

# Critical Assessment of Terranimo



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## Foreword

SoCoRisk was a collaborative research initiative involving partners from Denmark, Sweden, Switzerland, Italy, and Norway. This report focuses on the research conducted in Norway, which was led by Susanne Eich-Greatorex and Trond Børresen from the Norwegian University of Life Sciences (NMBU). Additional research partners included Truls Olve Terjesønn Hansen from the Norwegian Agricultural Extension Service (NLR), as well as Mads Dahl Gjefsen and Tommy Ruud from Ruralis – Institute for Rural and Regional Research.

A crucial component of this research was the involvement of a group of agriculturalists in Central Norway, comprising farmers, agricultural advisors, and agricultural contractors, whose insights formed the foundation of this report.

Our inquiries commenced in February 2021 and concluded in March 2024. Financial support was provided by the ERA NET ICT-AGRI-FOOD funding program from the European Union and BIONÆR from the Research Council of Norway. Opera Browser's large language model-based artificial intelligence, Aria, was used to enhance the wording and formulations in this report.

I extend my gratitude to all partners, participants, and funders for their invaluable contributions. Mads developed the Ruralis segment of the project and initiated the research before passing on the responsibilities to me. Well begun is half done; any errors in this report are solely my responsibility.

Tommy Ruud

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# Contents

- Foreword ..... 1
- Introduction..... 3
- Methods ..... 4
  - First Living Laboratory Meeting: SWOT-scheme and Questionnaire..... 4
  - Individual Interviews ..... 5
  - Second Living Laboratory Meeting: Group Interview ..... 6
- Results ..... 7
  - Initial Reflections on Terranimo ..... 7
  - Improvements for Terranimo Interface ..... 10
  - User Administration of Terranimo ..... 11
  - Output ..... 14
  - Leased Land Management ..... 17
  - Benefits for Landowners and Tenants ..... 17
  - Suggested Features ..... 17
  - Rental Terms and Cultivation Practices ..... 17
  - Challenges in Land Maintenance ..... 18
  - Contractor Considerations ..... 18
  - Shared Responsibility for Soil Condition ..... 18
  - Adoption of Terranimo..... 19
  - Strategies for Raising Awareness ..... 19
  - Incentives for Adoption..... 19
- Conclusion ..... 21
- Appendices ..... 23
  - Appendix I: Questions from the first seminar..... 23
  - Appendix II: Questions from the individual interviews:..... 23
  - Appendix III: Questions from the second seminar..... 24

## Introduction

Soils serve as the foundation for crop production. However, soil compaction caused by the use of agricultural machinery poses a threat to soil quality. Heavy farm machinery, in particular, leads to compaction of the subsoil—the layer of soil located below tillage depth.

Subsoil compaction is especially concerning because it is often persistent and difficult to remediate. This compaction negatively impacts various soil ecosystem services, particularly regulating services (such as flood control) and production services (including agricultural output). The consequences are far-reaching, resulting in considerable ecological damage and economic vulnerability that affect both farmers and society at large.

One effective measure to mitigate soil compaction is the development of a user-friendly decision support system. Terranimo® is an online decision support system designed to evaluate the risk of soil compaction during field traffic.

Terranimo assesses the risk of soil compaction by comparing soil strength with the mechanical stress exerted by agricultural machinery. Generally, wet soils are weaker, resulting in a higher risk of compaction compared to dry soils.

The implications of climate change, particularly increased rainfall before and during field operations, can exacerbate the risk of soil compaction. The mechanical stress experienced by the soil depends on various factors related to the agricultural machinery, such as:

- Weight
- Tires
- Inflation pressure
- Contact area

To effectively utilize the model, data regarding soil type, soil moisture content, and specific agricultural machinery characteristics is essential. The results from the calculations of soil strength and mechanical stress can be compared and visualized in a diagram. This diagram indicates whether the soil will be subjected to plastic deformation—which signifies serious compaction—or whether the compaction risk is minimal.

This report examines the reflections of Norwegian farmers, agricultural advisors, and agricultural contractors regarding the development of the Terranimo tool (refer to the Method section for specifics).

Currently, the use of Terranimo for planning field operations is limited among both farmers and advisory services. The primary goal has been to assist in the tool's development to promote broader adoption by enhancing its usefulness and improving user-friendliness.

The work involved identifying opportunities and barriers to the tool's usage, addressing these challenges, and suggesting developments based on informants' opinions regarding the

best possible assistance the tool can provide in their planning and decision-making processes for field operations and investments in machinery.

## Methods

The informants were recruited by NLR based on existing relationships. The group of informants consisted of:

- Eight farmers (two of whom were also contractors)
- Two contractors (one of whom also served as an advisor)

In total, there were ten informants involved in the study.

The informants were experienced in the production of grass, corn, and potatoes within the agricultural context of Trøndelag County, located by Trondheimsfjorden in Central Norway.

Key Details:

- Location: 350 kilometers south of the Arctic Circle
- Climate: Cool and humid
- Soil Composition:
  - Consists of 10,000-year-old marine clay and sand
  - Forms terraces rising up to 150-200 meters above sea level

To gather insights from the informants, we organized living laboratory meetings that included various methods:

- Group discussions
- Individual reflections
- Questionnaires
- One-to-one interviews with selected informants

These efforts aim to provide a comprehensive understanding of the perceptions and experiences surrounding the use of the Terranimo tool among Norwegian farmers and agricultural professionals. The findings from these inquiries are compiled in the Results section, encapsulating the key insights and perspectives shared by participants. Below is an outline of the contexts and activities from which the information in this report was collected.

### **First Living Laboratory Meeting: SWOT-scheme and Questionnaire**

The first living laboratory meeting took place on November 30, 2021, at the facilities of NLR in Kvithammar, Trøndelag. Ten informants attended the meeting. A four-page popular scientific synthesis on soil compaction, Terranimo, and SoCoRisk was distributed in advance.

At the meeting, the informants were briefed on the main purpose of SoCoRisk and introduced to our approach of conducting research through user-centered methods. This prompted them to share their reflections and contextual, hands-on knowledge through various formats, including group reflections, discussions, questionnaires, and individual interviews.

The informants engaged in group work based on a SWOT analysis, with a technical focus on functionality. Additionally, they completed an individual questionnaire that concentrated on visual presentations within the tool and local cultivation strategies.

The informants were divided into three groups to discuss their immediate reactions and questions. They were prompted to reflect on and document their thoughts in a SWOT analysis, focusing on what is beneficial and useful about the tool, as well as what could be improved or added. The SWOT analysis posed the question: “Which strengths, weaknesses, opportunities, and threats do you see in utilizing Terranimo?” Each group recorded their reflections to capture the participants' initial impressions based on the day's presentations.

Furthermore, we discussed the scenarios in which the informants envisioned the tool being useful, as well as how it might be experienced differently by various users and under varying conditions. An individual questionnaire was provided for them to reflect on and document their responses. The questions are detailed in Appendix I.

After completing the individual questionnaire, the group members compared and discussed their responses internally. This exercise aimed to capture the participants' views on dilemmas and uncertainties, as well as to comment on potential different or conflicting perspectives in various usage scenarios.

Each group was assigned a project partner to facilitate their group work. The tool was accessible on a laptop in each group, allowing participants to explore it during their tasks. The meeting concluded with plenary group reporting and a discussion.

## **Individual Interviews**

Based on the evaluation of the first living laboratory meeting, I aimed to conduct individual interviews with a selection of informants to gain a deeper understanding of the issues raised during that meeting.

- Interview Schedule: Individual interviews were conducted from January 18th to 20th, 2023.
- Participants: Assisted by Truls O. T. Hansen (NLR), I interviewed two contractors and two farmers.
- Format: The interviews took place via Teams.

- Additional Input: Additionally, two other farmers provided written responses to the same questions during the second living laboratory meeting, which was held in February.

The questions posed during the interviews were developed based on issues identified in the first meeting and were anticipated to yield varying responses from informants according to their roles.

Objectives of the Questions:

- Exploration of Roles: Primarily, I aimed to explore the envisioned roles for the extension service in relation to the tool.
- Feedback on Proposed Changes: I sought elaborations on the usefulness of the changes to the tool that were proposed in the first meeting.
- Discussion on Land Rent Agreements: Additionally, I wanted to problematize how the tool might be utilized in land rent agreements.

The specific questions can be found in Appendix II.

### **Second Living Laboratory Meeting: Group Interview**

The second living laboratory meeting took place on February 7th, 2023, at the facilities of NLR. A total of six informants were present, consisting of four farmers and two contractors. The remaining four informants out of the total of ten engaged in the project were unable to attend.

We presented recent changes to Terranimo, shared real cases of simulations utilizing the tool, and facilitated a focus group interview. I posed questions to the group and took notes on the ensuing conversation. The primary aim was to further explore the problems identified earlier. The questions were inspired by feedback from the informants during the first meeting and insights from the previously conducted individual interviews. The specific questions can be found in Appendix III.

## Results

These results are derived from the interpretations of informants' feedback collected during the previously mentioned tasks and activities at both the first and second living laboratory meetings, as well as from the individual interviews.

### Initial Reflections on Terranimo

Terranimo plays a role in raising awareness about the risks of soil compaction associated with mechanized cultivation, like:

- Factors Affecting Soil Compaction:
  - Weight of the equipment
  - Tyre dimensions and pressure
  - Soil conditions
- Benefits of the Tool:
  - Provides estimates of compaction risk, assisting in decision-making regarding:
    - When to cultivate
    - How to cultivate for optimal results
- Influence on Equipment Choices:
  - Users may reconsider:
    - Choice of equipment
    - Lowering equipment weight
    - Broadening ground impact
    - Reducing tyre pressure
    - Altering the order of tilling fields
- Specific Decision-Making Contexts:
  - Particularly beneficial for making cultivation decisions in spring.
  - Challenges during harvesting:
    - Limited ability to account for soil conditions due to:
      - Scarcity of time
      - Harvesting by contractors
      - Promised delivery of produce



The tool provides valuable insights, enabling users to make informed decisions that can ultimately enhance soil health and agricultural efficiency. However, in the context of working fields in Central Norway, several particular factors may lead users to overlook the simulated compaction risk provided by Terranimo in favor of immediate fieldwork:

- Unpredictable Rainy Weather:
  - Farmers face challenges in predicting weather patterns.
  - Sudden rain can disrupt planned activities, making flexibility crucial.
- Generally Moist Soil Conditions:
  - Soil tends to remain moist, complicating scheduling tasks for optimal conditions.
  - Continuous moisture may prevent effective assessment of soil compaction risks.

Implications for Scheduling:

- Opportunistic Work Approach:
  - Farmers often need to seize the moment when the weather is favorable.
  - Limited opportunities to adjust schedules may lead to prioritizing immediate work over assessment of compaction risks.
- Challenges in Task Scheduling:
  - The necessity to work fields whenever conditions allow can override the careful planning suggested by the tool.
  - There is often only a narrow window to complete essential tasks, making it difficult to adhere strictly to the recommendations from the tool.

These factors highlight the tension between technological recommendations and the practical realities faced by farmers in the field. Furthermore, the Terranimo tool is primarily designed for users who are already aware of the impacts of soil compaction on their farming practices. However, there are opportunities to broaden its adoption among less concerned agriculturalists, like:

Targeting Broader User Base

- Engagement with Less Concerned Farmers:
  - Strategies should be developed to engage farmers who may not currently prioritize soil compaction.
  - Educational initiatives can raise awareness about the importance of soil health and compaction risks.

## Enhancing Dealer Involvement

- Familiarity with the Tool:
  - Agricultural dealers should be well-versed in using Terranimo.
  - They can leverage the tool to recommend appropriate equipment choices to customers.
- Advising on Equipment Purchases:
  - When farmers purchase new machines or equipment, dealers can suggest alternative tyre options based on the tool's estimates.
  - This can help optimize performance while minimizing soil compaction risks.

## Specific Recommendations for Tyre Choices

- Consideration of Tyre Options:
  - Farmers often do not replace tyres unless necessary due to costs.
  - However, when acquiring new equipment, they can consider different tyre specifications that may better suit their soil conditions.
- Willingness to Pay for Better Options:
  - Many farmers might be open to paying a price difference for tyres that reduce compaction risk.
  - Dealers can play a crucial role in facilitating these discussions and recommendations.

By making Terranimo more accessible and relevant to a broader audience, including those less concerned about soil compaction, the agricultural community can benefit from improved practices. Despite the challenges faced by farmers, Terranimo remains a valuable resource for making informed decisions regarding tractors, equipment, and tyres. Engaging dealers as advocates for the tool can further enhance its utilization and promote sustainable farming methods. By leveraging the insights provided by Terranimo, farmers can make thoughtful decisions about their equipment investments, ultimately contributing to better soil health and sustainable agricultural practices.

## Improvements for Terranimo Interface<sup>1</sup>

The feedback received regarding the Terranimo tool's interface highlights several areas for enhancement to increase user accessibility and convenience. Below are key points and suggestions for improvement:

### Simplifying the Interface

- Complicated Navigation:
  - The current interface is perceived as complicated, requiring a certain level of computer literacy.
  - Simplifying the interface can make it more user-friendly and accessible to all farmers.
- Interpreting Estimates:
  - Users have difficulty interpreting the estimates provided by the tool.
  - Clearer instructions and intuitive graphics can help eliminate confusion.

### Version Options

- Simple vs. Advanced Versions:
  - Offering both a simple version for general users and an advanced version for those with specific concerns about soil conditions can cater to a wider audience.
  - This dual-approach allows users to select the level of complexity that best suits their needs.

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<sup>1</sup> Based on user feedback from experiences with an older version of the Terranimo tool during the first seminar, significant improvements have been made. Key updates are 1) enhancements to the interface: the interface has been redesigned to be more intuitive, making it easier for users to navigate and understand its features, 2) two versions available: a light version which simplifies the experience and focuses on essential functionalities, designed for general users, and an expert version, tailored for users who require advanced features and detailed insights, catering to those with specific concerns about soil conditions, 3) mobile compatibility: the tool is now compatible with smartphones, allowing users to access its features on-the-go, enhancing convenience for farmers working in the fields, facilitating quick decision-making and planning.

## Mobile Accessibility

- Smartphone and Tablet Application:
  - Developing a mobile application for smartphones and tablets can enhance accessibility.
  - A simplified version of the tool can provide quick access to its features while working in the fields.
- Offline Availability:
  - Allowing the tool to function offline would be beneficial for users who may not have reliable internet access while in rural areas.
  - This feature ensures that farmers can easily access the tool at any time, especially during fieldwork.

## User Use Case

- Planning vs. Everyday Use:
  - While the tool may not be intended for everyday use, it is still valuable for planning purposes.
  - Highlighting its role in long-term planning can encourage users to utilize it strategically, rather than as a routine tool.

By addressing the complexities of the interface and enhancing accessibility through mobile capabilities and version options, Terranimo can better serve its users. Simplifying the user experience while still providing advanced features for those who require them can lead to broader adoption and more effective decision-making in soil management.

## User Administration of Terranimo

Introducing user profiles in the Terranimo tool can enhance the user experience by allowing customization and flexibility. Here's a detailed overview of this proposed feature:

### Key Features of User Profiles

- Saveable User Profiles:
  - Users can create and save profiles that include their specific machines, equipment, tyres, and details such as dimensions and weight.
- Multiple Profiles:
  - Each user will have the option to set up multiple profiles, enabling them to switch between different configurations easily.

- This is particularly useful for farmers who operate various types of machinery or have different setups for different fields or crops.
- Easy Modifications:
  - Users can modify settings within each profile without needing to re-enter all input values each time.
  - This feature streamlines the process of adjusting configurations based on changing conditions or equipment.

#### Benefits of User Profiles

- Personalized Experience:
  - Tailoring profiles to individual user needs creates a more personalized experience, enhancing user satisfaction and engagement.
- Efficiency in Decision-Making:
  - Quick access to different profiles allows users to make informed decisions rapidly, especially during critical times like planting or harvesting.
- Flexibility:
  - Users can easily adapt to various farming conditions or equipment changes, improving overall productivity and reducing the risk of soil compaction.

The addition of user profiles in the Terranimo tool could improve usability and efficiency, allowing farmers to tailor the tool to their unique operational needs. This feature would facilitate better decision-making and enhance the overall utility of the tool in managing soil compaction risks.

To further improve the Terranimo tool's usability and effectiveness, several enhancements and suggestions can be implemented, like:

#### Data Input Improvements

- Simplified Data Input:
  - Recognizing that the tool requires extensive data input such as soil type, soil moisture, and machine weight, it's important to streamline this process for users with limited knowledge.

#### Integration of External Databases

- NIBIO Database Integration:
  - Integrating the Norwegian Institute of Bioeconomy Research (NIBIO) database on soil types would provide users with valuable information, especially for those unfamiliar with the characteristics of various soil types.

- Real-Time Soil Moisture Monitoring:
  - Strategically placed sensors can monitor soil moisture levels and provide real-time data, allowing users to input approximate conditions for their fields.
  - This service could be offered by agricultural extension services, which could own and operate the sensors, providing farmers with accurate moisture estimates.

#### Flexibility in Data Adjustment

- Manual Adjustment of Moisture Data:
  - While real-time data from sensors can be beneficial, it's crucial that users still have the ability to adjust moisture data within the Terranimo model independently.

#### Additional Service Packages

- Weighing Services for Machines:
  - Offering a service package that includes the weighing of machines when set up for use would ensure more accurate data, as the actual weight often differs from manufacturer specifications.

#### User Profile Sharing

- Shareable User Profiles:
  - Enabling users to share their profiles with agricultural advisors can facilitate the development of customized cultivation practices.
  - This collaboration can help less computer-literate users by allowing advisors to manage and input necessary data for them.

Implementing these enhancements can improve the Terranimo tool's functionality and accessibility. By simplifying data entry, integrating external resources, and allowing sharing of user profiles, the tool can better serve a wider range of users in the agricultural community.

To improve user experience and streamline data management in the Terranimo tool, the following interface enhancements are suggested:

#### Summary Frame on Default Page

- Compact Summary Frame:
  - Introduce a smaller frame on the default page that summarizes all chosen variables and input data.

- This feature would allow users to quickly review their settings without needing to navigate between multiple pages, enhancing efficiency.

#### Confirmation of Input Changes

- Update Confirmation Sign:
  - Implement a visual confirmation (e.g., a checkmark or notification) whenever users change their input data.
  - This indication would reassure users that their estimates have been successfully updated, reducing uncertainty during the input process.

#### Benefits of Proposed Enhancements

- Increased Efficiency:
  - By having a summary frame, users can quickly verify their inputs, saving time and reducing frustration.
- Enhanced User Confidence:
  - A confirmation sign for updated estimates provides clarity and builds confidence in the tool's functionality, making users more comfortable with making changes.

Implementing these interface enhancements in the Terranimo tool can improve usability, making it more intuitive and user-friendly. By simplifying data verification and providing clear feedback on changes, the tool can better support users in managing soil compaction risks effectively.

## Output

To enhance user understanding and engagement with the Terranimo tool, the following features for providing explanations behind estimates are recommended:

#### Rationale Behind Estimates

- Concise Explanations:
  - Provide brief explanations of the rationale behind the estimates generated by the tool. This ensures users understand the reasoning without overwhelming them with excessive information.
- Hidden Explanations with Exclamation Marks:
  - Utilize an exclamation mark (e.g., " ! ") to indicate that explanations are available. Users interested in deeper insights can click or hover to reveal these explanations.

- This approach minimizes immediate criticism by allowing users to explore the reasoning behind estimates at their own pace, reducing the risk of finger-pointing for potential ‘mispractices’.

#### Multiple Communication Formats

- **Diverse Presentation of Explanations:**
  - Offer explanations in various formats to cater to different learning styles. This can include:
    - **Graphs:** Visual representations that illustrate the impact of different setups on soil compaction.
    - **Numbers:** Key metrics and statistics that provide quantitative insights.
    - **Text:** Short written explanations that summarize the underlying principles.

#### Benefits of Proposed Features

- **Empowerment Through Knowledge:**
  - By providing accessible explanations, users can make more informed decisions based on a clear understanding of the implications of their choices.
- **Encouraging Constructive Engagement:**
  - The use of exclamation marks and varied formats encourages users to engage with the tool constructively and seek improvement without feeling accused of poor practices.

Incorporating these features into the Terranimo tool can enhance user experience and understanding. By providing concise, accessible explanations that are easily discoverable, users can better appreciate the tool’s functionality while feeling supported rather than criticized.

Furthermore, to enhance the Terranimo tool's utility for farmers and encourage decision-making that reduces soil compaction, the following economic features are recommended:

#### Estimation of Costs and Consequences

- **Cost Estimation for Different Set-ups:**
  - Implement a feature that estimates the economic costs associated with various equipment setups. This could include:
    - **Crop Reduction:** Quantifying potential yield losses due to soil compaction.



- Fuel Consumption: Estimating additional fuel costs incurred from inefficient practices.
- Equipment Wear: Assessing the financial impact of increased maintenance and replacement due to excessive wear on machinery.
- Economic Consequences of Soil Compaction:
  - Provide clear insights into how soil compaction affects profitability. This information could be crucial in motivating farmers to reconsider their equipment choices and field work schedules.

#### Compromise Calculation for Tyre Pressure

- Tyre Pressure Optimization:
  - Develop a calculation feature that determines the optimal tyre pressure for machines and equipment while traveling on asphalt and during field cultivation. This should consider:
    - Speed: Allowing certain speeds without causing excessive tyre wear on roads.
    - Soil Compaction: Ensuring minimal soil compaction during cultivation.

#### Fuel Consumption and Emission Savings

- Fuel Consumption Tracking:
  - Integrate a feature that tracks fuel usage based on different setups. Users can see:
    - Possible Savings: Estimates of fuel savings resulting from optimized machinery and practices.
    - Economic Interest: Highlighting the importance of fuel savings in light of rising fuel prices.
- Emission Savings Estimates:
  - Provide estimates of emissions savings that can be achieved with various setups and soil conditions. This could include:
    - Environmental Benefits: Raising awareness of the environmental impact of farming practices.
    - Regulatory Compliance: Assisting farmers in meeting potential regulatory requirements related to emissions.

#### Benefits of Proposed Features

- Informed Decision-Making:

- By providing economic insights, the tool can empower farmers to make informed decisions that balance productivity with sustainability.
- Enhanced Appeal of the Tool:
  - Showing the economic benefits of using the tool can increase its adoption among farmers, as it directly addresses their financial interests.

Incorporating these economic features into the Terranimo tool can enhance its value for farmers. By illustrating the financial implications of soil compaction and providing actionable insights on tyre pressure, fuel consumption, and emissions, the tool can promote more sustainable and economically viable farming practices.

## **Leased Land Management**

The tool may facilitate sustainable land use in lease or contracting agreements by addressing soil compaction.

## **Benefits for Landowners and Tenants**

- Landowners can:
  - Require tenants or contractors to use the tool to minimize soil compaction.
  - Ensure sustainable practices are being followed on their land.
- Tenants and Contractors can:
  - Present estimates generated by the tool to demonstrate their capability and knowledge in cultivating specific soils sustainably.
  - Build trust with landowners by providing data-driven evidence of their practices.

## **Suggested Features**

- Profile Functionality
  - A synchronized profile feature that allows both landowners and tenants or contractors to share information.
  - Enhances transparency and fosters better communication between parties.

The tool serves as an essential resource for both landowners and tenants or contractors, promoting sustainable cultivation practices while minimizing soil compaction.

## **Rental Terms and Cultivation Practices**

- Landowners' Choice:

- Landowners can rent their land only to tenants who cultivate in accordance with the tool's estimations.
- Tenants must accept these terms or risk losing the opportunity to lease the land, given the scarcity of agricultural land.

## **Challenges in Land Maintenance**

- Owner Maintenance Responsibilities:
  - Many fields are not well-maintained by landowners, particularly regarding drainage.
  - Tenants often have to take on the responsibility of improving the plots if they wish to enhance soil conditions.
- Leasing Duration:
  - Improvement of soil conditions is generally only feasible with long-term leases.
  - For short-term leases, the costs of improving soil conditions often outweigh the benefits, making such efforts economically unviable.

## **Contractor Considerations**

- Contractor Priorities:
  - Contractors may not prioritize avoiding soil compaction; they often work fields based on their scheduling convenience rather than sustainable practices.
- Risk for Tenants:
  - Some farmers may hesitate to lease land due to the fear of landowners demanding compensation for soil compaction or terminating their lease based on the tool's results.

## **Shared Responsibility for Soil Condition**

- Mutual Accountability:
  - The effectiveness of the tool in leasing agreements relies on the shared responsibility for soil condition between landowners and tenants.
  - If landowners do not maintain their fields, the tool's estimations may yield unfavorable results for tenants, regardless of their cultivation practices.

For the tool to be effectively integrated into leasing agreements, it is crucial to establish a clear understanding of responsibilities and expectations between landowners and tenants.

By addressing maintenance issues and fostering mutual accountability, both parties can work towards sustainable agricultural practices and better soil health.

## **Adoption of Terranimo**

Terranimo has yet to be widely used in the farming communities. Here are some suggestions for local and national efforts to promote the tool for adoption among farmers and agricultural contractors:

### **Strategies for Raising Awareness**

- Timing for Awareness Campaigns:
  - Focus on raising awareness of soil compaction and the Terranimo tool in late winter or early spring.
  - This timing allows for reflection on agricultural practices before the growing season begins, ensuring that farmers are not rushed to work the fields.
- Local Engagement:
  - Organize small meetings within each municipality rather than larger county-wide events.
  - This approach allows every attendee to participate and share their insights, fostering a more engaging discussion.
- Educational Integration:
  - Mention the tool in courses and seminars related to agriculture and soil management.
  - Promote its smartphone-friendly interface, enabling potential users to explore the tool easily in their daily lives.

### **Incentives for Adoption**

- Documentation for Emission Savings:
  - Highlight the possibility of using the tool to document emission savings.
  - This documentation can be beneficial when applying for refunds from governmental climate funds, providing an additional incentive for farmers to adopt the tool.
- Climate Advisory Services:
  - Consider implementing the tool within the framework of climate advice services for farmers.

- Ideally, this should be connected to a proposed extension service package that supports sustainable farming practices.
- Government Support for Advisory Costs:
  - Explore options for government refunds on a portion of the costs associated with advisory services.
  - This financial support can encourage more farmers to seek guidance and utilize the Terranimo tool effectively.

By strategically raising awareness and providing incentives, the adoption of the Terranimo tool can be enhanced. Engaging local farmers through community meetings, educational opportunities, and financial support will create a conducive environment for sustainable agricultural practices and soil health improvement.

## Conclusion

Estimates of compaction risk provide valuable insights for farmers, allowing them to reflect on when and how to cultivate their fields, as well as the appropriate setup to use. This tool proves particularly beneficial during the spring cultivation season when soil conditions are critical. During the harvesting period, factors such as time constraints, reliance on contractors, and promised deliveries can limit farmers' ability to consider soil conditions effectively. These pressures often lead to decisions that may not prioritize soil health.

It is anticipated that the tool will generally indicate a relatively high risk of soil compaction when soils are moist. However, this guidance may be overlooked if the weather is clear, as many users in Trøndelag regard this as an opportunity to work the fields, despite the tool's simulations indicating soil compaction risk. The Terranimo tool can, however, serve as a crucial resource for farmers in making informed decisions about cultivation and harvesting practices. By recognizing the importance of soil conditions and adapting to the insights provided by the tool, farmers can foster more sustainable agricultural practices, even amidst the pressures of time and weather.

To enhance field management, one possibility is to involve dealers by encouraging them to suggest setups for farmers based on the tool's estimates. This collaboration can lead to better overall management of fields concerning soil compaction, as dealers can provide practical solutions tailored to users' needs.

It is, furthermore, important to address knowledge gaps among users. Many users may have limited knowledge regarding the required inputs for the tool. This gap can hinder effective utilization of the tool's capabilities. A solution can be extension services offering suitable service packages to help users understand how to input the necessary data effectively. Such services can bridge the knowledge gaps and empower users to make informed decisions. This service can be enhanced by implementing a system for sharing profiles between users and advisors. This feature can simplify the tool's usage for those who may be less knowledgeable or not computer literate, as advisors can assist in administering the inputs.

There are missed opportunities for broader adoption of the Terranimo tool among users who may not be as concerned about soil compaction but could still benefit from its insights. To raise awareness of soil compaction risk and the Terranimo tool, one can organize small meetings at the municipal level to facilitate open discussions where every attendee can contribute. This localized approach ensures that potential users feel heard and engaged. Further, one can promote the tool by mentioning it in different forums and discussions related to agriculture and soil management. This could include workshops, community events, and educational seminars.

Another possibility for motivating adoption of the tool, is to integrate it with reward programs like existing agricultural services that reward users for sustainable practices. This could include programs where users receive financial incentives or refunds from the government for adopting best practices in soil management.

In the context of land leasing or contracting, one could establish a system for synchronizing profiles between landowners and tenants or contractors. This synchronization would promote transparency in practices and expectations, ensuring that both parties are aligned on soil management strategies. It must be emphasized that there should be a shared responsibility for soil condition between landowners and tenants or contractors. This collaborative approach ensures that all parties are invested in maintaining soil health and can lead to better outcomes when using the tool in leasing agreements.

By actively engaging potential users through localized meetings, integrating the tool into various forums, providing supportive services, implementing the tool within existing reward programs, and creating synchronized profiles for transparency between landowners and tenants, the adoption of the Terranimo tool can be enhanced. Addressing knowledge gaps and facilitating ease of use will empower a wider range of farmers to benefit from improved soil management practices, while emphasizing joint responsibility for soil conditions will foster a more collaborative environment. Also, incorporating additional functions and enhancing the tool's features inspired by the detailed overview in the Results section, will attract more potential users while accommodating existing users who possess a higher skill level. Ultimately, these improvements will encourage better soil management practices and contribute to greater sustainability in agriculture.

# Appendices

## Appendix I: Questions from the first seminar

In which situations do you believe Terranimo can contribute to reducing soil compaction?

What do you require of Terranimo to begin using it in farming or planning?

If Terranimo tells you that you shouldn't be cultivating the soil at the moment, but you have no other choice than do to it anyway, what do you do?

In a land lease agreement, could Terranimo be used by one of the parts in the agreement, and if so, how?

Which farmers and types of productions can Terranimo be more and less useful to?

What threats, eventually potential for improvement, does Terranimo have to show you, if you were to change anything in your own farming practices?

Are there situations where someone may not be willing to share calculations by Terranimo?

Are there any particular factors in Central Norway that may influence farmers use of Terranimo in this specific region?

A contractor wants to use Terranimo to market his/her services – is it sensible?

Should, or should not, Norwegian Agricultural Extension Service use Terranimo more when advising?

Other comments?

## Appendix II: Questions from the individual interviews:

How important is it to develop functions for/ portrayal of/ suggestions for/ explanations of ...  
Crop reduction by bad practice; the soils resilience; field routes; fuel savings; change of tyres; speed limit according to tyre air pressure; explanations of Terranimos calculations; most serious damage possibly done by set up alternatives; user profile; one simple and one advanced version of Terranimo?

Would a NLR service package to get the most out of Terranimos potential be a good idea?

How can awareness of soil compaction and Terranimos existence be raised?

How could Terranimo be part of land lease agreements?

Other comments?



### **Appendix III: Questions from the second seminar**

Should an application for smart phones and tablets be a simple or an advanced version, or is both needed in an application format?

Would one care more, less, or equally as much about soil damage on one's own soil, compared to leased land? Why?

What would you say if a landowner required a tenant to use Terranimo to reduce soil damage?

Does it exist landowners who are concerned about the state of plots they rent out? If so, does it increase the chances of tenants accepting requirements or expectations of use of Terranimo?

Do you have any other comments on Terranimo?