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Call 2019 Soils Final programme report

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CEDR Contractor Report 2023-03

by

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Frontpage illustration: Cross-section of a road (left), iStock, georgeclerk, and a cross-section of a clay soil (right), bgs.ch, Gabriela Brändle, Urs Zihlmann, Urs Grob and Benjamin Kuster.

Executive Summary

Soils provide vital functions and ecosystem services that we all depend on, but land use changes and global climate change threaten many of those functions and services. Road projects have a vital responsibility in safeguarding and supporting European soils through informed and responsible land-take, reduced soil sealing, reduced soil compaction during construction, and control of potentially contaminated soils. This calls for methods to assess the impact of road projects on soils, and for mitigating measures for offsetting, compensating, and minimising the environmental impacts on soil resources. These two needs constituted the objectives of the CEDR 2019 SOIL call. The project was commissioned to the ROADSOIL project that addressed both objectives for areas directly affected by land take, areas temporarily used for transport or storage of soils, and areas used for agricultural or ecological compensation or restoration based on soil resources from road projects. This Final Program Report presents the key findings from the project.

Approach: The project combined knowledge syntheses based on scientific literature with applied experience from a range of road projects. This was supplemented with information from workshops and questionnaires targeted to soil professionals. The project also applied machine learning approaches to develop a decision support system for soil workability to be used on a daily basis based on soil properties and soil moisture assessments. A further step in that direction was to provide data on construction machinery properties to the Terranimo toolbox used for planning machine operations based on machine- and soil properties. Current knowledge was structured in a set of six CEDR Reports. Key results and messages from these deliverables were then refined and structured in a Guideline document. The ROADSOIL guidelines attempted to provide coherent guidelines for soil management through planning, construction, maintenance and management of roads of sufficient detail to be of practical use. However, their principles have to be adapted according to local legislation and conditions.

Recommendations:

- Legislation should facilitate the reuse of soil that is not contaminated to protect soil as an extremely precious resource.
- Involve soil experts in all phases of road projects, from the initial investigations to the soil management plan in the Environmental Impact Assessment (EIA) process, and the more detailed plans and quality checks for the construction work. This is one of the key measures to assure proper soil management. Systems to certify such experts would promote the quality of this work.
- Establish systems for training of machine operators. There are good examples of how on-site, project-specific training on soil handling addressing soil properties, soil layering, soil moisture and soil compaction has achieved very good results. This will also support capacity building with contractors.
- Apply decision support systems to prevent soil compaction by construction machinery on a day-to-day basis to fine tune the choice of machinery and operations to soil properties and moisture. Avoid operation of heavy machinery on A- or B-horizons unless the soil is frozen or very dry. Always loosen compacted soil of storage areas, access roads etc. using excavators on completion.
- For reuse in landscaping or in compensation measures, strip and store topsoil (A-horizon) and subsoil (B-horizon) separately to maintain soil structure and prevent compact soils. Accordingly, soil profiles are rebuilt horizon by horizon. Storage areas are planned with temporary access tracks, drainage systems, and management of invasive species.
- Implement monitoring of soil functions through measurable soil properties to document effects on soils, and the efficiency of preventive and compensation measures, and establish systems for collecting and structuring soil data from field investigations across road projects to enable capacity building.

Given priority, these recommendations will raise the baseline for sustainable soil management and reduce the environmental impact of road projects.

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The 2019 Soils call

The Soils call for proposals had two objectives:

- Develop prescriptive methodologies for assessing and quantifying the impacts of national road projects on soils
- Outline practical mitigation measures to offset and minimise these impacts.

The motivation for the call, as detailed in the Description of Research Needs (DoRN), is the sectoral responsibilities of road authorities in promoting sustainable soil management in road projects that align with national strategies and the EU Soil Strategy for 2030. The project was commissioned to the ROADSOIL project that addressed both objectives.

Definition of the issue

Road construction and operation have considerable negative impacts on soils, both in the long and short term, through land-take, soil sealing, soil compaction, soil storage, changes to local hydrology during construction, and redistribution of potentially contaminated soils in the operation phase. This calls for methods to assess the impact of road projects and mitigating measures for offsetting, compensating for and minimising the impacts of national road projects on soils. With the extensive road networks in Europe, road projects have a vital responsibility in safeguarding and supporting European soils through informed and responsible actions.

To achieve this, it is critical that the importance of proper soil management and handling is addressed in all phases of road projects through soil management plans. However, knowledge of best practice is not always readily available nor embedded in all relevant project phases. Thus, guidelines of principles of good practice in soil management are essential. The ROADSOIL project collated and structured current knowledge based on both scientific and applied knowledge to provide coherent guidelines for soil management through planning, construction, maintenance and management of roads. The guidelines developed in this project attempt to bridge between project phases and provide sufficient detail to be of practical use. The ROADSOIL guidelines provide information about sustainable soil management in road projects, however, their principles might have to be adapted according to the local conditions.

The project used a range of approaches to synthesise and structure the information. The core approach was a knowledge synthesis based on scientific knowledge and experience from a range of road projects. This was supplemented with information from workshops and questionnaires targeted to soil professionals in education, consultancies, road administrations, and construction companies. The project also applied machine learning approaches to develop a decision support system for soil workability to be used on a daily basis based on soil properties and soil moisture assessments. A further step in that direction was to provide data on construction machinery properties to the Terranimo toolbox used for planning machine operations based on machine- and soil properties. Current knowledge was structured in a set of CEDR Reports available at https://www.cedr.eu/peb-call-2019-soils. Key results and messages from these reports were then refined and structured in a Guideline document. This Final Program Report presents the key findings and -messages from the project.

Roadsoil project deliverables

CEDR Reports

Comprehensive literature and best-practice review for avoiding, mitigating and compensating for impacts on soil

The report provides an overview of available soil information and a selection of guidelines (see appendix for links) and best practice examples of soil protection in road projects in a set of European countries. Countries were selected based on data availability criteria. It is based on an explorative literature review and document analysis as well as expert interviews. The availability of soil protection guidelines strongly varies among countries. The selected countries have published guidelines or legal documents to integrate soil protection in construction projects, and these guidelines are usually based on legislations of environment protection or waste management. Most countries provide digital open access soil data including nationwide soil maps at low resolution and detailed soil surveys of parts of the countries. The methods of mapping and mapped information vary between regions and countries, which makes a comparison between countries difficult. Overall, the review illustrates that field surveys are mostly indispensable for detailed organisation of a road construction projects, strategies to implement soil protection measures in road projects is needed, and that EU and national goals of soil protection need to be better included in the national transportation strategies.

Expert survey and workshop on best practices for soil protection

The report presents the results of an online survey among soil and road experts from 17 European countries about the state of implementation of soil protection measures in road projects as well as obstacles for implementation in the respective countries. It further summarises the conclusions of three workshops with experts from nine countries. Damage on soil due to road construction has been reduced in some countries, mainly due to better information and training of construction staff. Commissioning soil experts on construction sites to supervise soil handling was mentioned as an additional success factor to avoid damage on soil. However, the reuse of surplus soil faces legal obstacles in some countries.

Using machine learning to improve the prediction of soil mechanical properties

The report addresses a knowledge gap in terms of the availability of decision support tools that can be used to for day-to-day decisions whether a soil is in a "workable" state – i.e., not at substantial risk of soil compaction when a given machine is to be used. A new database of soil strength measurements, complemented with auxiliary soil and environmental information was assembled. A decision support tool was developed for estimation of the soils stress tolerance (i.e., soil strength) based on its texture and moisture status based on this database. We recommend consulting with a soil specialist while delineating hot-spots and specific areas of interest where this decision support tool should be used for proper planning and execution of the work.

Report on the framework for assessment of impact from road construction and operation on soil functioning

Changes in land use, also temporal, during road construction can severely reduce the extent to which a soil can fulfil its functions if functional characteristics are altered beyond critical limits. The loss of soil functions is offsetting the capacity of soils to deliver ecosystem services. Conceptually, soil threats, soil functions, and ecosystem services are closely related. This report sorts out the differences and connections and point out critical measurable soil properties to monitor in road projects to follow soil functionality and provisioning of ecosystem services. Further, the report develops conceptual frameworks for the protection of soil functioning in road projects based on a literature review on the concepts of soil functions, (soil) ecosystem services and soil threats. Two approaches were developed, one for the planning phase and one for the construction phase. The framework for the planning phase focusses on the soils that are part of proposed road trajectories. This framework anticipates a balanced supply and demand of soil functions at an (intra)regional scale also addressing the potential for compensation of any loss regionally. The framework developed for the construction phase focusses on the local sites that are temporary used in the construction phase (among others, for storage, buildings or as work roads). This second framework aims to reduce the likelihood and impact of soil threats that would degrade soil functioning. These frameworks need operationalization and testing before implementation but holds a promising structured approach to minimize road impacts on soils.

Assessment of access materials to reduce soil stress on construction sites

This report summarizes a field experiment that was set-up to investigate the effects of different access materials on soil stress for tyre- and tracked motorised machines and vehicles used in construction activities. Access material affected stress propagation with depth differently. The difference may be explained by differences in thickness of the access material and by differences in the elasticity or stiffness of a material, which affects the stress transmission through the material. Composite mats and sand tracks reduced soil stress better than wooden mattresses. Taking into consideration the thickness and weight per running metre of the composite mats, sand track and wooden mattrasses, the composite mats may be the most attractive choice of soil protection material in construction activities.

Examples from Norway and Switzerland of soil handling in infrastructure projects

The report gives several examples of solutions for soil handling in road projects, starting in the planning phase, during the construction periods and present recommendations for soil aftercare to be implemented after the construction period has been finished.

It is important to address soil management issues as early as possible in the planning of road projects. Plans for the reuse of soil and stone materials within the road projects must be evaluated as part of the Environmental Impact Assessment (EIA) and according to the EUs waste directive. It is recommended to make a detailed soil survey along the route of the chosen road corridor, as detailed soil information is needed for proper soil management during the construction phase. The information from the soil survey makes the basis for the soil management plan for the road project. Such soil information is also useful for the outcome of field training courses for construction companies and their construction machine drivers at construction sites. It is recommended to implement processes for utilizing uncontaminated soil materials within the road construction area or on other appropriate sites and to avoid treating surplus uncontaminated soil as waste.

Guidelines for good practice of soil management in road projects

Guidelines were developed to provide methodologies for assessing and quantifying the impacts of road projects on soils and to outline practical mitigation measures to offset and minimise these impacts. This concerns areas directly affected by land take, areas temporarily used for transport or storage of soils, and areas used for agricultural or ecological compensation based on soil resources from road projects. The guidelines accentuate comprehensive and critical actions and measures in all project phases: including the planning, construction, management and operation phases. The ROADSOIL guidelines may further supplement regional, national and international legislation and other guidelines. However, guidelines have to be adapted to a country's specific legislation and the project specific soils, climate and precipitation.

Datasets

A machine-readable database of soil strength measurements, complemented with auxiliary soil, environmental and management data was compiled in the project and used to develop the decision support tool for estimation of soil strength. The dataset and metadata are available at https://zenodo.org/doi/10.5281/zenodo.10060809.

Software contributions

Data on a representative set of construction machines was added to the Terranimo model for prediction of the risk of soil compaction due to field traffic. (www.terranimo.se), including vehicles with metal tracks and wheeled vehicles. Technical data of representative machinery frequently used in road construction was collated and is now stored in the Terranimo machinery database. Equations for calculation of vehicle-soil contact area and contact stress distribution for metal tracked-vehicles had to be developed and incorporated in Terranimo. The Terranimo® model can be used to pre-assess soil stress vs. soil strength scenarios and help plan machine availability.

Scientific papers in preparation

ten Damme L, Keller T. A framework for protecting soil functioning in road projects based on a review of soil quality concepts

ten Damme L, Keller T. Assessment of access materials to reduce soil stress on construction sites

Other dissemination

Poster and/or oral presentations

Geiges T, Tobias S, Borch H, Haraldsen T, Nemes A, Keller T, Ten Damme L, Dietrich M, Jayesingha M, Hanslin HM. 2021.Assessing and Mitigating the Impacts of Road Projects on Soil – The RoadSoil Project. Oral Online Presentation. Eurosoil 2021 Geneva, 24. August 2021

Geiges T, Tobias S. 2022. Übersicht über europäische Richtlinien und Best-Practice-Beispiele zum Bodenschutz im Strassenbau. Oral Presentation about the RoadSoil project and results of WP4. Soil Science Society of Switzerland, Annual Meeting 2022, 01. April 2022:

Geiges T, Tobias S. 2022. Overview and expert evaluation of European guidelines and best practice examples of soil protection in road construction. Poster & oral presentation. Glasgow 22 - 22nd World Congress of Soil Sciences, 31 July - 5 August 2022:

Geiges T, Tobias S. 2023. Challenges for soil protection in road construction from the perspective of European road and soil experts. Poster presentation, Wageningen Soil Conference 2023.

Hanslin HM, Geiges T, Haraldsen TK, Nemes A, Keller T, Ten Damme L, Chagas Torres L, Dietrich M, Jayesingha M, Tobias S. 2022. Assessing and Mitigating the Impacts of Road Projects on Soil – The RoadSoil Project. Oral presentation. IENE 2022, Cluj-Napoca.

Interviews

Haraldsen TK. 2022. Topsoil can be moved when we build roads and buildings, but bureaucracy puts a stop to that, says soil scientist (in Norwegian). English translation.

Multimedia

Haraldsen TK. 2023. Methods for moving soil. Practical management of soil materials for reconstruction of agricultural soils. Available at VIMEO.

End of programme conference

The end of programme conference was hosted August 28th, 2023, as a hybrid event with a physical session as a side-event to the Wageningen soil conference and with a Microsoft Teams meeting for online audience. The CEDR program manager Per Antvorskov and PEB leader Marguerite Trocmé introduced CEDR and the SOIL call. Then the RODSOIL project presented key findings from the projects based on guidelines and reports. Transnational Research Programme Coordinator, Naida Muirhead, coordinated the online session. Presentations have been uploaded to https://www.cedr.eu/peb-call-2019-soils. The number of participants was low, and for future end of programme conferences, a more targeted online event would probably reach a wider audience, also with the national road authorities.

Synthesis of key findings

Heterogeneous state of soil protection in road project across European countries

Availability of guidelines and similar documents for soil protection in road projects varies among European countries, and so do the measures of soil protection applied in practice. Some countries are advanced in publishing soil protection guidelines and implementing soil protection measures backed by legislation, while others lag behind. Some countries also face legal challenges, particularly the reuse of surplus soil from construction sites might be in conflict with the country’s waste legislation. Similar contrasts were also found in the quality and use of public available resources, such as soil- and land-use maps. The project provides principles and examples of good practice, that could be implemented across countries, as supplement to existing guidelines.

A need for soil expertise and training

Experience clearly illustrates that early involvement of soil expertise is critical to achieve successful soil management in road projects when combined with continuity in follow-up. This expertise should lay with a person with documented capacity and experience in soil science and construction work, hereafter called a soil expert. A major role is to develop the soil management plan in the Environmental Impact Assessment (EIA) process, and the more detailed plans for the construction work. In the EIA process, soil experts assess the potential impact of a road project on the soil functions based on their soil mapping and field investigations. Subsequently, they define strategies and measures to minimise these impacts and compile them in a soil management plan and monitor quality of the work. Systems for training and certification of soil experts are recommended combined with in-house training and capacity building in the road administrations and with the contractors to better benefit from the experts. An example of how the Swiss system for certification of soil experts is organised is provided. This also applies to the training of machine operators on-site, where project-specific training has achieved very good results. A Norwegian example is provided, where the hands-on training addresses soil properties and profiles, soil moisture measurements, drainage systems, etc. for use in day-to day operation on-site. These two measures are key to eliminate a critical bottleneck for future development of sustainable soil management. Given priority, these actions will raise the baseline for soil management and reduce the environmental impact of road projects.

Figure 1. On-site training of machine operators, here testing the structure and crumbling of stockpiled soil. Photo: Trond Knapp Haraldsen.

Soil management plans - not required but highly needed

The soil management plan as outlined in an Environmental Impact Assessment (EIA) and refined in the detailed planning, is the core of best practice in soil management. The soil management plan explains in detail which measures need to be implemented to avoid, mitigate or compensate for the soil impacts during the road construction process. Quality control during and after the construction work assures that the soil protection measures have been implemented according to the recommended regulations. The requirements for soil management plans differs vastly among countries, but what is clear is that the combination of overarching soil management plans for the road project and site-specific soil management plans of sufficient detail and quality is a powerful tool to minimise damage to soils in road projects. It is essential that these plans are adjusted to the soil properties, climate and terrain in the area of road projects, and account for predicted climate change. Unfortunately, there is a lack of manuals for this process and few good examples.

Quantify and monitor road impacts on soils.

Road projects affect soils both during construction and during operation. To document these effects and evaluate compensation measures, indicators of soil parameters can be monitored over time. A list of indicators (soil organic carbon, pH, total nitrogen, plant available phosphorus, salinity, soil texture classification, clay, silt and sand content, bulk density) is provided that will capture the state of measurable soil properties. The indicators can be used to evaluate the soil function parameters listed in the EIA Directive (compaction, sealing, erosion and organic content). This evaluation has to be done by a soil expert from case to case. Systematic use of soil data and indicators of soil processes and functions will over time contribute to capacity building and also provide data to improve mapped background information of soil resources in the landscape.

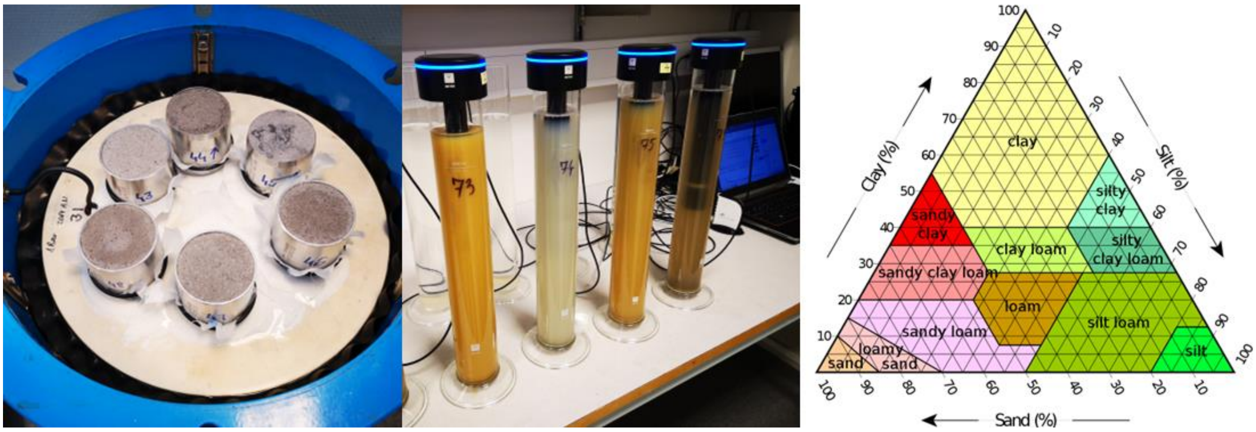

Figure 2. Methods for testing soil characteristics (from left), estimating the soil water retention curve (pF) using a pressure plate, particle size measurement with PARIO equipment, and a chart used to determine soil texture based on the content of clay, silt and sand. Photos: Attila Nemes, chart: USDA, Wikipedia Commons, Christopher Aragón).

Sophisticated road planning to reduce net soil sealing

In order to reach the EU target of no net soil sealing by 2050, strategies to avoid or compensate for additional soil sealing should be considered in the road planning phase. Digital technologies and traffic management measures (e.g., digital toll stations, road pricing, speed limitations) can help avoiding additional lanes. Equally, measures to compensate for additional soil sealing should be planned in the road planning phase. Dismantling obsolete road sections to create natural habitats or urban green spaces directly reduces net soil sealing (Figure 1). However, upgrading agricultural land with surplus soil from road construction or rehabilitation of natural habitats are also helpful to compensate for the loss of specific soil functions.

Figure 3. Vegetation succession after removal of a local road, Northern Switzerland Photo: Silvia Tobias.

Apply decision support systems to prevent soil compaction by machinery

The risk of soil compaction of both subsoil and topsoil has to be addressed during machine operation, soil handling and storage. Basic principles to prevent compaction include operation of heavy machinery on C-layer soil horizons only, and never on A- or B-horizons unless the soil is frozen or very dry. Strip soil for temporary storage and use construction roads or matting systems for short term use as transport corridors. To prevent machine operation on wet soils and simplify management of machine operations on a day-to-day basis, a decision support system is recommended. The recommended system is based on a decision tree where critical values for soil moisture are presented for a given soil texture and on-site measurement of soil moisture will guide operation of machinery (Figure 2). This approach depends on active use of soil data to inform machine operation and will build awareness and best-practice with contractors. This tool may well be included in the training of machine operators.

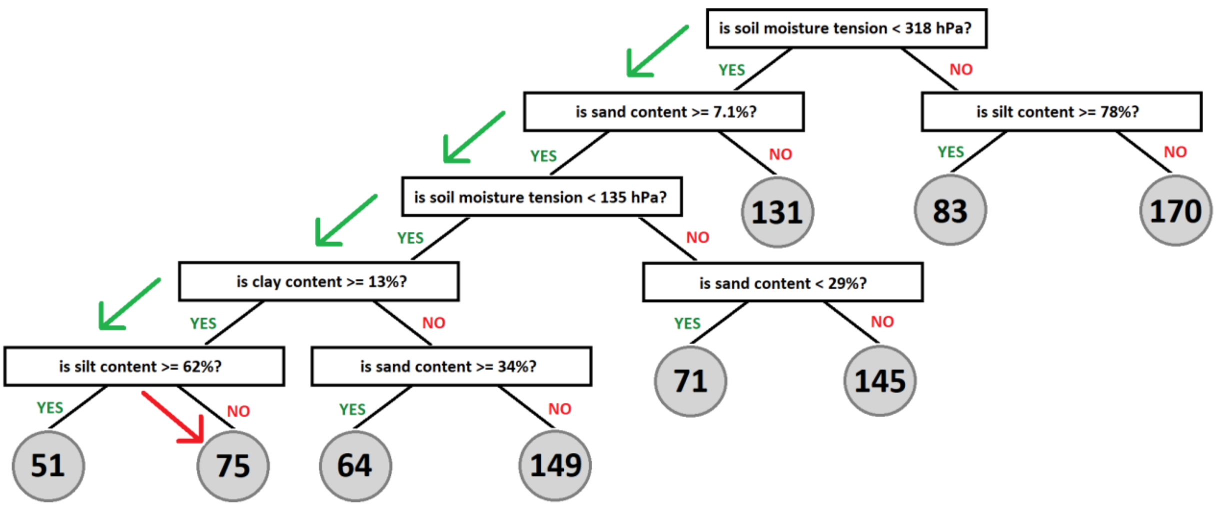

Figure 4. Demonstration of the decision model's use for a soil with 22% sand, 46% silt, and 32% clay content, and a soil moisture tension of 100 hPa. The resulting precompression stress estimate is 75 kPa.

This estimate is then compared to the stress exerted by the chosen machine (in kPa).

Estimating the risk of compaction using the Terranimo® toolbox

The Terranimo toolbox (www.terranimo.se) is efficient for estimating the risk of soil compaction for different machinery to simplify the planning of earthwork and use of machinery but was only available for agricultural machinery. To make this useful tool available also for road projects, the project collected and structured data on a representative set of construction machines and provided the data and equations required for an external company (afca in Zollikofen, Switzerland; www.afca.ch) to implement the code. The work included selection of construction machinery, collection, and description of representative tyres (tyre dimensions and characteristics) and metal tracks (dimensions), and the development of a function to calculate contact stress for metal tracks (vehicles with metal tracks were not included in earlier versions of Terranimo). This new information including both vehicles with metal tracks and wheeled vehicles are now included in the online version of Terranimo[1] (Figure 3).

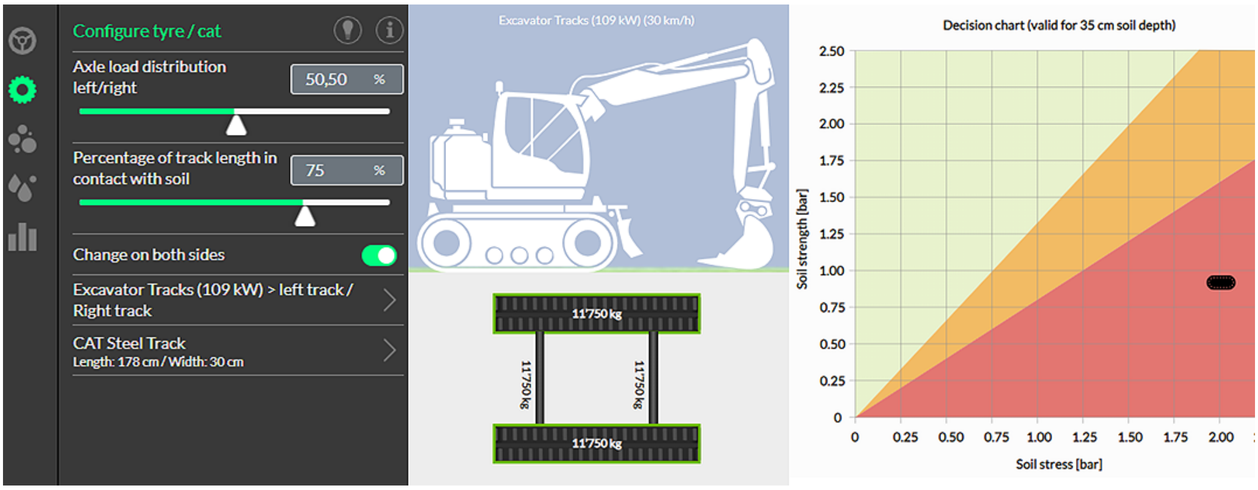

Figure 5. An example illustration of the Terranimo® dashboard, the chosen machine, and the corresponding graph for decisions based on data on the machine, soil and soil moisture.

Strategies for soil stripping and storage

To contribute to sustainable soil management, it is critical to maintain the quality of the soil resources throughout the road project. For reuse in landscaping or in compensation measures, topsoil (A-horizon) and subsoil (B-horizon) to be affected by construction work (Figure 4) are best stripped and temporary stored in separate stockpiles. To prevent loss of soil structure and compact soils, the B-horizon should preferably not be mixed with materials without soil structure development (C-horizon) which instead may be used directly for landscaping. Stockpiles are shaped and spaced to ease weed and invasive alien plant management and seeded with a competitive grass cover to maintain soil qualities. It is crucial to plan

[1] Terranimo was developed by scientists from HAFL, Agroscope, Aarhus University, and SLU. Further development is dependent on project funding.

logistics and sites for this temporary soil storage, with temporary access roads and drainage systems including approaches to loosen the soil and soil aftercare of the site when the stored soil is removed.

Figure 6. Examples of the upper layers of two soil profiles that show the horizontal layering with A, B and C horizons. The profile on the left also has an E layer where leaching of material has occurred. Photos: Trond Knapp Haraldsen.

To reduce temporary land take, it is important to keep land in cultivation for as long as possible before stripping and then translocate stripped soils directly to their final location when possible. This reduces soil handling, soil storage, and the risk of soil compaction thus preserving soil structure and quality. This approach also prevents propagation of unwanted plant species before and during the construction work. Accordingly, it is highly recommended to start a landscape-wide management of weeds and invasive species as early as possible. Make agreements with owners of adjoining land early in planning. Ideally, start this management two years prior to construction start.

Transport of soil material within the road project must always be on temporary access tracks to minimize the risk for compaction damage. Such access tracks may be placed above the B-horizon. When the management area is restored back to the original land use, such as cultivated or forested land, the B-horizon needs to be loosened with excavator before replacement of the A-horizon in order to restore natural soil functions.

Figure 7. Stockpiles of A horizon (left) and B horizon (right) in a railway project. Photo: Trond Knapp Haraldsen.

Soil profile rebuilding

An initial survey of topsoil and subsoil qualities will provide the required information to prioritise soil allocation to different uses, such as landscaping, agriculture, forestry or urban greening. The recommended primary principle for soil restoration in road construction projects is to reconstruct soil layers horizon by horizon in narrow strips where machine operation on relocated soil is avoided. All driving is done on the C-horizon during reconstruction. For example, the B-horizon material is placed on the C-horizon surface, while the A-horizon materials are the topsoil on top of the B-horizon material. A prerequisite is that soils have been stripped and stored with soil horizons separated.

If there are shortages of topsoil, constructed soil can be made on-site from crushed rock blended with organic material and natural mineral soil. Coarser material can be used as drainage layers and contribute to mass balance of the project.

Figure 8. Rebuilding a soil profile (A, B, and C horizons) using an excavator. Photo: Trond Knapp Haraldsen.

Major bottlenecks for a sustainable soil management

Knowledge gaps

Science-backed strategies and approaches for soil management

Our research showed that knowledge about proper soil handling in road projects is not lacking in general. The appropriate techniques of careful soil management on construction sites are described in a number of guidelines published in different European countries. However, their implementation varies strongly among countries, and not all players hold the necessary knowledge. The main reasons for damage on soil due to road project are the lack of knowledge among earthworks staff and the lack of incentives or obligations for careful soil handling. Training courses for machine drivers and soil experts on construction sites, translating the rather general knowledge of the guidelines to specific construction cases, have essentially improved soil management in road projects in many countries. In the scientific literature we have not found papers following road projects from the planning phase, through the construction phase with evaluation after the aftercare period. Although several guidelines for soil management in road and infrastructure projects exist, scientific papers of soil management from road projects are limited. Hence, there is a need for better follow-up and solid documentation of methods used in road projects. This also points to the urgent need of manuals for soil management plans in road projects and good examples of their use adjusted to local conditions.

Soil physics data

This project also helped identify that joint soil physical and soil mechanical data sets covering diverse geographical areas, soil types and land uses are sparse and often do not adhere to uniform standards. An action is recommended to develop these relationships for relevant European soils. This is needed to gain the most from the decision support system and machine operator training.

Conflict of legislations

Conflicts between sustainable soil management and national waste legislation was found in some of the investigated countries. Here the reuse of surplus soil is in conflict with the waste legislation. This does not only apply to polluted soils, but also to unpolluted soils. In such cases, soil is not used as a natural resource, but instead used in construction work or eventually landfilled. Solutions should be sought to prevent landfilling of soils suited for other use and promote the principles of circular economy and define unpolluted soil as a natural resource. This would be the basis for a legal obligation to reuse surplus soil in upgrading and compensation projects instead of landfilling.

Data management and availability

Soil information is needed in the road planning phase to assess the potential impact of a road project on the soil functions and, if appropriate, to select the road alignment causing the least damage to soil. Many countries have produced soil maps at different scales which are sometimes available in digital format. However, their usefulness for roads can be limited because the resolution of nation-wide soil maps is often very low, or detailed soil maps are only available for agricultural land and not all land-uses affected by the road project. Further information about sensitive areas might be provided by spatial planning requirements, forestry or nature protection legislation, such as prime cropland areas or protected natural habitats. For detailed planning and implementation of the road construction phase, field investigations are indispensable. These include field soil mapping of the area dedicated to the road project, and regular soil moisture assessments because wet soils are far more susceptible to compaction by machinery than dry soils. Consequently, a large amount of soil data is collected during field investigations in road projects according to standard soil-science methods. This is a valuable resource both to understand soil qualities in a landscape and to monitor road impacts on soils. Therefore, it is recommended to systematically make these data available in a public repository as Open Government Data. The requirement to make data from such investigations available should be included in contracts, together with a minimum list of indicators and their analytical methods.

Conclusions

The ROADSOIL project output provides background information and guidelines on sustainable soil management in road projects. The first objective of the programme on prescriptive methodologies for assessing and quantifying the impacts was met, providing indicators (as measurable soil properties) to quantify and monitor soil functions in road projects and a framework for the assessment of the impact from road projects on soil functioning. The soil function parameters listed in the Environmental Impact Assessment (EIA) Directive can be assessed by soil experts on a case-to-case basis using these indicators.

The second objective to outline practical mitigation measures to offset and minimise these impacts was fully met and backed by applied experience. There is however a bias towards experience from the participating countries. This is indeed a consequence of a considerable lack of documentation of long-term effects of measures to reduce road impacts on soils internationally. Available scientific literature is limited. Thus, there is a need for better follow-up and solid documentation of applied methods in road projects. Questionnaires and workshops with soil experts revealed a considerable interest in learning and exchange of experience across countries and disciplines, indicating a potential for follow-up activities.

As a key output of the project, the guidelines present key approaches to soil management in road projects, from planning through construction and maintenance. The reader is made aware that detailed general protocols are not possible and would be risky, due to the huge differences in soil and climate between regions, and the large variation in soil characteristics even within a single road construction project. To properly address the local conditions, soil expertise should be included early in the project. To include soil experts in projects and to provide sufficient on-site training of machine operators are among the key messages of the project.

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