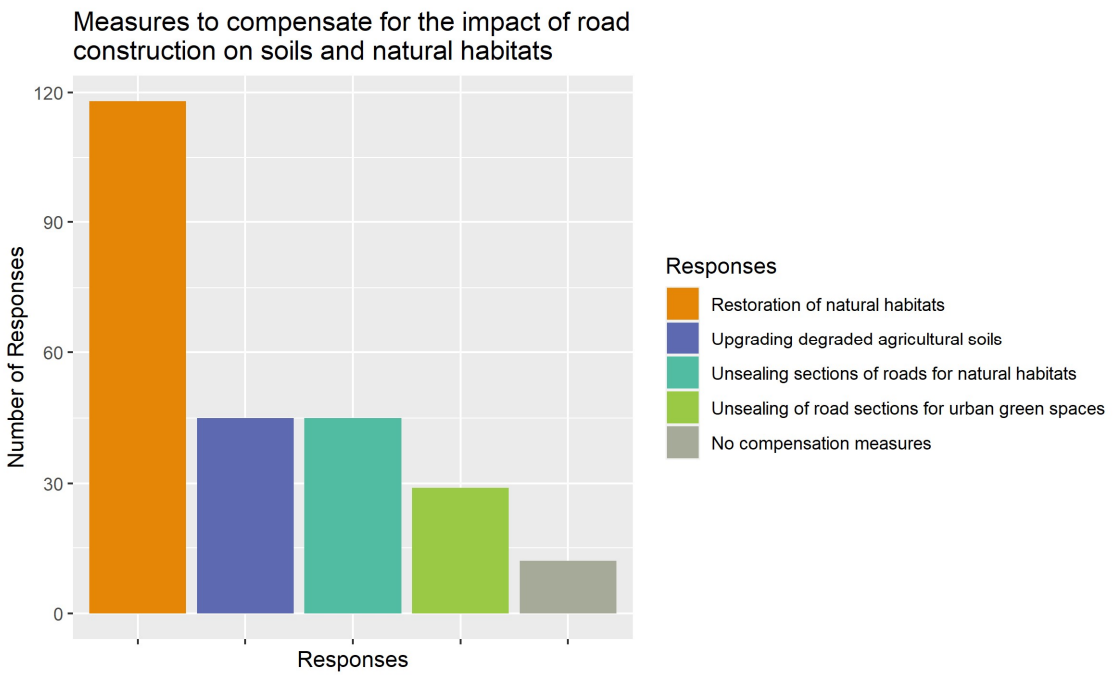

Figure 11: Measures implemented to compensate for the impact of road construction on natural habitats (N=249).

According to the experts, there are attempts to avoid additional soil sealing for roads by using digital technologies or other traffic management strategies (Figure 12). However, only a small proportion of the experts from each country indicated that traffic management measures are frequently applied.

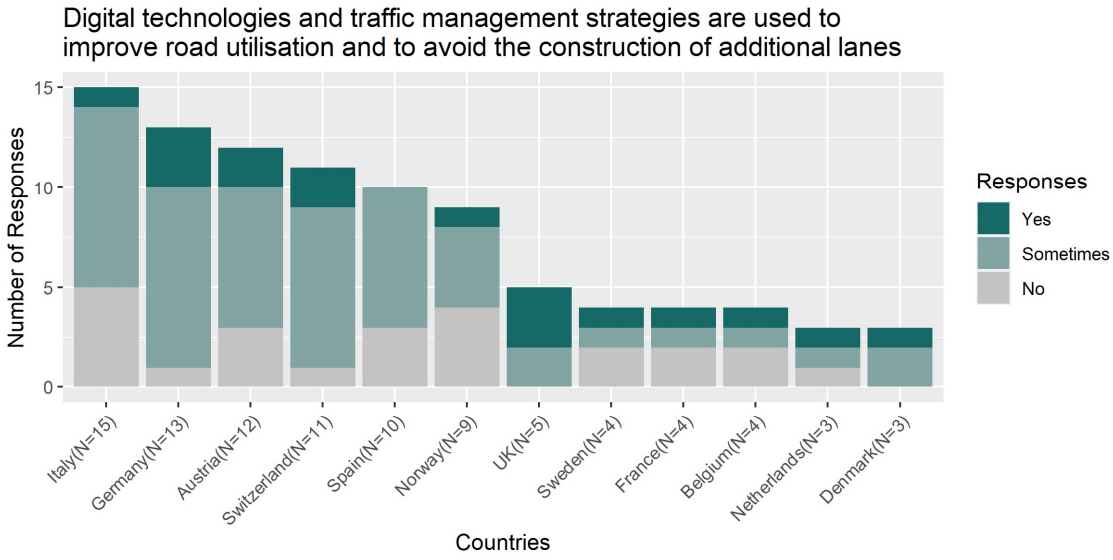

Figure 12: Application of digital technologies to increase efficiency of the existing road network analysed per country.

On the other hand, the alignments of new roads do not really seem to be chosen according to soil protection criteria in most countries (Figure 13). However, there are attempts in almost all countries to account for soil vulnerability at least sometimes.

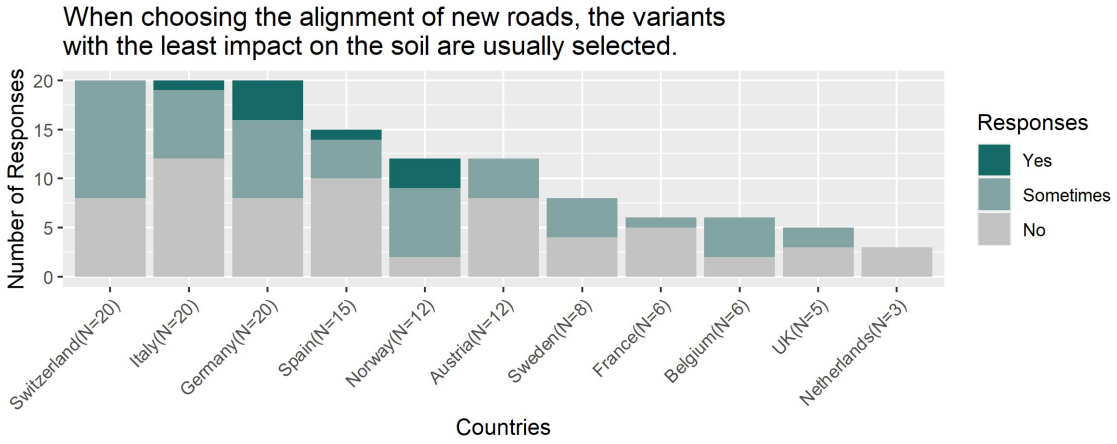

Figure 13: Results considering the adaptation of road alignments to the local soil conditions, analysed per country.

3.1.5 Soil information & field investigations

Soil information is a decisive resource for integrating soil protection in road planning and construction. The experts stated that detailed soil information about a number of topics was available in their countries (Figure 14). Soil maps with information about soil types, agricultural priority areas and polluted soils were mentioned the most. Detailed maps with information about physical and chemical soil properties were also mentioned rather often. Information about current soil moisture and soil biology is, however, only rarely available.

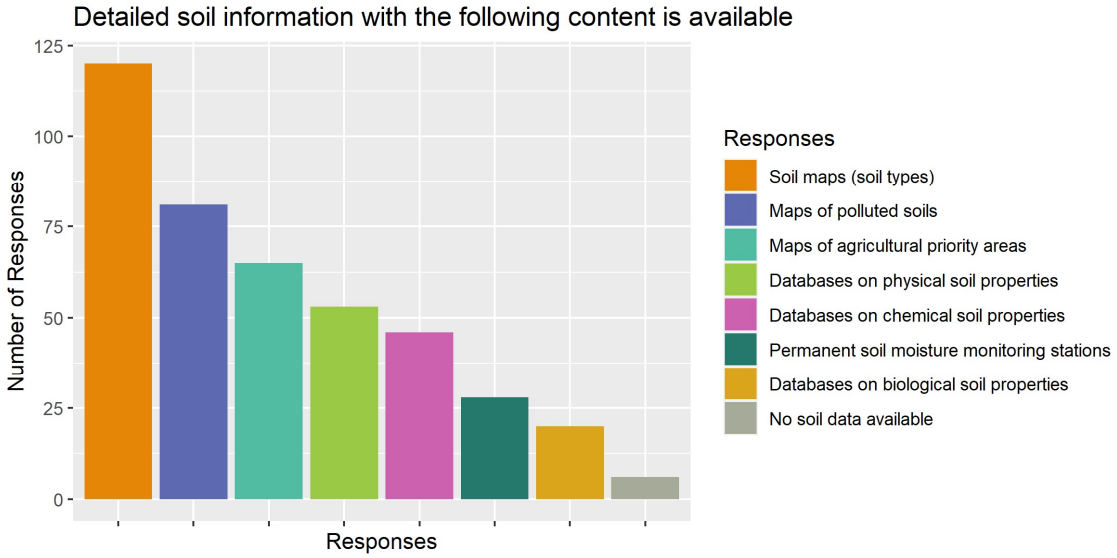

Figure 14: Answers about the availability of different kinds of soil information (N=419).

Open access data seem to be used in all countries in the context of road construction, but to a rather moderate extent (Figure 15). Especially in the countries with a higher response rate, a larger proportion of experts indicated that such soil maps were not or only sometimes used.

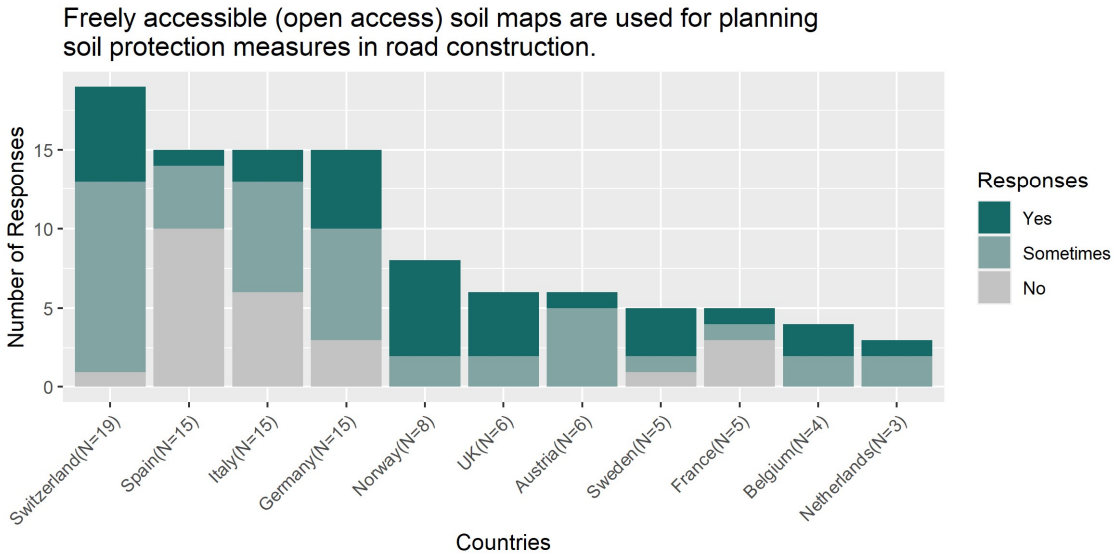

Figure 15: Responses about the use of open access soil data, analysed per country.

The experts mentioned a number of impediments for using open access soil maps (Figure 16). The most frequently mentioned drawback is the inappropriate resolution of the maps. Additionally, they do not provide the necessary contents which might be a consequence of the fact that mostly only parts of the countries' areas are covered and not all land-uses are considered.

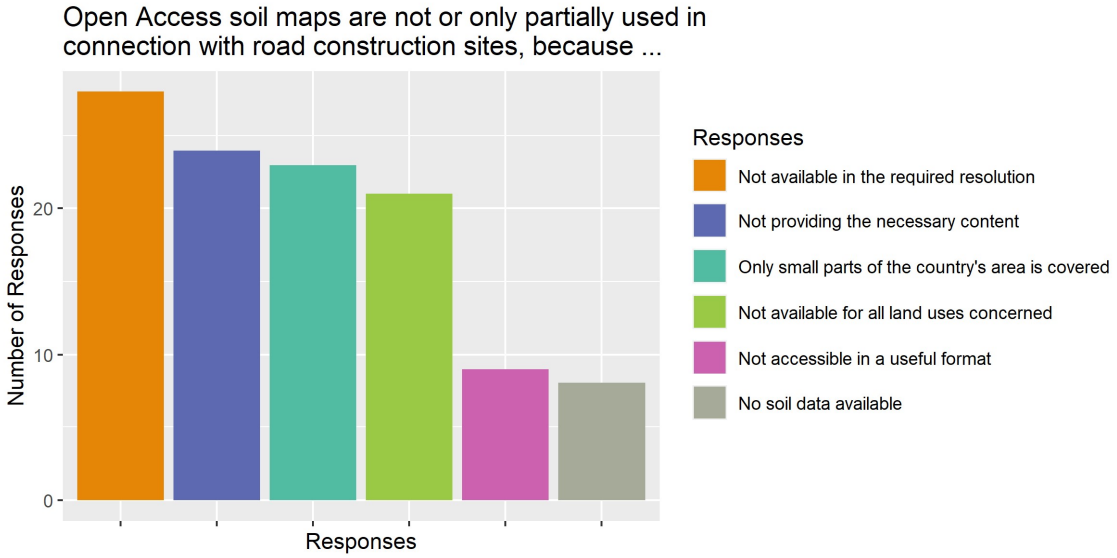

Figure 16: Reasons why open access data is not or only partially used; multiple answers were possible (N=113).

With the exception of Spain and France, the experts indicated that field investigations were at least sometimes carried out before the start of construction work in order to record the original

condition of the soil. According to the experts, these field investigations mainly include soil profiles and on-site soil analyses (Figure 17). The collection of soil samples for laboratory analysis of chemical and physical soil properties was also mentioned often. Soil biological analyses and the installation of soil moisture meters were mentioned only rarely.

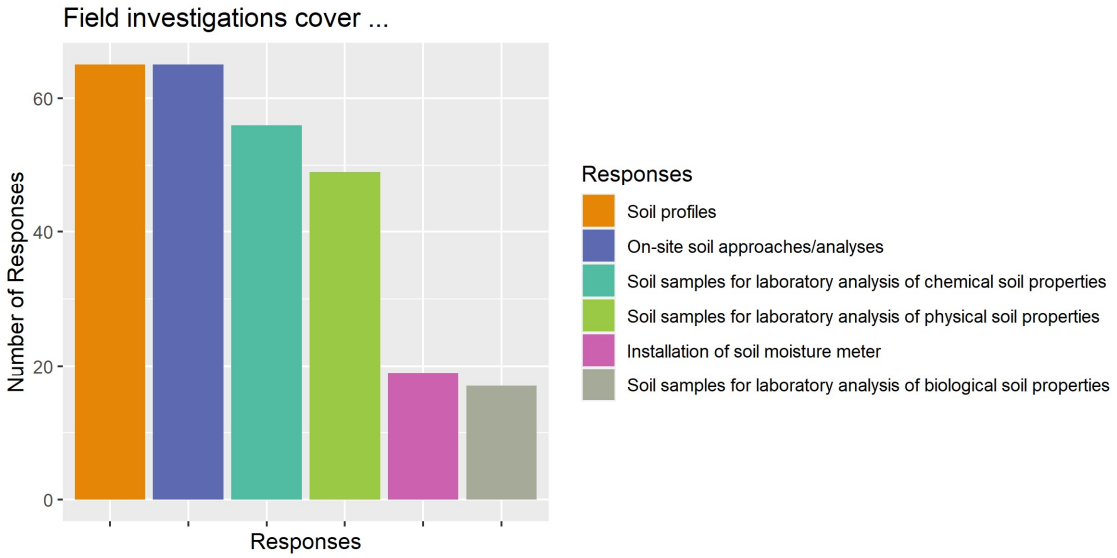

Figure 17: Collected data in the course of field investigations; multiple answers were possible (N=271).

We asked the experts who said that no field investigations were done in their countries about the reasons (Figure 18). Regardless of their professional background, they saw the main reason in the fact that field investigations were not mandatory. The lack of expertise and the costs were mentioned as additional reasons.

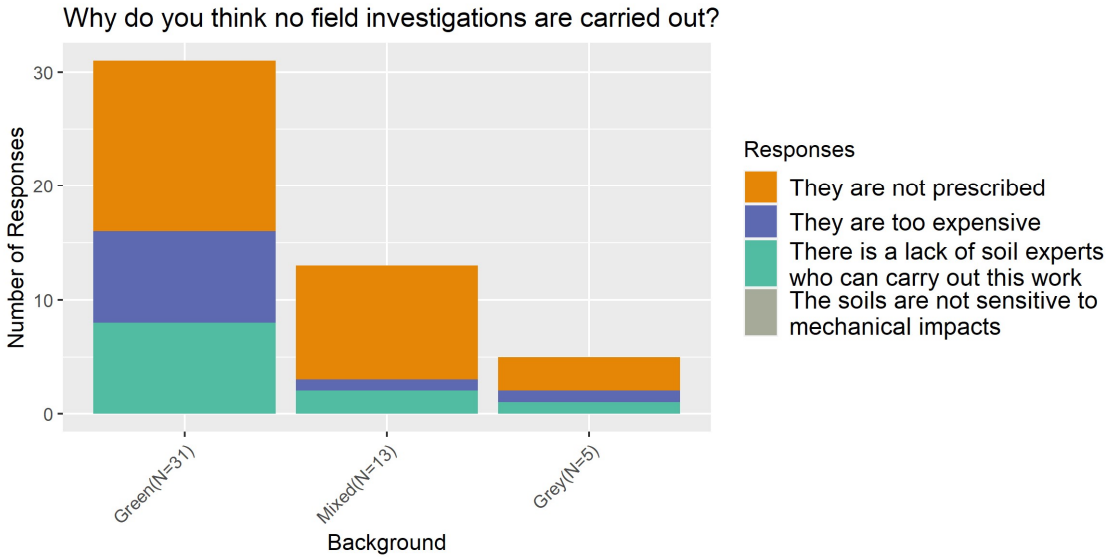

Figure 18: Reasons for why field investigations were not carried out, analysed according to the professional background of the respondents.

3.1.6 Construction phase

Measures to protect soil on road construction sites are implemented differently (Figure 19). Frequently implemented measures are the separate handling of topsoil and subsoil during excavation and storage, the restoration of agricultural soils and the reuse of excess soil. Commissioning a soil expert to supervise the construction sites as well as selecting the construction machines according to the soil's susceptibility do not seem to be well established yet. Finally, the success of soil restoration after termination of the construction process is rather rarely evaluated.

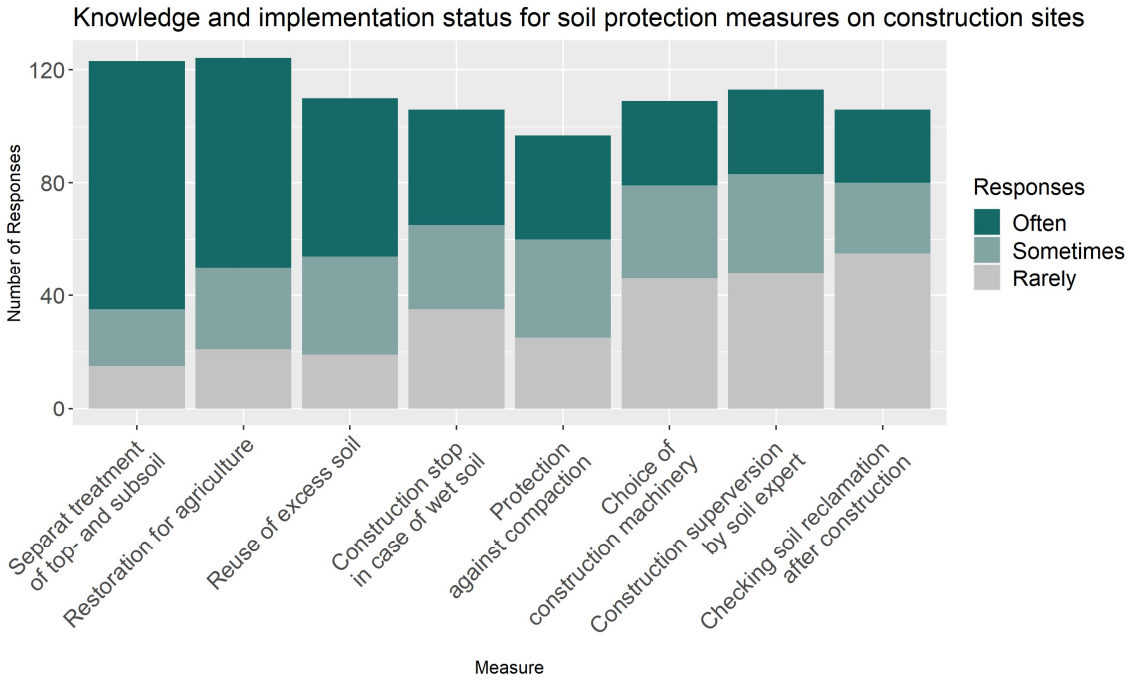

Figure 19: Frequency of implementation of selected soil protection measures on road construction sites.

3.1.7 Reuse of surplus soil including polluted soils

Surplus soil is usually reused and, as Figure 20 shows, mostly for restoring or upgrading agricultural soils. Further, surplus material is recycled to create urban green spaces. The reuse in natural habitats or forests was mentioned less often, probably because topsoil is usually not applied to these land-uses.

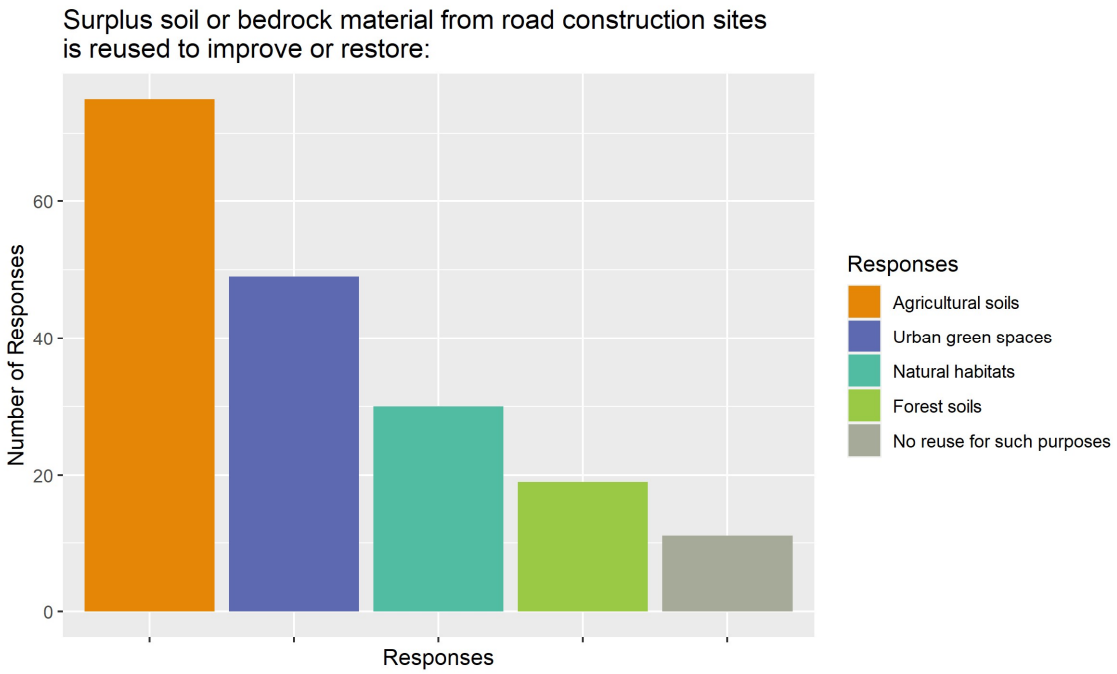

Figure 20: Reuse of surplus soil or bedrock material from road construction sites; multiple answers were possible (N=184).

The few experts who stated that there is no reuse of surplus material mainly mentioned conflicts with other legal requirements or a lack of legal obligation as the reasons (Figure 21). According to the experts, incentives might also enhance the reuse of surplus soil.

Figure 21: Reasons why surplus material from road construction sites is not reused; multiple answers were possible (N=20). Respondents are those who stated that there is no reuse of surplus material.

The recycling of surplus material seems to be usually organised locally and within the same company, i.e. between the construction companies and the landowners (often farmers) or between different construction sites of the same construction company (Figure 22). The least mentioned was the use of online exchange platforms to organise the recycling.

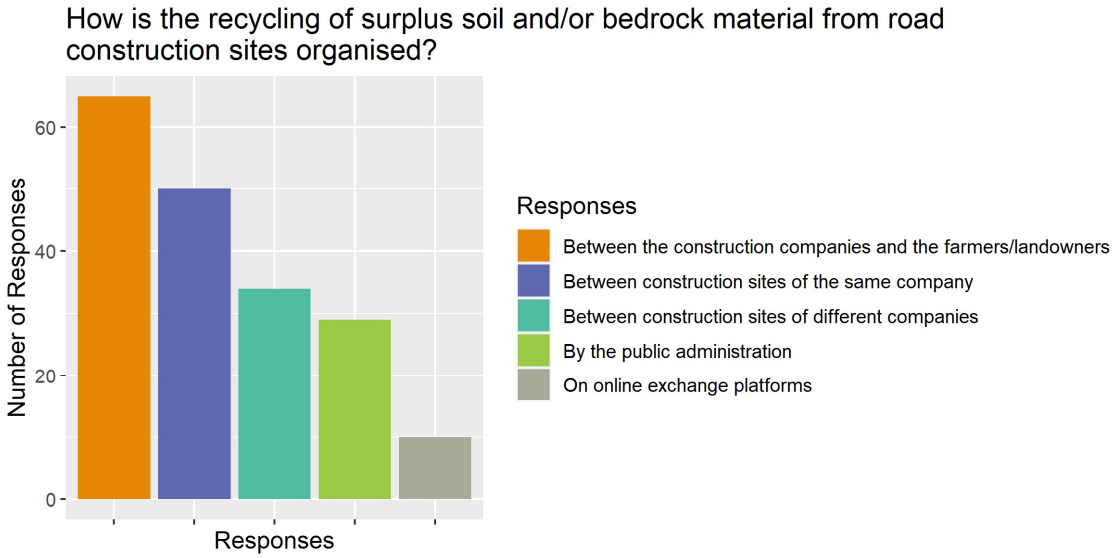

Figure 22: Results of the questionnaire on how the recycling of surplus material is organised; multiple answers were possible (N=188).

Polluted soils that accrue on road construction sites are mostly disposed of in hazardous waste landfills (Figure 23). Far less mentioned was the use of this material on site e.g. for embankments or noise barriers. Again, considerably less mentioned were the reuse on similarly polluted soils, soil remediation or the use for building material.

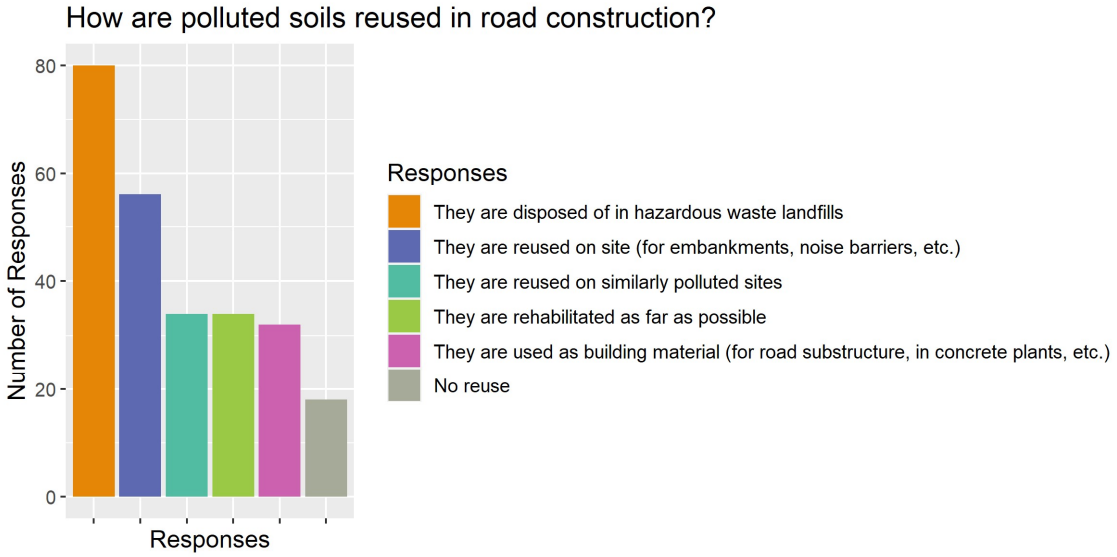

Figure 23: Results of the questionnaire on the reuse of polluted soils; multiple answers were possible (N=254).

3.1.8 Soil infested with invasive species

Regardless of their professional background, the majority of the experts consider invasive species as a serious problem on road construction sites (Figure 24). Only a small proportion of experts stated that the situation was mostly under control or that there was no problem at all. Multiple measures to avoid the spread of invasive species were mentioned (Figure 25). The problem is mostly tackled within the single countries with species records and national regulations, international collaboration was hardly known.

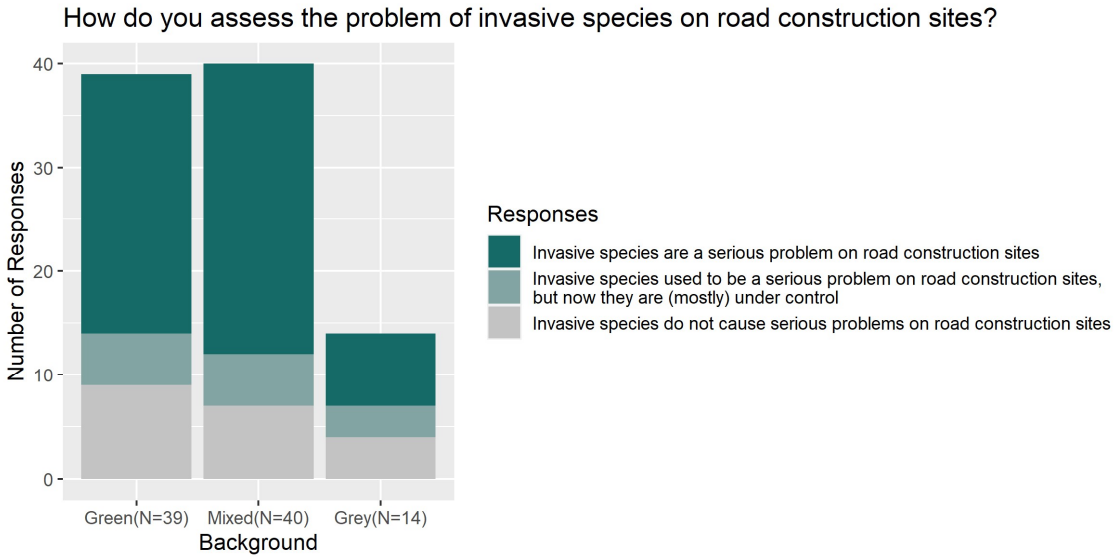

Figure 24: The experts' assessments of invasive species on road construction sites (N=93).

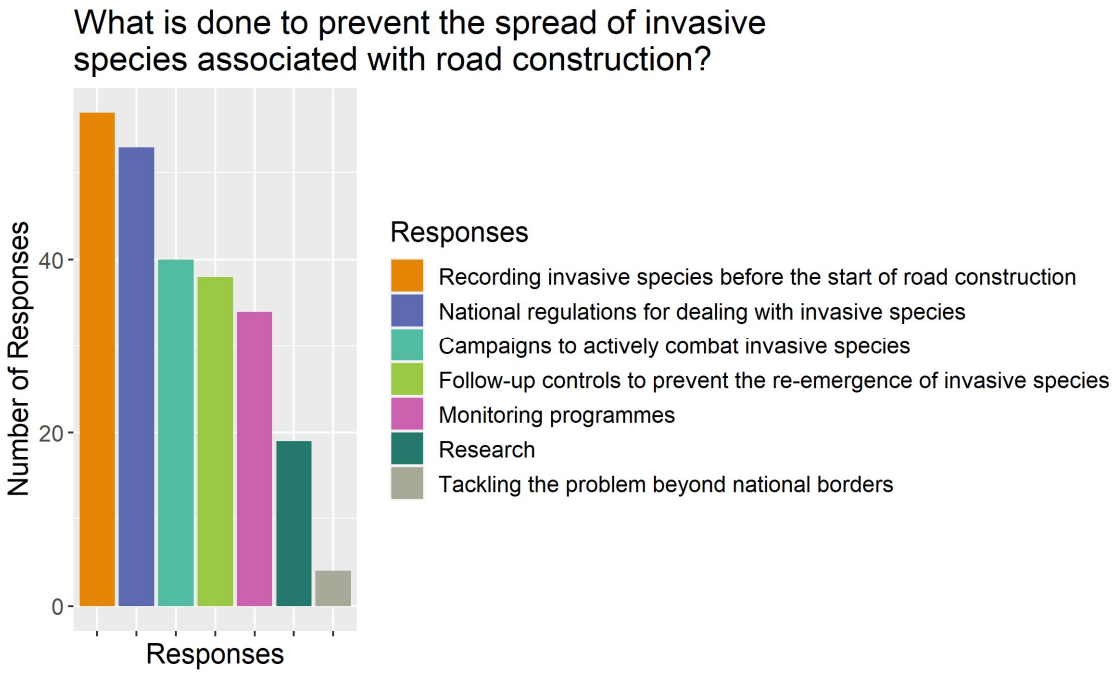

Figure 25: Measures to prevent the spread of invasive species in road construction; multiple answers were possible (N=245).

Many experts stated that they did not know whether infested soils were treated separately or not. The experts with a “mixed” background, i.e. the actual specialist in environmental issues on road construction sites, were most experienced in separate treatment of infested soils (Figure 26).

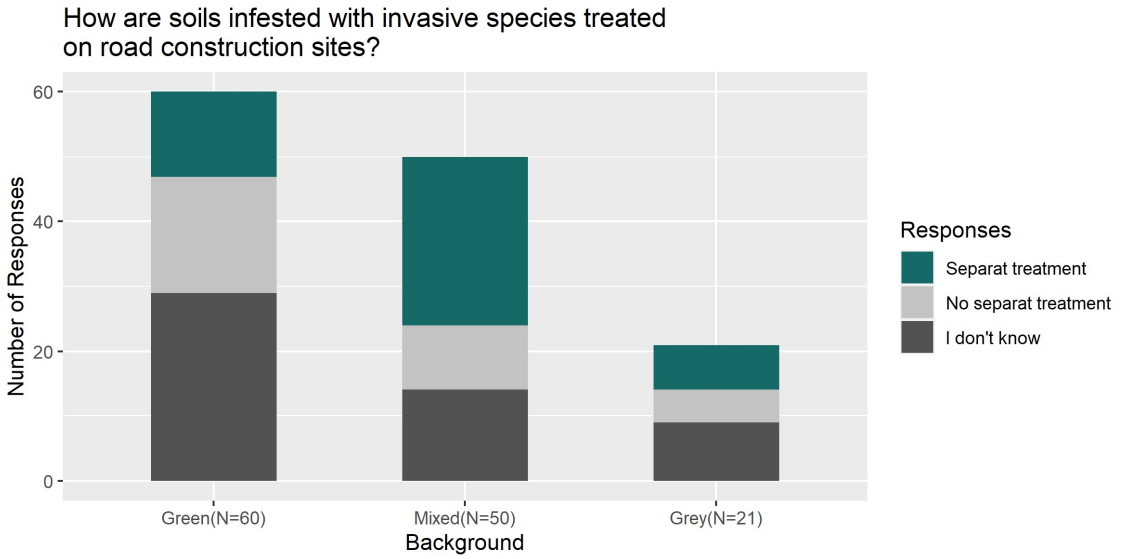

Figure 26: The results of the questionnaire about separate treatment of infested soils, analysed according to the professional background of the respondents (N=131).

The reported treatment of infested soils was, however, limited to disposal as hazardous waste or burning (Figure 27).

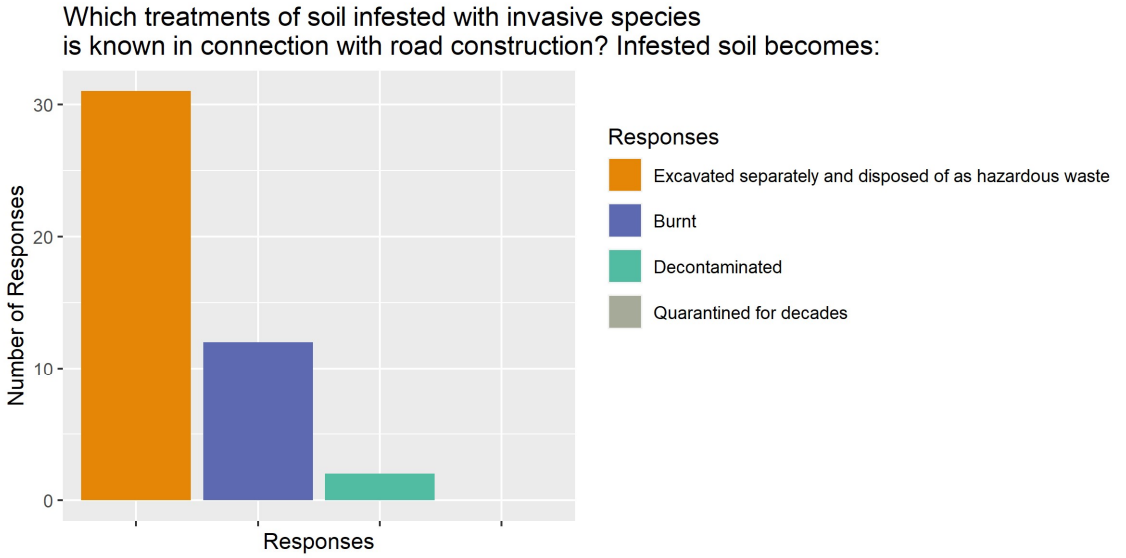

Figure 27: Special treatments of infested soils according to the experts; multiple answers were possible (N=45). Respondents were those who stated that infested soil was treated separately.

The main reasons for no special treatment of infested soils are the lack of expertise, no obligation to treat infested soils separately, and high costs (Figure 28).

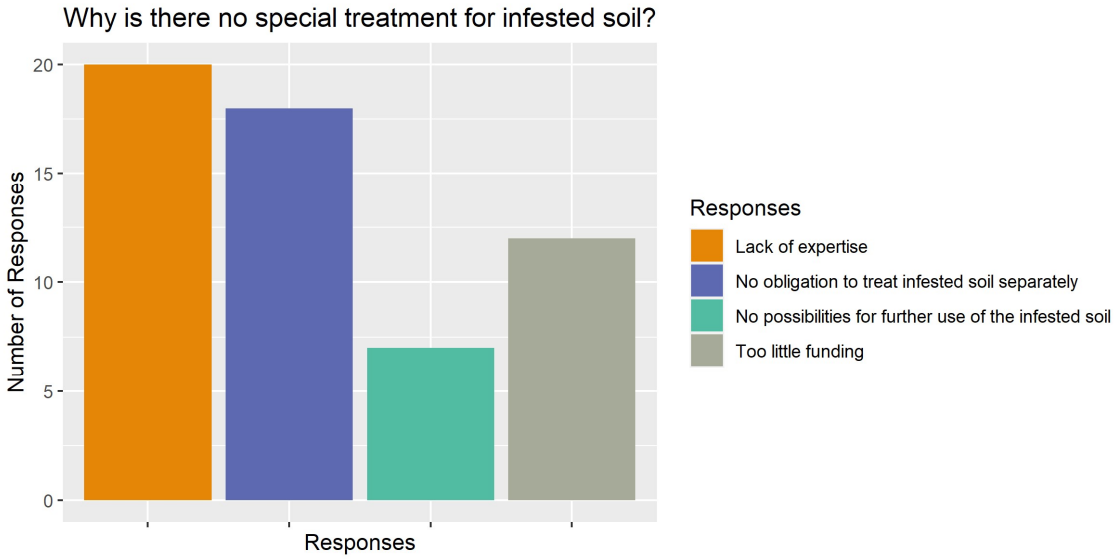

Figure 28: Reasons why infested soils were not treated separately; multiple answers were possible (N=57). Respondents were those who stated that infested soil was not treated separately.

3.2 Workshops

3.2.1 Workshop participants

In total, 30 experts registered and were assigned to one of the three workshops. Almost all experts followed the invitation and attended the workshop. Only a few experts per day were absent for various reasons. Three experts cancelled their registration in advance, three could not attend due to technical issues and three did not show up without cancelling. For this reason, Belgium and France were unfortunately not represented and the number of representatives from the road construction sector was reduced especially in the third workshop. The 21 experts who effectively participated in the workshops were from the following countries: Switzerland (6), Norway (4), Germany (3), Sweden (2), Ireland (2), The Netherlands (1), Denmark (1), Austria (1), and the UK (1). They work either in the private sector (11), in authorities (7) or in research (3). The representatives from the private sector are mainly employed in planning and consulting offices. Authorities included national and regional road agencies as well as environmental agencies. The first two workshops were well mixed in terms of countries and professional background, whereas the third was mainly represented by experts from the private sector.

During the workshops, four main topics were addressed:

- Knowledge exchange;
- Awareness rising and communication;
- Management of surplus soil;
- Compensation measures.

The following sections present the specific problems the participants identified in the context of these issues and the suggestions created to solve the problems.

3.2.2 Knowledge exchange

The participants strongly appreciated the knowledge exchange across countries during the workshops. Particularly in the third workshop where, due to some absences, only one stakeholder group, the soil experts working on construction sites, was represented, the discussion focused on current practices of soil protection in the different countries.

The international exchange revealed a number of specific problems in the different European countries. The soils differ which entails different challenges for soil protection on road construction sites. While in Switzerland, construction sites are often on rather sandy soils, Scandinavian countries have to cope with fine-grained clayey and silty soils which are far more susceptible to compaction. In Ireland, organic soils (peat) are abundant which are even more vulnerable and play an important role for biodiversity conservation and carbon storage.

Moreover, differences in legislation were identified, particularly in terms of surplus soil management and land-use planning. Surplus soil is defined as waste in some countries, e.g. Sweden, while other countries follow a policy of circular economy and prescribe the reuse of surplus soil whenever possible, e.g. Germany, Austria and Switzerland (see also section 3.2.4). Considering the protection of specific land-uses, particularly forests are treated differently across countries. In Scandinavian countries, arable land is most protected and forests are cut for construction or to compensate for building on agricultural land. In contrast, the Swiss forest legislation prohibits any reduction of the forest area and, consequently, construction activity is usually in strong conflict with agriculture.

The exchange across countries, equally, helped learning from other practices and developing approaches to overcome the specific problems. The participants exchanged their experiences on practical issues, such as a soil management plan which is usually set up for Norwegian construction sites and mandatory in Switzerland, or a protocol for the procedure of the final quality check of the restored soil. The soil experts on construction sites were particularly interested in such templates because they could adopt them for their own work and, thus, foster innovation in countries with less regulations for soil protection in road construction.

3.2.3 Awareness raising and Communication

The participants emphasised awareness and communication of soil protection issues as the key success factors for proper implementation in road construction. Key players in soil protection in road construction are interdisciplinary, well-trained experts who communicate their knowledge to the stakeholders involved such as land owners and decision makers. Such experts have a background in soil sciences as well as in construction projects, and usually work as soil experts in consultancy offices. In Switzerland and Germany, it is mandatory to appoint a soil protection expert who is certified by an independent institution to supervise the construction process, at least for large construction projects. Among the most important tasks of such soil experts is explaining the ways of careful soil handling to engineers and machine drivers.

The participants postulated that interdisciplinary training about soil as a resource should address a larger number of stakeholders, such as spatial planners, architects, civil engineers and, particularly, decision makers. Specific training courses in soil science, such as NIBIO's courses for machine drivers or the course "soil science for policy makers" at Cornwall College, should be extended.

According to the participants, technical knowledge of good soil management is often sufficient, but it has not been translated into policies. Therefore, the participants stressed the need to raise awareness for soil among the decision makers, i.e. the politicians, because they are responsible for regulations. Several approaches were suggested. One was to invite politicians to construction sites and explain them the role of soil as an ecosystem and for human health. For example, members of the German parliament visited road construction sites to see how effective the appointment of soil experts on construction sites is and, if the respective legal prescription should still be valid. Another proposal was to set up an “advocacy plan” for the soil which explains to the politicians which problems can be solved, if soil is protected. An aspect of such an advocacy plan could be the management of soil for biodiversity conservation and for reducing the carbon footprint. Another aspect could be circular economy for soil with an emphasis on biodiversity enhancement. A conclusion of such an advocacy plan should be standardised functional requirements on soil handling at the policy level. Such standards should be defined at EU level because contractors for road constructions usually work in several countries. In addition, the participants suggested to appoint “soil ambassadors” to actively inform about soil as an ecosystem and raise awareness about soil as a resource among the general public and the politicians. An alternative could be to establish meeting places where experts from administration, politics, practice and science can exchange their knowledge and experiences. The Global Soil Partnership was mentioned as potential meeting place.

3.2.4 Management of surplus soil

The participants saw the main obstacle of sustainable management of surplus soil in the fact that surplus soil is treated as waste in many legislations. To solve this conflict the countries’ policies should change towards the principle of circular economy and define surplus soil as a natural resource and not as waste. This should lead to incentives or even the obligation to reuse surplus soil.

Uncertainties in the estimation of the amount of soil that should be stored on a construction site or reused elsewhere were mentioned as an additional problem. This often results in a lack of space for temporal soil deposits or a mismatch of supply and demand of surplus soil in the specific region. The experts recommended that soil storage and the handling of surplus soil should be planned at an early stage of the project when different options can still be evaluated. Such a soil management plan should be part of the EIA.

The participants proposed several solutions to reconcile supply and demand of surplus soil. In Norway, the national transportation plan indicates the location and urgency of road construction projects and should help avoiding too many construction sites in the same region at the same time. Soil banks or soil trading platforms were deemed as a powerful tool to link the supply and demand sides. Successful examples of such soil banks were reported from the Netherlands. They are established for specific regions and operated by private companies or authorities. Their use was promoted both by financial incentives as well as by obligation to reuse surplus soil. The experts suggested to compare different systems of soil banks to assess ways of quality assurance of the traded soils and to promote the system in other countries.

Due to the intensive construction activity all over Europe, the supply of surplus soil often exceeds the demand for it. In order to increase the demand, the authorities of some Swiss cantons have defined priority areas for upgrading and restoration which are indicated on maps. Many of these areas are degraded agricultural land. This measure could make soil banks work better in regions with many construction sites where a large amount of surplus soil accrues.

Finally, information about the amount of surplus soil is rare in most countries. In Denmark, the

local authorities have to record the quantity of surplus soil in urban regions. In Norway and probably other countries, private companies often have a better overview of the amount of processed material than authorities. An obligation to use soil banks could make this information available to more actors involved in road construction.

3.2.5 Compensation measures

The participants agreed that measures to compensate for damage to soils are necessary, but they should be selected and implemented according to strict criteria assuring the overall sustainability of these measures. The compensation measures should, in particular, be embedded in the local context and not promote specific soils or ecosystem traits while having negative effects on the rest of the ecosystem.

Compensation measures were deemed particularly effective at sites that had been damaged in the past. However, knowledge about the location of such sites is lacking in many countries. The participants proposed that national and regional authorities should define degraded land suited for compensation measures and publish them on maps that are available for construction companies. These sites have to be assessed according to the local conditions in order to define appropriate targets for compensation measures by local authorities. On this basis, compensation measures can be integrated into the planning phase of a road construction project, i.e. at an early stage of the project. The regulations about how to implement compensation measures should be specified in more detail. This would not only help the authorities to ensure the correct implementation of compensation measures, but also the construction companies to plan them. The participants expressed that precise and specific regulations enable a fair tendering process in a construction project because the expected measures and their pricing would be the same for all companies.

4 Discussion

4.1 Survey

The results of the survey allow a general assessment of the current state of soil protection in road construction in more than 13 European countries. According to the conceptual framework of the questionnaire, the results i) show how the experts assess the effectiveness of soil protection in road construction in their countries, ii) give an overview of the soil protection measures applied in road construction projects in the different countries, and iii) inform about the feasibility and obstacles of soil protection in road construction. However, the response rates from the single countries were rather low and particularly the statements on countries with 3 or less participants should be assessed with caution.

The survey results clearly show that damage on soil caused by road construction is largely acknowledged by all professional groups. However, a considerable number of experts said that the situation has improved in the recent past, indicating that soil protection in road construction has become more effective. Particularly experts with a mixed professional background reported on improvements what probably means that they experienced the change in their practical work.

The analysis of the questionnaire showed that the same arguments were stated as reasons for damages caused by road construction as well as success factors for the improvement of soil protection in road construction. The lack of knowledge about and no legal obligation for soil protection were mentioned as the main reasons for damage on soil. Conversely, the experts deemed education of staff on construction sites and guidelines providing information about soil protection together with stricter legal regulations as the decisive success factors for improved soil protection in road construction. In addition, the lack of incentives and penalties were often mentioned as reasons for damages on soil due to road construction. However, they were hardly seen as success factors which might indicate that these measures have not been implemented.

The environmental impact assessment (EIA) is an important procedure to promote soil protection in road construction, but there seems to be room for interpretation. Particularly experts with an environmental (“green”) background criticised that the measures prescribed in the EIA were fundamentally too weak. However, the EIA Directive of the EU has, according to the experts, a decisive influence on the implementation of the EIA at national level. Hence, extensions of the EU EIA directive might have an influence on soil protection in road construction in the European countries.

Soil information is available in most countries, but it is only partly used. This is particularly visible in the example of the road alignment which, according to the experts, is not or only rarely chosen with the inclusion of soil criteria. As each road construction site is a single case, the available soil information is not seen as useful due to low resolution or missing contents. Hence, it cannot replace field investigations. An interesting result is that field investigations are carried out quite often to assess the original state of the soil, but a check of soil quality after termination of the construction work and soil restoration is rather rarely done. The quality of the restored soil could be improved, if a final check was required by the EIA.

The road planning phase includes the planning of measures to avoid and compensate for damages on soil. Our survey results show that there is an emphasis on the protection and restoration of natural habitats. This might be a consequence of the fact that in many countries, the nature protection act requires ecological compensation in the context of infrastructure compensation. Additional spatial planning requirements that are considered in the road planning phase are the conservation of agricultural land and forests. Upgrading degraded

agricultural soils was mentioned among the compensation measures, though less than half as often as the restoration of natural habitats. Unsealing road sections to create natural habitats or urban green spaces were also mentioned as compensation measures practiced. Road unsealing is, of course, the most effective measure to avoid secret paths and to reduce the traffic burden of the neighbouring population.

Agricultural land is usually restored after road construction which is probably a consequence of the spatial planning requirements mentioned before. Accordingly, surplus soil from road construction sites is mostly used to restore or upgrade agricultural land. Impediments of the reuse of surplus soil are mainly the lack of a legal basis or conflicts with other legislations. The lack of incentives was additionally mentioned as an obstacle for reusing surplus soil. These points correspond to the initially detected challenges for implementing soil protection in road construction. However, excess soil that is polluted is mostly deposited in hazardous waste landfills. It is unclear, if this is, again, a matter of regulations, or if the techniques to reuse polluted soils on-site or elsewhere are not well established. A similar situation could be observed with the treatment of soils infested with invasive species. A separate treatment of these soils usually consists of depositing as hazardous waste or burning. However, infested soils are not always treated separately, and the experts justified this again with a lack of expertise and no obligation.

In the road construction phase, many soil protection measures seem to be at least partially implemented. According to experiences from Switzerland, a key measure to improve soil protection on construction sites is the appointment of soil experts to supervise the construction process (Deliverable 4.1, 4.2). According to our survey, this is not frequently done in other countries. Adopting this system to other countries might be beneficial for increasing the knowledge about soil protection on construction sites in general.

4.2 Workshops

In the workshops, the results from the survey were generally confirmed. The participants agreed that knowledge about proper soil handling on construction sites is a key to more soil protection in road construction. They did not only mean people working on construction sites, but they stressed that politicians should be better informed about soil as an ecosystem and its services for humans. Raising awareness of soil among politicians was a big issue and the participants came up with proposals such as site visits on construction sites, an advocacy plan for soil and “soil ambassadors” spreading the message about the importance of soil.

Informing politicians is important because they have a strong influence on the countries’ regulations. The policies should acknowledge soil as a precious natural resource and follow the principles of circular economy in its use and management. This could be the basis to adapt certain legislations so that conflicts between soil protection and e.g. waste management could be reduced or avoided.

The participants further pointed out that all steps of soil management on road construction sites have to be planned at an early stage of the project. In this sense, they stressed the importance of the environmental impact assessment (EIA). The EU EIA Directive should be improved because standards and guidelines at EU level have a great influence, since many companies work in several European countries.

A policy of circular economy would enhance the reuse of surplus soil so that it is not disposed of as waste. The participants promoted soil banks to match supply and demand according to the quality of the surplus soil and the soil at the destination. Maps of degraded land suited for improvement would support the use of soil banks.

Compensation measures have to be planned early and comprehensively. Ideally, compensation measures improve sites that were damaged in the past. The measures must be adapted to the local conditions so that they compensate for the damage without negatively affecting the rest of the ecosystem in the area.

Finally, the participants strongly appreciated the knowledge exchange across country boarders. They enjoyed the exchange with colleagues working on the same problems which gave them a feeling of togetherness and encouraged them in their work. There was a wish for more meeting places for knowledge exchange. By chance, we explored such a meeting place with our third workshop. Due to absences, exclusively soil experts on construction sites attended the workshop. They discussed specific practical issues and learned from the other countries. This experience gave us the idea that online meetings would be an easy to access place for international knowledge exchange. These could be organised by researchers or authorities that want to promote soil protection in road construction. They could also be an additional offer of soil science societies that certify soil protection experts on construction sites.

5 Conclusion

The survey revealed differences between the various countries in implementing soil protection in road construction. Although their importance is recognised by most experts regardless of their professional background, in some countries certain soil protection measures are only partly known and implemented. According to the experts, making soil protection measures mandatory has improved the situation in many countries. This is, in addition, the necessary basis for penalties for no or bad implementation of soil protection measures.

The EIA is a decisive step in the road planning phase where soil protection measures are set up. Additional specifications in the EU EIA Directive could have an impact on soil protection in road construction in many European countries. The specifications should go in the direction of a mandatory soil management plan indicating the soil protection measures during and after the construction work. Such a soil management plan should include the reuse of surplus soil. It should further commit the constructor to have the soil quality checked by field investigations, not only before the start of construction work, but also after completion of the soil restoration. Another set of specifications should inform about the selection and implementation of compensation measures so that these are adapted to the local conditions and comprehensively contribute to ecosystem enhancement.

Soil experts who supervise the construction process were mentioned in the survey as an important success factor to improve soil protection in road construction. In some countries, there are specific training courses for soil experts on construction sites offered by research institutions, universities, soil science societies and private companies specialised in environmental education.

In addition, awareness for soil as a natural resource has to be raised among the politicians because they are responsible of setting up certain policies and enacting the corresponding legislations. Reaching out to politicians with site visits, specific training courses or similar can help promoting policies of circular economy and sustainable soil use and management.

A change of policies towards circular economy would foster the reuse of surplus soil from road construction sites which is currently in conflict with the waste legislation in some countries. The workshop participants promoted soil banks as an effective tool to link supply and demand of surplus soil, although, according to the survey results, soil banks have hardly been used. Different soil bank systems should be evaluated in terms of quality assurance of the traded soils and the appropriate provider (authorities or private companies or public private partnership).

The workshop participants appreciated the opportunity to learn from other countries and said that there should be more meeting places for knowledge exchange between practitioners, authorities and researchers. The format of our workshops as online meetings revealed to be a low-threshold service for such international meeting places. With a pilot run of a few more online meetings it could be tested out, how strong the demand is, which topics are relevant at international level, and how the meetings could best be organised, so that a transfer of best practices can take place across national borders.

6 References

Chirk, N., Mmed, J., Ng, D., & Jenn, C. (2006). Designing A Questionnaire. *Malaysian Family Physician : The Official Journal of the Academy of Family Physicians of Malaysia*, *1*(1), 32. https://doi.org/10.4324/9780203875728-26

DeepL SE. (2022). *DeepL Pro Translator* (Pro).

Deliverable 4.1, 4.2. Geiges, T., Haraldsen, T. K., & Tobias, S. (2022). *Comprehensive Literature and Best-practice Review for Avoiding, Mitigating and Compensating for Impacts on Soil*.

Momentive Inc. (2022). *SurveyMonkey Momentive Inc.* (EXTRA). www.momentive.ai

Pew Research Center. (n.d.). *Writing Survey Questions*. Retrieved April 28, 2022, from https://www.pewresearch.org/our-methods/u-s-surveys/writing-survey-questions/

Pearce B 2020. Design Thinking. td-net toolbox profile (11). Swiss Academies of Arts and Sciences: td-net toolbox for co-producing knowledge. www.transdisciplinarity.ch/toolbox. doi.org/10.5281/zenodo.3717021

R Core Team. (2021). *R: A Language and Environment for Statistical Computing* (4.1.1). R Foundation for Statistical Computing. https://www.r-project.org

Slavík, V. (2021). *Poedit* (3.0.1). https://poedit.net/