The Norwegian Soil Information System

Data capture, Data management, Data processing and Dissemination

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Sammendrag

Dette er en rapport som beskriver det norske jordkartleggingsprogrammet. Kjennskap til det norske programmet og de erfaringer som er gjort for bruk av WRB (2014) vil sannsynligvis være nyttig for det latviske arbeidet i prosjektet "E2SOILAGRI". Arbeidet er definert som underaktivitet 4.1.1 i Terms of Reference for NIBIOs rolle i prosjektet.

Summary

This is a report which describes the Norwegian Soil Information System. Knowledge on the use and adjustments of the WRB (2014) in Norway, and the experiences which have been encountered, is considered useful for the Latvian work in the project "E2SOILAGRI". This task is defined as sub-activity 4.1.1 in the Terms of Reference for the NIBIO assignment.

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GODKJENT /APPROVED	PROSJEKTLEDER /PROJECT LEADER
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Preface

NIBIO is a partner in the project “Enhancement of sustainable land soil resource management in agriculture” (E2SOILAGRI) implemented by the Ministry of Agriculture of the Republic of Latvia and funded under the Norwegian Financial Mechanism Program “Climate Change Mitigation, Adaptation and Environment”. The main objective of the project is to improve Latvian soil data for the development and implementation of climate change policies. The project is managed by Latvian authorities. The project period is from February 2021 to January 2024.

NIBIO has an advisory role in the project. NIBIO is owned by the Norwegian Ministry of Agriculture and Food and has a role in contributing to food security and safety, sustainable resource management, innovation and value creation in Norway. NIBIO is a partner in E2SOILAGRI due to its ongoing soil survey on agricultural land and the experience in making data from the survey easily accessible for different users.

The E2SOILAGRI project is supported by Norway through the Norway Grants. The Norway Grants, together with the EEA Grants, represent Norway’s contribution towards a green, competitive and inclusive Europe. Through the Norway Grants and the EEA Grants, Norway contributes to reducing social and economic disparities and to strengthening bilateral relations with beneficiary countries in Central and Southern Europe and the Baltics. Norway cooperates closely with the EU through the Agreement on the European Economic Area (EEA). Together with the other donors, Norway has provided €3.3 billion through consecutive grant schemes between 1994 and 2014.

Norway Grants are financed solely by Norway and are available in the countries that joined the EU after 2003. For the period 2014-2021, the Norway Grants amount to €1.25 billion. The E2SOILAGRI benefits from a EUR 1,56 million contribution from Norway Grants.

This is a report which describes the Norwegian Soil Information System. Knowledge on the information system, the use, and adjustments of the WRB (2014) in Norway, and the experiences which have been encountered, is considered useful for the Latvian work in the project “E2SOILAGRI”. This task is defined as sub-activity 4.1.1 in the Terms of Reference for the NIBIO assignment. Ingvild Nystuen has contributed in chapter 3, Data management, and Hege Ulfeng has contributed in chapter 5, Dissemination - public outreach and data availability. Chapter 6, Adjustments of the WRB (2014), is based on documents prepared by the former soil survey supervisor, Åge Nyborg, who is now retired.

Ås, 22.04.22

Hildegunn Norheim

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1 Introduction

The department of Agricultural Soil Survey in NIBIO is responsible for carrying out agricultural soil surveys in Norway. The survey is commissioned by the Norwegian Ministry of Agriculture and Food, and is funded by an annual allocation from the state budget. The objective of the survey is to map the distribution of different soil types to provide decisions makers with knowledge on soil resources. This knowledge can be used for knowledge-based decisions for a sustainable utilisation of the soil resources in Norway.

Soils develop over time via the combined processes of climate, topography, parent material, biological and human activity. Therefore, the soil that develops in any one place is a product of the conditions around it. The result is that soils are highly varied in the properties they contain. These properties can have a significant influence on their suitability for different types of plant growth, the risk of erosion and agronomy. Therefore, knowing what type of soils are found where, is valuable information for food production and environmental management.

Information system with four steps

Annually, NIBIO surveys around 100 km² using a standardized method developed from over 40 years of experience. The Norwegian Soil Information System (NoSIS) is an information system consisting of four steps: Data capture, Data management, Data processing and Dissemination. Two departments in NIBIO are involved in the information system, the Department for Geomatics and the Department for Agricultural Soil Survey. For the information system to be able to function properly, it's essential that there is good cooperation and interaction between the two departments. The steps in the information system are shown in figure 1 below.

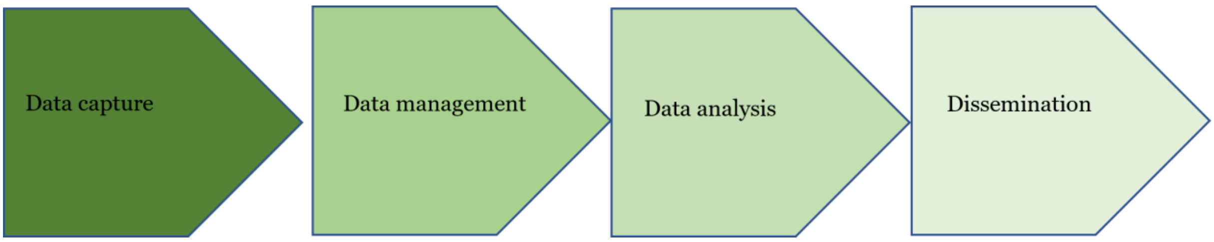

Figure 1. The steps in the Norwegian Soil Information System (NoSIS)

The information system requires an effective and reliable data capture, a secure data management, adequate data processing and thorough dissemination. All steps are described in the report. Also included in the report are the adjustments which have been made of WRB (2014) to make the system more applicable for soil mapping and for describing Norwegian soils. Finally, there is a chapter with recommendations based on experiences from the NoSIS.

Steering group for the Norwegian Soil Information System

The NoSIS has a steering group, which was established in January 2017 with the overall objective to ensure that all the steps in the information system operate in the best possible way, both within each step and regarding the interactions between the steps – in accordance with the purpose of the information system and the available resources.

Participants in the steering group are: Hildegunn Norheim (Director - Division of Survey and Statistics), Geir-Harald Strand (Head of Research - Division of Survey and Statistics - leader of the steering group), Ingvild Nystuen (Head of Department – Department of Geomatics) and Siri Svendgård-Stokke (Head of Department – Department of Agricultural Soil Survey – secretary of the steering group).

The steering group meets twice a year, or more frequently if needed.

The systematic soil survey in Norway has been conducted since 1980. During the years, mapping methodologies have changed. In 2012, a new methodology was introduced – this one representing a major change. This methodology used the classification system more directly than the previous one, using abbreviations from the adjusted version of the World Reference Base for Soil Resources as mapping units. In the following years, both the new and the old methodology were used: the new in some municipalities, the old in other municipalities. The data base contained soil data from two different mapping methodologies, causing two different ways of data processing and publishing results. This was complicated for all the steps in the Norwegian Soil Information System - the data capture, the data management, the data processing, and the dissemination.

The steering group decided that a new soil survey methodology had to be established – combining the best from both previous methodologies, *and* that a new soil data base had to be established. This has been called the harmonization project. The harmonization process has been very comprehensive and has involved many people in both the department of Geomatics and the department of Agricultural Soil Survey – in all the steps of the information system.

At present, the harmonization process is almost completed. The harmonized soil survey methodology was established in 2018, soil types from the old methodologies have been translated into the methodology, a new soil data base has been established, new thematic maps have been programmed and models have been run, cartography of the new maps have been decided and information pages on the maps have been written. Only the final follow-up of the last technical and quality controls remains.

This report is written according to the harmonizing process, in all steps of the Norwegian Soil Information System.

2 Data capture

Systematic soil survey began in 1980, and between then and now the method has developed in line with technology, experience and research. Technology has changed, for example handheld computers with aerial images and GPS have replaced paper aerial photographs, but the soil auger remains an important tool in the soil survey and the same soil properties are identified and documented.

2.1 Soil classification

The NoSIS uses an adjusted version of the World Reference Base for Soils (WRB), 2014. This system has been adjusted where necessary to make it more applicable to the soil conditions and the soil survey in Norway.

These adjustments include:

- Definitions of diagnostic features (properties) and WRB groups
- Definitions and use of Qualifiers
- The addition of Qualifiers that describe special soil properties

A soil classification key is developed with 15 WRB groups and more than 4000 units that function as potential soil mapping units. The Norwegian adjustments of WRB (2014) are described in detail in chapter 6.

2.2 Naming the soil

The surveyor selects points for auger testing based upon the area size, topography, vegetation, old aerial photographs or other signs of differences in soil types. The soil mapping units are identified using soil auger observations and the classification key. The key uses observed soil properties in a step-wise procedure resulting in the final classification according to the Norwegian version of the WRB (2014). The final classification is the name of the soil in the NoSIS. The steps in the key, and the options at each step, are listed below. All the Norwegian definitions are in chapter 6.

2.2.1 The classification key

Below is a description on how the key is working, the options on some of the steps vary according to the choices made on previous steps.

Step 1: Properties of the upper horizon

As the soil survey is conducted on agricultural land, a standard depth of the upper horizon, the standard plough horizon, is fixed at 15-30 cm. Options: Histic, Umbric, Umbric + Pachic, Chernic, Chernic + Pachic, Mollic, Mollic + Pachic, Hortic and Ochric.

Step 2: The soil's ability to infiltrate excess water

The stagnic/gleyic properties are considered in the depth 0-50 cm only, if present.

Options: poor drainage and gleyic, poor drainage and stagnic, gleyic or stagnic features only in the Ap-horizon and with an underlying plough sole, and none of the above-mentioned options.

Step 3: Dominating soil forming process and/or important features of the parent material

For mineral soils, the first choice is to decide whether the horizon below the plough layer fulfills the criteria for diagnostic horizons, if the soil has fluvic properties or if the "soil" consists of fillings other than soil with a thickness more than 50 cm. For organic soils, the degree of humification is determined.

Options for diagnostic horizons for mineral soils: Spodic, Spodic + Ortsteinic, Retic, Cambic + Argic, Argic, Cambic and none of the above-mentioned options.

Options for parent material: Fluvic, Spolic or Urbic

Options for organic soils: Fibric, Hemic or Sapric

Step 4: Depth to solid bedrock

Options: within 25 cm, Epileptic, Endoleptic or deep.

Step 5: Base saturation and carbonates

As the soil survey is based on decisions in situ, base saturation must be decided due to the parent material and the texture. Carbonates are detected using hydrochloric acid. Options: Rendzic, Calcaric, Eutric and Dystric.

The choice in this step is depending on choices made in previous steps. Due to this, the number of options is reduced, or the step does not appear in the key. For the latter, base saturation is implied.

Umbric, *Spodic, Fluvic: Dystric is implied*

Hortic, *Argic, Retic: Eutric is implied*

Chernic or Mollic: Rendzic, Calcaric or *Eutric are the options*

Step 6: Content of coarse material

Options: Hyperskeletic, Episkeletic, Skeletic, Endoskeletic and Low

Step 7: Dominating texture below the surface horizon

Most of the map units include information on the dominating texture below the surface horizon, except map units which are Histosols, Leptosol, Epileptic, Hyperskeletic or Rendzic. Options: Epiarenic, Arenic, Siltic), Clayic and Loamic. If loamic is chosen, loamic is not a part of the name of the soil, the map unit.

Step 8: Properties of the parent material

This step concerns properties related to lithologic discontinuities and some given parent materials. All soil groups except Leptosols can get qualifiers from this step, for Planosols the qualifier Abruptic is implied. The choices available are depending on the choices which have been done at earlier steps in the key. Options: Abruptic, Ruptic, Thaptohistic, Humic, Alum shale, Alum shale overlying Ruptic, Limnic and None.

Step 9: Human disturbances other than ploughing / drainage measures

Options: Transportic, Relocatic, Planeric, Profilic and None.

2.2.2 Rules on naming the soil

The name of the soil type consists of a soil group name, one or more prefix-qualifiers and suffix-qualifiers if present. The full name of the soil type starts with prefixes in an opposite prioritized order, followed by a soil group name and ending with suffixes in parentheses separated by commas. The abbreviated soil type, used when digitizing in the field, starts with two capital letters identifying the soil group, followed by qualifier codes separated by hyphens. Example:

Full name: Dystric Endoleptic Regosol (Humic, Arenic), Soil type in the field: RGlen-dy-hu-ar

2.3 Soil survey methodology

Classification systems characterize soil based upon their properties. During the soil survey, these properties are identified between the surface and one meter in depth, or to solid bedrock if present within the depth of one meter.

The field handbook contains detailed instructions on how the survey is to be conducted, including definitions. The main content of the field handbook is described below.

2.3.1 Map unit signature

The map unit signature is one of the two main basis results from the soil survey. The map unit signature has the following information:

- Soil type: pre-defined from the adjusted version of the WRB (2014)- system, corresponding to the WRB unit level
- Code for texture and gravel in the plough layer (code 10-19, 99, table 1)
- Code for stones and boulders in the upper 50 cm (codes 30-32, table 2)
- Additional information on the polygon, if present (code q, t, v, p, z, m – only one of these can be used, the priority is given, table 2)

Table 1. Codes for texture and content of gravel in the plough layer

Code	Description
10	Sand (coarse-/medium-/fine) og silty sand (silty coarse-/medium-/fine), ≥40 % gravel
11	Coarse sand, < 40 % gravel
	Medium sand and fine sand, ≥20-<40 % gravel
12	Medium sand and fine sand, <20 % gravel
13	Silty coarse sand, < 40 % gravel
	Silty sand (medium- or fine-) / sandy silt /silt, ≥20-<40 % gravel
14	Silty sand (medium- or fine-), <20 % gravel
15	Sandy silt and silt, <20 % gravel
16	Silty light clay (12-25 % clay), <20 % gravel
17	All clay, all gravel
	All silty clay (>12 % clay), ≥20 gravel
18	Silty medium clay, <20 % gravel
19	Heavy clay and very heavy clay, <20 % gravel
99	Organic

Table 2. Codes for stones and boulder and additional information on the polygon

Stones and boulders in the upper 50 cm		Additional information on the polygon	
Codes	**Description**	**Codes**	**Description**
30	< 10 m^3/daa from the surface to 50 cm depth	**m**	Scattered areas of mineral soil *if* Histosol and/or Histic are used in the polygon
31	10-50 m^3/daa from the surface to 50 cm depth	**p**	Scattered areas of land levelling
32	> 50 m^3/daa from the surface to 50 cm depth	**q**	Rock outcrops ≥ 0,4 per decare
		t	Scattered areas of organic soil *if* Histosol and/or Histic are NOT used in the polygon
		v	Scattered areas with low ability to infiltrate water *if* Gleyic nor Stagnic not is used in the polygon
		z	Scattered areas with signs of human disturbances other than land levelling

The classes for grain sizes are shown in table 3, the textural classes and grain size distribution are shown in table 4.

Table 3. The classes for grain sizes

	Description	Diameter size (mm)
Coarse material	Boulder	> 200
	Stone	200 – 60
	Coarse gravel	60 – 20
	Medium gravel	20 – 6
	Fine gravel	6 – 2
Fine material	Coarse sand	2 – 0,6
	Medium sand	0.6 – 0.2
	Fine sand	0.2 – 0.06
	Coarse silt	0.06 – 0.02
	Medium silt	0.02 – 0.006
	Fine silt	0.006 – 0.002
	Clay	< 0.002

Table 4. Textural classes and grain size distribution

Decription		Grain size distribution
Sand		< 10 % clay og ≥ 85 % sand
	Coarse sand	The sand fraction has ≥ 1/3 coarse sand
	Medium sand	The sand fraction has < 1/3 coarse sand and < 2/3 fine sand
	Fine sand	The sand fraction has ≥ 2/3 fine sand
Silty sand		< 10 % clay and < 50 % silt and < 85 % sand
	Silty coarse sand	The sand fraction has ≥ 1/3 coarse sand
	Silty medium sand	The sand fraction has < 1/3 coarse sand og < 2/3 fine sand
	Silty fine sand	The sand fraction has ≥2/3 fine sand
Sandy silt		< 12 % clay and between ≥ 50 % and <80 % silt
Silt		< 12 % clay and ≥ 80 % silt
Sandy light clay		Between ≥10 % and <25 % leir and < 25 % silt
Light clay		Between ≥10 % and <25 % clay and between ≥25 % and <50 % silt
Silty light clay		Between ≥12 % and <25 % clay and ≥ 50 % silt
Sandy medium clay		Between ≥25 % and <40 % clay and < 25 % silt
Medium clay		Between ≥25 % and <40 % clay and between ≥25 % and <50 % silt
Silty medium clay		≥ 25 % clay and ≥ 50 % silt
Heavy clay		Between ≥40 % and <60 % clay and < 50 % silt
Very eavy clay		≥ 60 % clay

2.3.2 Delineation of soil polygons

The spatial distribution of each soil type is decided by multiple core points, together with topographical location and differences in vegetation. Older aerial photographs are often useful for setting boundaries between soil types and to guide the classification choice. Boundaries between mapping units are digitized using a pen on the computer screen, or by using GPS and walking along the boundaries in the field. Out of necessity, boundaries on the resulting soil maps are clear and sharp, however in reality boundaries between soil types are often gradual.

Areas of agricultural land for soil survey are extracted from the National Land Resource Map (AR5) and the delineation between mapping area and none-mapping area is shown as green boundaries on the field computer. Changes on these boundaries are not to be done if the change of area class concerns less than 4 decares.

<u>The minimum size of polygon is 10 decares, with the following exceptions:</u>

- Isolated polygons from the National Land Resource Map (AR5) with the size 2-10 decares can identified as unique polygons
- Two soil polygons with the identical map signature which are placed on each side of a boundary from the National Land Resource Map (AR5) can be less than 10 decares each, but must be minimum the size of 10 decares combined
- A soil polygon can be the size between 4 and 10 decares if the neighboring polygon is either a Histosol or a Leptosol or has one or several of the following properties: histic, epileptic, skeletic, episkeletic, hyperskeletic, rendzic, epigleyic, epistagnic, planeric, relocatic or profilic and the

neighboring polygon is minimum 10 decares and does not have these properties. This rule can also be applied the other way.

A soil polygon consists of a complex (has two soil types) if:

- The two soils have different agronomical properties
- Both soil types are distributed on the whole polygon, and it is not possible to separate them in different polygons
- The soil types have several limiting properties and one of the properties only belongs to one of the soil types

Complexes are allowed if:

- The size of the polygon is 10 decares or more
- Two different soil types are present and each of them has to cover at least 25 % of the area of the polygon
- The dominating soil type (regarding distribution) is determined as the main soil type

2.3.3 Responsibilities in the field

Doing soil survey involves many tasks and responsibilities. All personnel in the soil survey area are soil surveyors, but some personnel have additional tasks. All the tasks and the responsibilities are described in the field handbook. The roles in each soil survey area are stated in the annual plan for the field work. The roles in the data capture: soil surveyor, soil responsible, field responsible and logistics- and data responsible. The overall responsibility of the data capture lies to the head of department.

The main tasks for the role of soil surveyor are to:

- Conduct the soil survey in the given area according to the methodology
- Check the completed soil survey for correct use of the map signature, included the soil names used. A digital check on the signature is established. This check regarding the soil names is based on the soils which are defined in the soil polygon data base.
- Correct the file if errors are identified in the check. If new soils are found, there must be a dialogue within the group of soil surveyors, and the person who is soil survey responsible for the mapping area is determining what to do: establishing a new soil type or not.
- Report on progress in the end of the week - decares mapped and days used. The reporting is to be done to the person who is assigned to be field responsible.
- Submit the completed soil mapped file as an attachment per e-mail to the field responsible as soon as all the checks have been done and errors, if present, have been corrected

The main tasks for the role of soil survey leader are to:

- Conduct all the tasks listed for the soil surveyor
- Convey routines and premises regarding the soils in the area and the naming of the soils for the rest of the team
- Arrange joint inspections for the team, both in the start-up of the mapping period and during the mapping period
- Do training of new soil surveyors, supervision, and guidance of all surveyors (both one on one and for the whole team)
- Approve new soil types, if any

- Preform profile descriptions and soil sampling
- Communicate with the head of department
- Communicate with the municipality and the county, and invite representatives of both levels of public administration to join the soil survey for half a day

The main tasks for the role field leader are to:

- Conduct all the tasks listed for the soil surveyor
- Distribute the areas for soil mapping to each soil surveyor
- Technical checks on the files received from the soil surveyors
- Do weekly reporting on progress to the soil survey responsible and to the head of department
- Assist the soil survey responsible in profile descriptions and soil sampling, or performing them
- Check if all the area for mapping is mapped
- Submit the fully checked files to an email address established for receiving the files

The main tasks for the role logistics- and data leader are to:

- Conduct all the tasks listed for the soil surveyor
- Give technical support and guidance to the soil surveyors
- To make a draft for the field plan
- Make sure that all necessary equipment is provided in the areas, included all the preparations concerning the field computers

The main tasks for the head of department are to:

- Arrange annual field courses for all soil surveyors
- Communicate with the soil survey responsible in the different areas
- Approve the field plan
- Make adjustments on the field plan if necessary, during the soil survey period
- At present, the head of department is the overall supervisor of the data capture

2.3.4 Other information

The field handbook also contains instructions for soil profile description and soil sampling. An application has been made for the soil profile description. The description is imported in the soil profile data base when the laboratory analysis is completed. Doing profile descriptions and taking soil samples are expensive, both in direct costs for analysis and regarding use of hours. In the field handbook, there is an instruction on how to choose areas and soil types for profile descriptions and/or soil sampling to get the highest value for the cost that this activity implies.

The NoSIS uses the digitizing software FYSAK in the data capture. Instructions regarding the main operations in FYSAK are described in the field handbook.

2.4 The field computer

Each soil surveyor has her/his own field computer during the soil survey. The field computers are highly resistant to rain and soil and have a built-in GPS. The digitizing computers are equipped with the following maps and files for the survey:

- Maps for digitizing soil polygons where the agricultural areas are delineated. The agricultural land is extracted from the National Land Resource Map (AR5)
- Geological maps (bedrock and sediments)
- Aerial photographs – old and new
- Digital elevation model data – 1 m equidistance
- Classification key with soil mapping units
- Field handbook with descriptions of the methodology and definitions
- Digital forms for describing and sampling soil profiles

2.5 In the field

Every soil survey season starts with a three-day field course for the soil surveyors. This ensures that surveyors are updated on the classification system and the methodology. Even though there is a defined methodology, a classification key and comprehensive training in advance, soil survey is based on the decisions made by each soil surveyor, regarding both selection of points for auger testing, the soil's properties, the name of the soil and the boundaries between soil polygons. In the field course soil survey is conducted in groups and resulting maps from the groups are compared and discussed to increase the degree of uniform decisions.

Supervision and joint inspections for the team are organized, the supervision and guidance are either done in groups or one on one.

Soil survey is performed in 4-5 municipalities each year. Municipalities are selected according to a list of priority which has been made due to inquiries from un-mapped counties or municipalities. In each municipality chosen for soil survey, there is a team. The teams vary in size, depending on the size of the mapping area, but the most common is 4-5 surveyors in each team-

The personnel in each soil mapping area are appointed to roles, described 2.2.3 and each soil surveyor is assigned a work area.

2.6 Soil samples for laboratory analysis

Soils that occur frequently in a soil survey project are described and sampled by auguring or by digging soil profile pits. Digital soil profile description forms are submitted to the soil database, and soil samples are delivered to NIBIOs soil laboratory for analysis. The results from the analysis are used in the documentation of soil mapping units, and as a quality control for the field survey data.

2.7 Tasks following the soil survey in the field

A production line is established for processing the data from the soil survey in the field and to the following steps in the information system. The production line has several tasks, all defined concerning both what to do and who is responsible for performing the tasks. The production line involves both the department of geomatics and the department of agricultural soil survey. One of the tasks is to assign the dominating inclination for the soil polygons. This is done using a digital terrain model.

3 Data management

Data management includes all activities related to managing data, including technological and administrative tasks. The data are a valuable resource, and well-functioning data management is a prerequisite to be able to exploit the data in the best possible way. This is a long-term investment, to ensure the data remains valid, usable, and accessible in the long term. It is essential that the data are usable for purposes which were perhaps not foreseen when the data were first collected.

Data must be easy to access, available in a structured, logical format, and complete. It must always be remembered that good data management does not ensure data quality.

Information security is an important aspect in data management and can be divided into three main topics: confidentiality, integrity, and availability. The system for data management must take these three topics in sufficient consideration. In the management plan there must be strategies and safeguards in place for maintenance and adapting to technological advances. Therefore, within the management plan, roles must be defined, such as the system owner, system manager, data supplier, and data owner. Moreover, user rights must be defined, making it clear who can make use of the data and for what purpose.

The soil data in the NoSIS is organized in two different data bases; one for soil polygon data and one for soil profile data.

3.1 The soil polygon data base

The soil polygon data base can be described as organized in four parts, each of them described below. Only the fourth part is available for downloading and map services.

3.1.1 Geometry and map units

The first part contains the geometry and the map unit for all soil mapped areas. At present, the soil data base contains approximately 650 000 soil polygons. When the results from the soil survey is imported in the data base, each polygon is assigned with a unique number for identification.

This part of the data base contains the soil name (-s) of the polygon, the inclination of each soil polygon and the dominating texture for the mapped soils. Also included is the content of boulders and rocks in the depth of 0-50 cm. If present, additional information relating to parts of the polygon is also included, such as rock outcrops, wet spots, human disturbances etc. Figure 2 shows an example of the input data from the survey in this part of the data base.

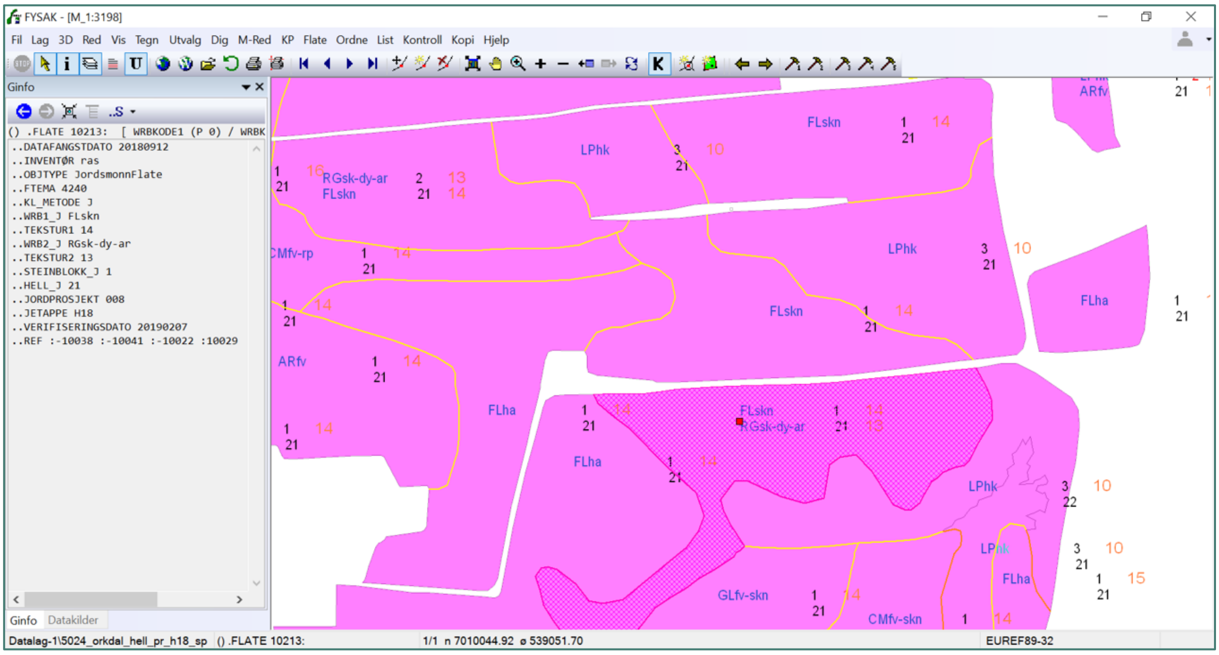

Figure 2. Example on information from the soil survey which contains the geometry and the map unit, to be imported in the first level of the soil polygon data base. When imported, each soil polygon is assigned with a unique number. The information for the marked polygon is showed at the left in the figure: date for survey (..DATAFANGSTDATO), soil surveyor (..INVENTØR), type of object (..OBJTYPE), soil surveyed area (..FTEMA), classification method (..KL_METODE), dominating soil type (..WRB1_J), dominating texture of the surface horizon in the dominating soil type (..TEKSTUR1), less dominating soil type (..WRB2_J), dominating texture of the surface horizon in the less dominating soil type (..TEKSTUR2), content of boulders and stones in the depth 0-50 cm (..STEINBLOKK), dominating inclination of the polygon from a digital terrain model (..HELLING), project number (..JORDPROSJEKT), season and year for data capture (..JETAPPE), date for verification of file before import (..VERIFISERINGSDATO) and the geometry of the polygon (..REF).

3.1.2 Soil classification

The second part of the data base is the classification of each soil type which has been mapped. The classification is organized in accordance with the classification key used in the survey. Codes are identifying the property chosen at each step of the key for the given soil. Table 5 shows three examples of this part in the data base.

Each soil type has a string which identifies the soil properties according to the soil classification, the wrbq-string. Then, the wrbq-string is separated in factors 1-8. This way of organizing the information from the classification makes the data base easily accessible for extractions into models for producing thematic maps. The factors 1-8 are listed in table 6 and the codes for the soil types in table 5 are shown in table 7.

Table 5. Examples on soil classification in the soil polygon data base - three soil types

		The codes for classification soil properties – per factor									
Soil type	**wrbq-string**	**1**	**2a**	**2b**	**3**	**4**	**5a**	**5b**	**6**	**7**	**8**
ARdy	ox-bx-fx-dx-gx-ar-dy	8	-	9	5	6	5	1	5	-	-
HSsa-dy-rp-zp	hi-sa-fx-glp-gx-sx-dy-rp-zp	1	3	-	5	1	5	5	5	1	7
PHlen-cm	mo-cm-len-dx-gx-sx-eu	5	-	1	4	6	5	5	3	-	-
STeu-ce-pp	ox-bx-fx-stp-gx-ce-eu-pp	8	-	9	5	2	5	4	3	-	8

Table 6. Description of the factors in the soil classification

Factor	Description
1	Properties of the surface horizon
2a	Degree of humification in organic soils
2b	Soil forming process
3	Depth to solid bedrock
4	Ability to infiltrate water
5a	Content of coarse material
5b	Dominating texture below the surface horizon
6	Base saturation and carbonates
7	Lithologic discontinuities and properties of the parent material
8	Human disturbances

Table 7. The codes for each factor in the soil classification for the soil types in table 5

Factor	Code and description for the soil types in table 4			
	ARdy	**HSsa-dy-rp-zp**	**PHlen-cm**	**STeu-ce-pp**
1	1 = ochric	1 = histic	5 = mollic	1 = ochric
2a	[null]	3 = sapric	[null]	[null]
2b	9 = no structure	[null]	1 = cambic	9 = no structure
3	5 = not within 100 cm	5 = not within 100 cm	4 = endoleptic	5 = not within 100 cm
4	6 = no sign of reducing conditions nor redoximorphic features within 50 cm	1 = epigleyic	6 = no sign of reducing conditions nor redoximorphic features within 50 cm	2 = epistagnic
5a	5 = low	5 = low	5 = low	5 = low
5b	1 = arenic	5 =not arenic, nor epiarenic, nor siltic nor clayic	5 =not arenic, nor epiarenic, nor siltic nor clayic	4 = clayic
6	5 = dystric	5 = dystric	3 = eutric	3 = eutric
7	[null]	1 = ruptic	[null]	[null]
8	[null]	7 = profilic	[null]	8 = planeric

3.1.3 The generic soil information

The third part of the soil polygon base is the soil data for each horizon in the soils. The data are generic, representing the soil in the best possible way – within the accepted budget. This part contains horizon symbols, the upper and lower boundaries of the soil horizons, content of sand, silt, clay and organic carbon in all horizons for each map unit. Table 8 shows some examples of this part of the data base.

3.1.4 Soil polygons in the thematic maps

The fourth part of the data base contains the classification of each soil polygon in the thematic maps. This part also contains all necessary additional input data for the models producing the thematic maps, such as meteorological data (from the Norwegian Meteorological Institute).

Table 8. Examples of the generic soil information for two soil types – extracted and summarized

Soil type	Texture in S1	Horizon				Content of gravel (%)	Particle size distribution (%)			Content of carbon (%)
		Number	Design-ation	Upper limit (cm)	Lower limit (cm)		Sand	Silt	Clay	
ARdy	12	1	Ap	0	25	0	86	12	1	2,3
ARdy	12	2	Bw1	25	55	0	92	4	1	0,3
ARdy	12	3	Bw2	55	80	0	94	5	1	0,2
ARdy	12	4	Cg	80		0	91	7	1	0,1
STeu-ce-pp	19	1	Ap	0	25	1	6	45	49	1,5
STeu-ce-pp	19	2	Cg	25		0	0	49	51	0,2

3.2 The soil profile data base

The profile data base includes both profile descriptions, analytical data and coordinates for all the soil profiles that have been dug and recorded. The data are used as documentation of the dominating soils in surveyed areas, and for correlating soil assessments between the soil surveyors.

4 Data processing

The overall aim with the NoSIS is to provide decision makers and those working with the soil with knowledge of the agricultural soils through thematic maps and statistics. As the user needs vary, there are many thematic maps that result from the soil survey.

For each thematic map, there must be a defined requirement specification on the input data needed and how to produce the map. The programming of the requirement specification is done in open-access software. After programming is done, checks are done on the results. These checks are done to ensure that the resulting map is in compliance with the requirement specification and that all the soil polygons are classified in the given map. Finally, the cartography for the map must be decided and tested, web map services (wms) established, and the data must be adapted for downloading.

Annually, the results from the soil mapping being imported in the data base, established procedures running the models for the thematic maps are done and the thematic maps are available for the public.

The descriptions below, including the examples, are according to the new harmonized soil data base, although the harmonized data are not yet published.

4.1 Input data for thematic maps

The input data from the soil polygon data base in the models for the thematic maps vary. Some of the maps requires only information from the geometry and map units, other maps also require the input from the soil classification. More complicated thematic maps require information from the generic soil data base and the most complicated models for thematic maps require meteorological data and growth models to be produced. The maps can be divided into different groups according to the complexity of the models which are used:

- Maps made by simple extraction from the geometry and map units: Soil Classification, Dominating Texture of the Surface Horizon
- Maps which require information from the geometry and map units and/or the soil classification: Organic Material, Natural Soil Drainage Capacity, Disturbances other than ploughing / drainage measures, Soil Quality, Classes for Soil Resources and Limiting Soil Properties
- Maps which require information from the geometry and map units, the soil classification and the generic soil data base, meteorological data and the Pan-European Soil Erosion Risk Assessment – PESERA: Soil Erosion Risk
- Maps which require information from the geometry and map units, the soil classification, the generic soil data base, meteorological data and models for plant growth: Potential for Cereal Growth, Potential for Gras Growth and Potential for Horticulture

4.2 Requirements specification for thematic map – examples

4.2.1 Soil Classification

The map Soil Classification classifies the soil polygons into 15 classes according to the groups in the Norwegian version of the WRB (2014). If two soil types are present in the polygon, the group in which the dominating soil type belongs, is used for the classes in the map. Table 9 shows how the map is made.

Table 9. Requirement specification for the thematic map Soil Classification

First two letters in the WRB1_J	Class in the map Soil Classification
FL	Fluvisol
CM	Cambisol
PH	Phaeozem
UM	Umbrisol
HS	Histosol
LV	Luvisol
GL	Gleysol
ST	Stagnosol
PL	Planosol
RG	Regosol
AR	Arenosol
PZ	Podzol
LP	Leptosol
AT	Anthrosol
TC	Technosol

An example of the map Soil Classification is shown in figure 3.

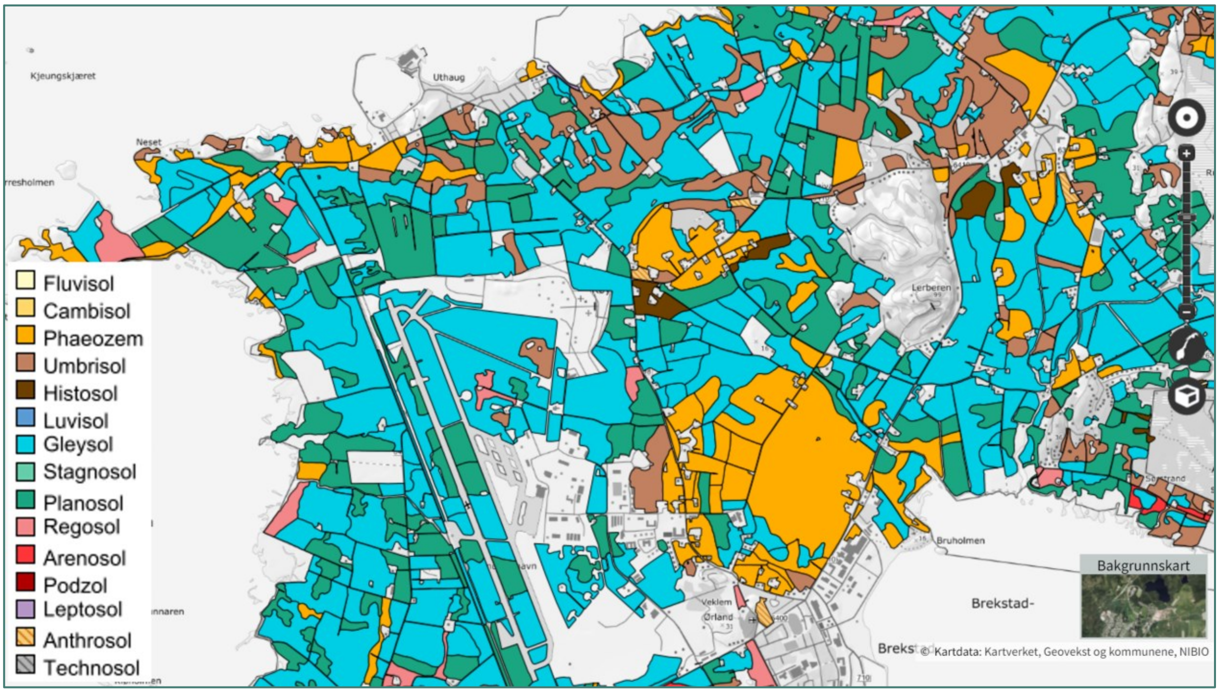

Figure 3. The Soil Classification map - a part of the municipality of Ørland

4.2.2 Natural Soil Drainage Capacity

The map Natural Soil Drainage Capacity classifies the soil polygons into four classes according to soil's ability to infiltrate excess water. Data from the soil classification and from the geometry and map unit are the input data for the map. Table 10 shows how the requirements specification of the map.

Table 10. Requirement specification of the map Natural Soil Drainage Capacity

Class in the map Natural Soil Drainage Capacity	From the geometry and map unit		From the soil classification WRBQ, factor 4	Description of the class
1	WRB1_J	Additional information (..TILL_J) **is not** v nor t	6	Well drained – no redoximorphic features nor reducing conditions in the depth 0-50 cm
	WRB2_J		6	
2	WRB1_J	Additional information (..TILL_J) **is** v or t	6	Well drained, but parts of the polygon have problems with excess water
	WRB2_J		6	
3a	WRB1_J	-	6	One soil type has poor ability to infiltrate excess water, the other is well drained (3a and 3b are shown as one class in the map)
	WRB2_J	-	1 or 2	
3b	WRB1_J	-	1 or 2	
	WRB2_J	-	6	
4	WRB1_J	-	1 or 2	Poor ability to infiltrate excess water
	WRB2_J	-	1 or 2	

The map Natural Soil Drainage Capacity is shown in figure 4.

Figure 4. The Natural Soil Drainage Capacity map - a part of the municipality of Hå

5 Dissemination - public outreach and data availability

5.1 Thematic maps

5.1.1 Access to thematic maps from the soil survey

The information produced is freely available via the map portals, Kilden (Kilden.nibio.no) and Gårdskart (Gardskart.nibio.no) and for downloading. Thematic maps are designed for differing user groups and needs, including farmers, advisors in both the private and official sectors, public administration on different levels and politicians. The aim is to enable informed decision making based on soil properties from the soil survey and the derived thematic maps.

NIBIO has extensive contact with the differing user groups and tries to keep updated with the user's needs and issues related to soil use in society. This makes it possible to ensure the data are presented and available in forms that are relevant and meet the needs of users today and in the future. The information needed by society at large changes over time. The data capture methods for soil survey are detailed enough to make the results relevant and useful for many of society's needs, making public outreach and dissemination a vital part of the process.

5.1.2 Application areas for thematic maps

The four main areas where soil data has an essential role are spatial planning, environmental management, climate change mitigation, and agronomy. Other areas where the data are used include many areas of research, agricultural management, and land-value assessments.

Spatial planning

The map titled Soil Quality belongs to the public map base in Norway (https://www.kartverket.no/en/geodataarbeid/dok-og-temadata/det-offentlige-kartgrunnlaget). Hence, if the Soil Quality Map is published for an area, it must be taken into account in matters of spatial planning concerning agricultural land. The map classifies the soil polygons in three classes depending on the soil properties and properties of the terrain, climate is not included in the model for this map. Also, the maps showing the potential for growing different crops, are used in assessments concerning the impact building upon agricultural land will have on food production and land use. These maps can also identify regions and areas that are especially important for agriculture.

The maps are used by local and regional planning offices and decisions on whether an area is to be taken out of agriculture for building purposes are made by politicians at the municipality level.

The Ministry of Agriculture and Food also request information based on soil survey data when creating new guidelines for land use in Norway.

Large administrative authorities and developers, such as the Norwegian Public Roads Administration, Nye Veier (Road Management), and Bane NOR (Railway Infrastructure Authority) also seek soil survey data in assessing potential infrastructure projects. In connection to these projects, NIBIO has been commissioned to survey affected areas as part of the evaluation process. Consultancy firms also use the survey data in environmental impact assessments for developers.

Environmental management

The maps titled Soil Erosion Risk and Natural Soil Drainage Capacity are used to allocate subsidies. The Soil Erosion Risk Map classifies the soil polygons in four classes depending on the risk of erosion from the area if ploughing is conducted during the autumn. The highest subsidies are paid out for the areas which are classified with the highest risk of erosion.

The map Natural Soil Drainage Capacity classifies the soil mapped areas in four classes depending on the soil's natural ability to infiltrate water. This map is used to allocate subsidies for drainage measures to be done on the areas having a soil with poor ability to infiltrate water. The distribution of soils with a poor ability to infiltrate water is unevenly between the regions in Norway.

Climate change mitigation

A tool has been made for the Norwegian farmer to calculate the emissions at farm level, The Klimakalkulator (https://klimasmartlandbruk.no/klimakalkulatoren/). The tool also calculates the possibilities both to reduce emissions and for carbon sequestration. In this tool, data from the soil survey is an input dataset.

For the climate change mitigation in agriculture, the map Organic Content is highly relevant. In this map, the soil polygons are classified according to the organic material in the soil. The risk of emissions being highest from organic soils and the potential for carbon sequestration being highest in soil polygons having a low to medium content of organic matter.

For agriculture to be well adapted to climate change, an agronomy which is based on the properties of the soil is essential – an agronomy in which the soil's functions are maintained in a sustainable way. A soil which has poor ability to infiltrate excessive amounts of water, will be able to produce more food of a good quality if drainage measures have been done. The risk of both soil compaction and soil erosion will be less in a soil with a good ability to infiltrate water. Hence, the map Natural Soil Drainage Capacity is also a tool for better climate change mitigation.

Agronomy

Crop production and soil management are depending on the natural conditions – both the properties of the soil, the terrain, and the climate. The best farming practice takes all these aspects into account and adapts the practice to the local conditions. The above-mentioned maps Natural Soil Drainage Capacity, Organic Content and Soil Erosion Risk and the maps showing the potential for growing different crops are all relevant. In addition, the map Dominating texture of the upper horizon is a good tool for agronomy purposes. The map Soil classification is useful for people with a having knowledge on the classification system. The maps showing the potential for differing crops (19 maps in total) are useful in measures to increase the production of horticultural products.

Other use

Soil data are also extensively used in research. Examples of research projects include those connected to soil compaction risk and the risk of leaching of agricultural chemicals. In 2021, the GreenRoad project was launched, which will use soil data in its research into 'bottle necks' that limit horticultural production in Norway, and how to solve this.

5.2 Soil statistics

The soil survey has produced two groups of statistics, based on differing spatial data. The first is based upon a nation-wide program of selected survey areas, which provides the knowledge base for national, regional and county-based statistics. These are often used in development assessments. At this scale, the statistics provide useful information on, for example, where in the country or region soils with high organic content are found, or where the soils are most in need of drainage. NIBIO Report 13/2018, Jordsmonnstatistikk Norge (Lågbu *et al,* 2018), summarizes the results of the sample survey at national and regional level.

The second set of statistics is based upon the regular soil survey, which is ongoing. Some areas of Norway have all their cultivated soil surveyed already, whereas other regions and counties are yet to be completed. Statistics are therefore available in municipalities that have more than 50 % of their cultivated land surveyed. Where available, these statics are also used in area-planning and development assessments and provides information on the municipality level to supplement the map-based data. Some of these statistics are also included in the web service Arealbarometer (https://arealbarometer.nibio.no/). The Arealbarometer is a fully digital presentation of the basis of production for agriculture and forestry in Norway at national, county and municipality level.

5.3 Other dissemination methods

NIBIO uses a wide variety of channels to reach differing user groups. In addition to the map portals mentioned previously, NIBIO's website contains easily accessible information and statistics. Information booklets and reports are published and freely available on subjects related to soil survey data, and how to use the data available. Each year, NIBIO organizes seminars and talks for municipalities that have recently been surveyed. Presentations are also given at regional and national conferences and meetings to reach new and established users.

NIBIO's outreach work is often connected to helping those who work in local administration and locally elected officials become familiar with the data produced.

Articles based on the soil survey are also published in mass media, both local, regional, and national, as a contribution in the public debate where relevant. In addition, quite a lot of effort is done in keeping the website updated, on various themes related to all the steps in the NoSIS. Academic research articles are also published to a smaller extent.

As a result, the data produced and shared is requested and used more and more, and new users are seeing the valuable contribution it can make to their needs in administration, research, and agriculture, to name a few.

6 Adjustments of the WRB (2014) in the NoSIS

6.1 Overall description of the adjustments in the NoSIS

The WRB (2014) is an expedient basis for classifying the soils in the Norwegian soil survey. It's a thorough system and it is extensively used among soil researchers in the world, as it is considered to be easier to become familiar with than other classification systems. The NoSIS is an ongoing soil survey program with the purpose to provide reliable information on the properties of the agricultural soil to the decision makers in Norway.

The NoSIS must produce good enough information on the mapped soils – within the budget and within the reasonable level of detail for the users of the results. This has implications on the data capture – regarding both identifying the soil properties and the scale in which the soil survey can be conducted in the field. Also, this has implications on the use of the classification system. The decisions in classifying the soil in the field must predominantly be depending on properties which can be determined in the field, by each soil surveyor on each mapped soil polygon. The NoSIS emphasizes standardization of the soil mapping. It's important that soil surveyors are naming identical soils in the same way – regardless of time and place. If all qualifiers listed in the WRB (2014) should be used in the soil survey, the knowledge requirements for being a soil surveyor would be impossible to fulfil within a reasonable time and budget.

The WRB is a living classification system, changes are made based on new and better knowledge on the soils of the world. For the NoSIS, all the changes in the WRB cannot be implemented. Implementing changes will demand to many resources and will not be cost effective. Hence, the NoSIS will be using the 2014 edition of the WRB many years to come.

Classifying soils in profiles, with all necessary physical and chemical analysis available, is a completely different use of a classification system. The adjustments of the WRB (2014) in the NoSIS make the system adapted for use in the ongoing soil survey in Norway. The disadvantage is that transferring information from the soil mapping in Norway to the original WRB (2014) for international purposes is complicated. As the purpose of the NoSIS is to provide reliable information on the properties of the agricultural soil to the decision makers in Norway, this has the upmost priority. The adjustments that have been made ensure that this information is gathered at a reasonable level of detail, within the provided budget.

Due to the above-mentioned, the WRB (2014) has been adjusted where necessary to make it applicable to the soil conditions and the ongoing soil survey in Norway. Main adjustments are listed below:

- 16 of the 32 WRB groups are found on agricultural land in Norway. The other groups are not used in NoSIS, including parts of the definitions separating them from the remaining groups
- Luvisols and Retisols that occur in Norway have similar soil properties, hence they are joined together as Luvisols
- Some adjustments have been done to make the classification system more applicable in differencing important soil properties in Norway
- Qualifiers that are not relevant for Norwegian agricultural soils are not used
- Some qualifiers are implied in the name and therefore not shown as part of the name (e.g. loamic)
- Definitions (WRB groups, qualifiers and diagnostic properties and diagnostic material) are adjusted for practical reasons to make it possible to identify WRB units in the field using soil augers, without physical nor chemical analysis
- The use of qualifiers and the rules for creating WRB units deviate from the WRB (2014)

- Three new qualifiers are added to cover soil conditions/properties that are important for agricultural soils in Norway
- WRB groups are named as soil groups, WRB units are named as soil types in the following

6.1.1 Soil classification key

A digital classification key is used in the field. Soil mappers identify soil type by choosing between several alternatives in a 9-step system where each step represent different soil properties. This digital key contains more than 4000 possible soil types.

A more conventional key to our soil mapping units follows. This is followed by adjusted definitions of diagnostic properties, diagnostic material, qualifiers and soil groups.

The soil mapping units consist of a soil group name, one or more prefix-qualifiers and suffix-qualifiers if present. The full name of the soil type starts with prefixes in an opposite prioritized order, followed by a soil group name and ending with suffixes in parentheses separated by commas. The soil mapping unit code starts with two capital letters identifying the soil group, followed by qualifier codes separated by hyphens. Example:

Full name: Dystric Endoleptic Regosol (Humic, Arenic), Soil mapping unit code: RGlen-dy-hu-ar

6.2 Definitions of soil groups, listing of prefix and suffix qualifiers in the NoSIS

Table 11 contains definitions of soil group (in classification key order), and the prefix- and suffix qualifiers that are allowed in each soil group. Note the following:

- Prefixes and suffixes separated by / means only one may be used
- Prefixes in bold are mandatory
- Prefixes and suffixes in *italics*, the use of them deviates from the WRB (2014)

Table 11. Definitions of soil groups, listing of allowed prefix qualifiers and suffix qualifiers in the NoSIS – in classification key order

Soil group	Definition	Prefix	Suffix
HISTOSOL	Soils with organic soil material that: • Starts at the soil surface and is at least 10 cm thick over bedrock; or • Starts within 40 cm of the soil surface and have within 100 cm depth a combined thickness of 60 cm if Fibric, or a combined thickness of 40 cm if Hemic or Sapric	**Fibric/Hemic/Sapric** Endoleptic *Umbric* *Calcaric/*Dystric Endoskeletic	Limnic *Ruptic* Novic *Profilic/*Relocatic/ Transportic *Ochric*
ANTHROSOL	Other soils having a *Hortic* horizon with a thickness of at least 50 cm	***Hortic*** *Endoleptic* *Endoskeletic*	*Abruptic/Ruptic* Arenic/Siltic
TECHNOSOL	Other soils consisting of: • *Landfill materials* with a thickness of at least 50 cm thickness consisting of mineral materials, free of SOM, from road construction, mining, or other similar activities*;* or • *Landfill materials* with a thickness of at least 50 cm having a layer of at least 20 cm thickness consisting of at least 20 % garbage or other refuse	**Spolic/Urbic** Hyperskeletic *Histic* *Gleyic/Stagnic* *Umbric/Mollic/Chernic* *Skeletic/Endoskeletic*	Arenic/Siltic/Clayic
LEPTOSOL	Other soils having: • Bedrock within 25 cm depth from soil surface; or • Less than 20 % by volume fine soil material from the plough layer down to 75 cm depth from the soil surface and no Spodic horizon	Hyperskeletic Histic *Gleyic* Rendzic/Mollic/Umbric/ Dystric	
GLEYSOL	Other soils having a 25 cm thick layer starting below the plough layer with: • Gleyic properties; or • Reducing colors; and no abrupt textural change	Histic Chernic/Mollic/Umbric *Epileptic/Endoleptic* Fluvic *Skeletic/Endoskeletic* Calcaric/Eutric/Dystric	*Thaptohistic* Humic Limnic *Ruptic* Arenic/Epiarenic/Siltic/ Clayic *Planeric/Profilic/* Relocatic/*Transportic*
PODZOL	Other soils having a Spodic horizon	Ortsteinic Hyperskeletic Epileptic/Endoleptic Histic Epigleyic/Gleyic/Stagnic Umbric Skeletic/Episkeletic/ Endoskeletic *Fluvic* *Haplic*	Thaptohistic *Humic* Abruptic/Ruptic Arenic/Epiarenic/Siltic Transportic

PLANOSOL	Other soils having: • Abrupt textural change within about 50 cm depth from soil surface; and • Gleyic or Stagnic properties in the layer between the plough layer and the abrupt textural change	Histic Chernic/Mollic/Umbric Fluvic *Episkeletic* Calcaric/Eutric/Dystric	Humic Epiarenic/Siltic Transportic
STAGNOSOL	Other soils having a 50 cm thick layer, starting under the plough layer, where Stagnic properties cover at least 50 % of the volume	Epileptic/Endoleptic Histic *Chernic*/Mollic/Umbric Fluvic Retic/Luvic Skeletic/Episkeletic/ Endoskeletic Calcaric/Eutric/Dystric	*Thaptohistic* Humic *Alunic* Ruptic Arenic/Epiarenic/ Siltic/Clayic *Planeric/Profilic/* Transportic
PHAEOZEM	Other soils having a Mollic or Chernic horizon and a base saturation of at least 50 % from the soil surface to 100 cm depth or to bedrock	Rendzic Chernic Epileptic/Endoleptic Luvic Cambic Skeletic/Episkeletic/ Endoskeletic Calcaric Haplic	*Thaptohistic* Pachic/*Humic* *Alunic* Abruptic/Ruptic Arenic/Epiarenic/Siltic *Planeric*/Transportic
UMBRISOL	Other soils having an Umbric or Histic horizon	Epileptic/Endoleptic Histic Epigleyic Fluvic Cambic Skeletic/Episkeletic/ Endoskeletic Haplic	*Thaptohistic* Pachic/*Humic* Arenic/Epiarenic/Siltic *Planeric/Profilic/* Relocatic/Transportic
LUVISOL	Other soils having an Argic horizon within 100 cm depth from the soil surface	Endoleptic *Cambic* Endoskeletic Haplic	Ruptic Siltic/Clayic
CAMBISOL	other soils having a *Cambic horizon* starting within 50 cm depth from the soil surface	Endoleptic Fluvic Endoskeletic Calcaric/Eutric/Dystric	Abruptic/Ruptic Siltic
ARENOSOL	Other soils having: • *Arenic* texture between the plough layer and 100 cm depth from the soil surface, allowing lamellas of other textures that are less than 15 cm thick, cumulative; and • Less than 40 % coarse fragments in the same volume	Fluvic Calcaric/Dystric	Humic *Planeric/Profilic/* Relocatic/ Transportic
FLUVISOL	Other soils developed in alluvial materials	*Epigleyic* Endoskeletic *Haplic*	*Thaptohistic*/Humic *Abruptic*/Limnic/*Ruptic* Arenic/Epiarenic/Siltic Transportic
REGOSOL	Other soils	Epileptic/Endoleptic Skeletic/Episkeletic/ Endoskeletic Calcaric/Eutric/Dystric	*Thaptohistic*/Humic *Abruptic/Limnic*/Ruptic Arenic/Epiarenic/Siltic/ Clayic *Planeric/Profilic/* Relocatic/Transportic

Example on use of the key:

The observed soil: Transported topsoil material on top of massive glacio-lacustrine silt with the following characteristics:

Ap 0-20 cm, light-coloured plough layer, about 4 % SOM, sandy loam texture, about 25 % gravels

A 20-60 cm, about 4 % organic material, sandy loam texture, about 45 % gravels and some rocks

2C 60-100 cm, massive with silt texture

- Step 1 (surface horizon): light-coloured surface horizon (no Hortic, Histic, Chernic, Mollic nor Umbric) → **Ochric**
- Step 2 (ability to infiltrate excess water): no redox patterns within 50 cm depth (no Gleyic nor Stagnic) → **well drained**
- Step 3 (diagnostic features): no diagnostic horizons nor other features present between the plough layer and 50 cm depth (no Spodic, Argic, Cambic, Fluvic nor landfill materials) → **none**
- Step 4 (depth to bedrock): no bedrock within 100 cm depth → **deep**
- Step 5 (base saturation and carbonates): no carbonates present and no evidence of high base saturation (no Calcaric nor Eutric) → **Dystric**
- Step 6 (coarse fragments): more than 40 % coarse fragments between the plough layer and 60 cm depth, no coarse fragments from 60 cm to 100 cm depth (no hyperskeletic, Skeletic nor Endoskeletic) → **Episkeletic**
- Step 7 (texture below plough layer): → **Loamic**
- Step 8 (properties inherited from the parent material): an A-horizon below the plough layer, and a layered soil with gravelly sandy loam over silt. Since the bottom layer has a low clay content, we choose Ruptic instead of Abruptic → **Humic and Ruptic**
- Step 9 (human disturbances): the top 60 cm of the soil is transported →**Transportic**

The resulting soil type is: **RGskp-dy-hu-tn**

6.3 Diagnostic features - adjusted definitions in the NoSIS

In table 12, 13 and 14 the definitions used in the NoSIS are listed, definitions marked with [1)] are adjusted in the NoSIS and differ from WRB (2014)

6.3.1 Diagnostic horizons

Table 12. Definitions of diagnostic horizons in the NoSIS

Horizon	Definition	Note
Argic[1)]	A clay illuviation horizon that is identified in the following way: • Higher clay content than the horizon above it • Clay coatings in pores and on aggregate surfaces	It is difficult identifying an Argic horizon by using a soil auger. In NoSIS, identifying Argic horizons, relies on profile descriptions in areas where Argic horizons are likely to occur
Cambic	A subsurface horizon with pedological change (structure and change in color) which: • Does not have Arenic texture • Less than 50 % coarse fragments • Soil structure and different color than the horizon below • A thickness of at least 15 cm • Does not meet the criteria of other diagnostic horizons	In NoSIS, the definition is similar to the WRB (2014)
Chernic[1)]	A dark surface horizon with high base saturation: • Dark color (value and chroma less than 3.5 moist) • High base saturation (Chernic when the parent material is rich in bases) • Minimum 6 % soil organic material • Thickness as a normal plough layer	In NoSIS, Chernic is used as a version of Mollic horizon, having minimum 6 % soil organic material
Histic	Surface or subsurface horizon consisting of organic soil material: • Thickness of at least 10 cm • Water saturated at least 30 consecutive days unless drained	
Hortic[1)]	Manmade surface horizon developed through years of adding organic manure and waste: • Thickness of at least 50 cm Anthrosols	In NoSIS, Plaggic horizon is included in the definition of Hortic horizon The presence of the Hortic horizon is used as the only diagnostic criterion for identifying Anthrosols Where the Anthrosols are likely to occur in the soil scape is described in the field handbook)
Mollic	A dark surface horizon with high base saturation. • Dark color (value and chroma less than 3.5 moist) • High base saturation (Mollic is used if the parent material is rich in bases) • Less than 6 % soil organic material • Thickness as a normal plough layer	

Spodic[1)]	• Acid parent material • Color 5YR or redder, or 7.5YR with value 5 or less and chroma 4 or less • May be cemented (Ortstein) • Thickness of at least 2,5 cm	The WRB (2014) includes morphological and chemical criteria, identification of a Spodic horizon in NoSIS relies on the color criteria
Umbric[1)]	Dark colored surface horizon with low base saturation. • Acid parent material • At least 6 % soil organic material • Dark color (value and chroma less than 3.5 moist) • Thickness as a normal plough layer	In NoSIS, the definition deviates in the soil organic material criterion

6.3.2 Diagnostic properties

Table 13. Definitions of diagnostic properties in the NoSIS

Diagnostic properties	Definition	Note
Abrupt textural differences[1)]	• Upper layer has less than 12 % clay (20 % clay in the official definition) • Lower layer has at least a doubling in clay content • The boundary between the layers is less than 5 cm thick	In NoSIS, some small adjustments from the WRB (2014) have been made
Gleyic properties	As WRB (2014)	
Lithological discontinuity[1)]	Layered parent material with: • Difference in texture (apart from abrupt textural difference) • Difference in coarse fragment content (Skeletic/not Skeletic) • Mineral soil with organic soil layers	In NoSIS, the definition is simpler than in WRB (2014)
Retic properties[1)]	Argic horizon with horizontal or vertical tongues of albic material	In NoSIS, definition is adjusted for practical reasons, only observations from auger borings
Stagnic properties[1)]	• Reduced colors lining cracks and pores • Oxidized colors inside aggregates	In NoSIS, parts of the WRB (2014) are used

6.3.3 Diagnostic materials

Table 14. Definitions of diagnostic materials in the NoSIS

Diagnostic materials	Definition
Artifacts[1)]	Human-made materials. According to the WRB (2014), it also applies to mineral materials, not affected by pedological processes, which is transported from another location or brought to the surface by removal of soil materials. In NoSIS, the definition is as the official version, but the following materials are exceptions: • Soil that are leveled by bulldozer (see Planeric) • Soils with mechanically formed surface for drainage purposes (see Profilic)
Calcaric materials	Soil material containing carbonates in the fine earth fraction, inherited from the parent material. Effervescence when applying 1M HCl.
Fluvic materials[1)]	In NoSIS, the definition is adjusted from WRB (2014): • Alluvial parent material (with or without stratification)
Limnic materials	Lacustrine parent material containing sedimentary organic material (gyttja) or carbonates (marl)
Mineral soil materials	Containing less than 20 % soil organic carbon
Organic soil materials (OSM)	Containing at least 20 % soil organic carbon
Soil organic carbon (SOC)	Carbon that is not considered an artifact (coal, ash etc)

6.4 Qualifiers used in the NoSIS

Table 15. Qualifiers which are used in the NoSIS

Qualifier	Code	Adjusted definition
Abruptic	ap	having Abrupt textural difference at about 50 cm depth from soil surface
Alunic	al	INTRODUCED BY NIBIO: having mineral soil material below the plough layer that consists of at least 50 % "alun"-shale fragments (black shale)
Arenic	ar	sand or loamy sand texture from the plough layer down to 100 cm depth or bedrock
Calcaric	ca	having Calcaric material between the plough layer and 50 cm depth from the soil surface
Cambic	cm	having a Cambic horizon starting below the plough layer
Chernic	ch	having a Chernic horizon at the soil surface
Clayic	cl	having a 30 cm thick layer, starting under the plough layer, with texture "heavy clay" (> 40 % clay and < 50 % silt)
Dystric	dy	dominating low base saturation below plough layer, estimated from parent material (acid minerals, sandy textures etc)
Endoleptic	len	having hard bedrock between 50 and 100 cm depth from the soil surface
Endoskeleic	skn	having at least 40 % coarse fragments from about 50 cm to 100 cm depth from the soil surface
Epiarenic	arp	sand or loamy sand texture from the plough layer down to a Lithic discontinuity
Epigleyic	glp	having Gleyic properties in a plough pan
Epileptic	lep	having hard bedrock between 25 and 50 cm depth from the soil surface
Episkeletic	skp	having at least 40 % coarse fragments from the plow layer to 50 cm depth from the soil surface, and few coarse fragments below
Eutric	eu	dominating high base saturation below plough layer, estimated from parent material (basic minerals, clayey textures etc)
Fibric	fi	Histosol dominated by little decomposed OSM (von Post H1-H4)
Fluvic	fl	having Fluvic material starting below the plough layer
Gleyic	gl	having Gleyic properties starting within 50 cm depth from soil surface
Haplic	ha	no other prefixes aplies
Hemic	hm	Histosol dominated by medium decomposed OSM (von Post H5-H6)
Histic	hi	having a Histic horizon starting at soil surface
Hortic	ht	having a Hortic horizon with thickness of at least 50 cm (in Anthrosols)
Humic	hu	having an A-horizon that is thicker than the plough layer and at the same time does not meet the criteria of Pachic, or have remnants of an A-horizon below the plough layer (in disturbed soils)
Hyperskeletic	hk	having less than 20 % (by volume) fine soil materials between the plough layer and 75 cm depth from the soil surface
Limnic	lm	having Limnic material starting within 50 cm depth from the soil surface in mineral soils and within 100 cm depth from the soil surface in Histosols
Luvic	lv	having an Argic horizon below the plough layer or below a Cambic horizon or an E-horizon
Mollic	mo	having Mollic horizon at the soil surface
Novic	nv	having a layer of fresh sediments at the soil surface (used in Histosols)
Ochric	oh	having a light-coloured surface horizon with less than 6 % SOM (used in Histosols together with Relocatic and Profilic)
Ortsteinic	os	having an indurated Spodic horizon starting within 50 cm depth from the soil surface

Pachic	ph	having a Chernic, Mollic or Umbric horizon with a thickness of 50 cm or more
Planeric	pp	INTRODUCED BY NIBIO: the soil is disturbed by land levelling
Profilic	zp	INTRODUCED BY NIBIO: the soil surface is mechanically formed to create water runoff
Relocatic	rc	soils that are mixed to at least 50 cm depth from the soil surface by mechanical digging (excavator)
Rendzic	rz	having a Mollic or Chernic horizon and at least 40 % CaCO3 equivalents in the horizon below
Retic	rt	having Retic properties directly below the plough layer or below an E-horizon
Ruptic	rp	having Lithological discontinuity
Sapric	sa	Histosol dominated by highly decomposed OSM (von Post H7-H10)
Siltic	sl	having a layer, at least 30 cm thick, starting directly below the plough layer, containing more than 50 % silt
Skeletic	sk	having at least 40 % coarse fragments from the plough layer to 100 cm depth from the soil surface
Spolic	sp	having landfill materials (Artifacts) consisting of mineral materials with no pedological development,t from the plough layer down to at least 50 cm depth from the soil surface
Stagnic	st	having Stagnic properties starting below the plough layer or below a thin Spodic horizon
Thaptohistic	hib	having a buried Histic horizon
Transportic	tn	having an A-horizon consisting of soil materials that are transported from another location
Umbric	um	having an Umbric horizon at the soil surface
Urbic	ub	having landfill materials (Artifacts) mixed with garbage and other refuse, from the plough layer down to at least 50 cm depth from the soil surface

6.5 Soil groups in the NoSIS

Table 16. Soil groups in the NoSIS

Soil group	Definition in the NoSIS
ANTHROSOL	Mineral soils having a *Hortic horizon* with a thickness of at least 50 cm
ARENOSOL	Mineral soils having: • Arenic texture from the plough layer to 100 cm depth from the soil surface, allowing layers of other texture with a combined thickness of less than 15 cm; and • Less than 40 % coarse fragments; and • No *Histic, Chernic, Mollic, Umbric or Hortic* surface horizons, and • No *Spodic horizon*; and • No *Gleyic or Stagnic properties* in the upper 50 cm of the soil
CAMBISOL	Mineral soils having: • A *Cambic horizon* starting directly below the plough layer; and • Less than 40 % coarse fragments in the upper 50 cm of the soil; and • No *Histic, Chernic, Mollic, Umbric or Hortic* surface horizons, and • No *Argic horizon* directly below the *Cambic horizon*; and • No *Gleyic or Stagnic properties* in the upper 50 cm of the soil
FLUVISOL	Mineral soils having: • *Fluvic material* (alluvium) in at least the upper 50 cm of the soil; and • Less than 40 % coarse fragments in the upper 50 cm of the soil; and • No *Histic, Chernic, Mollic, Umbric or Hortic* surface horizons, and • No *Spodic, Argic or Cambic horizon*: and • No *Gleyic or Stagnic properties* in the upper 50 cm of the soil, apart from the plough pan
GLEYSOL	Mineral soils having: • *Gleyic properties* in all horizons between the plough layer and 50 cm depth from the soil surface; and • No *Spodic horizon*; and • No *Abrupt textural difference*; and • No landfill materials in the upper 50 cm of the soil
HISTOSOL	Organic soils having: • Organic soil layer with thickness of at least 10 cm that rests directly on bedrock; or • Organic soil layer with thickness of at least 40 cm if Hemic or Sapric; or • Organic soil layer with thickness of at least 60 cm if Fibric; and • No mineral soil layer at the soil surface with thickness of 40 cm or more

LEPTOSOL	Mineral soils having: • Bedrock within 25 cm depth from the soil surface; or • Less than 20 % by volume fine soil materials (< 2mm diam.) between the plough layer and 75 cm depth from the soil surface; and • No *Spodic horizon*
LUVISOL	Mineral soils having: • An *Argic horizon*; and • No *Histic, Chernic, Mollic, Umbric or Hortic* surface horizons, and • No *Gleyic or Stagnic properties* in the upper 50 cm of the soil
PHAEOZEM	Mineral soils having: • A *Mollic or Chernic horizon* at the soil surface; and • High base saturation down to at least 100 cm depth from the soil surface or down to bedrock (estimated from the parent material); and • No *Gleyic or Stagnic properties* in the upper 50 cm of the soil; and • No landfill materials in the upper 50 cm of the soil
PLANOSOL	Mineral soils having: • *Abrupt textural difference*; and • *Gleyic or Stagnic properties* between the plough layer and 50 cm depth from the soil surface
PODZOL	Mineral soils having: • A *Spodic horizon*
REGOSOL	Mineral soils having: • No *Histic, Chernic, Mollic, Umbric or Hortic* surface horizons, and • No *Spodic, Cambic or Argic horizons*; and • No *Gleyic or Stagnic properties* within the upper 50 cm of the soil; and • No *Fluvic materials* or landfill materials; and • Texture that does not meet the criteria of an Arenosol
STAGNOSOL	Mineral soils having: • At least 50 % *Stagnic properties* in the horizons between the plough layer and 50 cm depth from the soil surface; and • No *Argic or Spodic horizon*; and • No *Abruptic textural difference*; and • No landfill materials in the upper 50 cm of the soil
TECHNOSOL	Mineral soils having: • Landfill material at least in the upper 50 cm of the soil • No *Spodic, Cambic or Argic horizon* within 50 cm depth from the soil surface

UMBRISOL	Mineral soils having: • An *Umbric* or *Histic* surface horizon; and • Low base saturation from the plough layer down to 100 cm depth from the soil surface or to bedrock (estimated from the parent materials); and • No *Spodic horizon*; and • No *Gleyic or Stagnic properties* within 50 cm depth from the soil surface; and • No landfill materials in the upper 50 cm of the soil

7 Recommendations on establishing a soil information system

Working in the Norwegian Soil Information System for decades, some experiences have been encountered. In this chapter some of these experiences are listed and they might be useful for organizing other soil information system.

Overall strategy for the information system

The most important is to have a thorough strategy for the information system and the purpose of the system. This strategy must also define the steps in the information system, together with roles and responsibilities in each step.

Data capture

- The level of detail in the data capture must be in accordance with the available budget, regarding both the scale of mapping and in which detail the soil properties are to be registered
- Make sure that the methodology is adapted to the soils which shall be mapped, for the data capture to give the best possible information on the soils
- Establish a soil survey methodology which ensures reliable and well-documented information on the properties and the distribution of the soils
- The majority of the soil properties to be identified in the soil survey must be able to determine in situ, without location specific analysis on physical and chemical properties
- Comprehensive training of new soil surveyors and supervision of soil surveyors in the survey must be emphasized to ensure standardization and good quality of the data
- Roles and responsibilities among the soil surveyors in the mapping areas must be defined

Data management

- A plan for a long-term functioning data management must be set
- The structure of the data base must be in such a way that the data are easy to access, available in a structured, logical format, and complete
- The data management must ensure that the data remains valid, usable, and accessible in the long term. It is essential that the data are usable for purposes which were perhaps not foreseen when the data were first collected.
- Confidentiality, integrity and availability must be given sufficient consideration
- The plan for data management must include strategies and safeguards for maintenance and adapting to technological advances
- Roles must be defined, such as the system owner, system manager, data supplier, and data owner. Moreover, user rights must be defined, making it clear who can make use of the data and for what purpose
- There must be a good dialogue between the soil science personnel in the information system and the geomatics personnel for the data management to be accurate and precise in both aspects – the soil science and the geomatic science

Data processing

- Make sure that the products from the soil information system are based on reliable models
- Do not use the data on a more detailed scale than the scale of the survey
- Well documented models and input data for the products are essential

Dissemination

- Make sure that the users are aware that all soil surveys and all maps are simplifications of the reality
- Pay attention to the users' needs for soil information, but keep in mind that the soil surveyors are the ones having the best knowledge on how to use the results from the survey
- Ensure a good dialogue with different user groups

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Afterword

The purpose of this report is to give an overview of the steps in The Norwegian Soil Information System and to describe the adjustments that have been made for the World Reference Base for Soil Resources (2014) applicable for the information system. The report is written with the intention to make it thorough enough for Latvian partners in E2SOILAGRI finding it useful.

There are many tasks and details in the Norwegian Soil Information System, not all of them can be included nor described in such a report.

Key words:	Norwegian Soil Information System, soil survey, data capture, data management, data processing, dissemination
Other publications from the project:	Enhancement of sustainable land soil resource management in agriculture - E2SOILAGRI. NIBIO Inception report (https://hdl.handle.net/11250/2978145)

Norsk institutt for bioøkonomi (NIBIO) ble opprettet 1. juli 2015 som en fusjon av Bioforsk, Norsk institutt for landbruksøkonomisk forskning (NILF) og Norsk institutt for skog og landskap.

Bioøkonomi baserer seg på utnyttelse og forvaltning av biologiske ressurser fra jord og hav, fremfor en fossil økonomi som er basert på kull, olje og gass. NIBIO skal være nasjonalt ledende for utvikling av kunnskap om bioøkonomi.

Gjennom forskning og kunnskapsproduksjon skal instituttet bidra til matsikkerhet, bærekraftig ressursforvaltning, innovasjon og verdiskaping innenfor verdikjedene for mat, skog og andre biobaserte næringer. Instituttet skal levere forskning, forvaltningsstøtte og kunnskap til anvendelse i nasjonal beredskap, forvaltning, næringsliv og samfunnet for øvrig.

NIBIO er eid av Landbruks- og matdepartementet som et forvaltningsorgan med særskilte fullmakter og eget styre. Hovedkontoret er på Ås. Instituttet har flere regionale enheter og et avdelingskontor i Oslo.

Cover photo front: Siri Svendgård-Stokke: Soil survey in the municipality of Halden
Cover photo back: Siri Svendgård-Stokke: Soil types with different properties

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