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A Tier 1 methodology for estimating changes in soil organic carbon after land use change on mineral soil

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SAMMENDRAG/SUMMARY:

Norsk

Denne publikasjonen presenterer en ny metodikk for estimering av endringer i lageret av jordkarbon som følge av arealbruksendringer på mineraljord. Metodikken er utviklet for bruk i den nasjonale rapporteringen av arealbrukssektoren under FNs klimakonvensjon. Metodikken baserer seg på den enkleste tilnærming i følge IPCC sine retningslinjer, en såkaldt Tier 1. Tier 1 metodikken baseres i stor grad på standardverdier fra retningslinjene (IPCC default), men trenger en kopling mot nasjonal arealinformasjon. Denne koplingen beskrives i rapporten. Metodikken tar utgangspunkt i standardverdier for lageret av jordkarbon (SOC_{REF}). Disse er basert på jordtype-grupperinger og klimasone som stammer fra en verdensdekkende jorddatabase. Endringer i jordkarbon etter arealbruksendring estimeres ved hjelp av SOC_{REF} i kombinasjon med et sett faktorer (også standardverdier) som er arealbruksavhengige. Metodikken legger til grunn at endringer i jordkarbon skjer lineært over 20 år (ifølge 2006 IPCC Guidelines). Grunnleggende informasjon for å kunne kople standardverdier mot arealer på en konsistent måte er stort sett manglende for Norge på nasjonal skala. Rapporten gir derfor detaljert informasjon om de datakildene som har vært brukt til å kunne definere hvilke standariserte verdier som tilhører et bestemt areal i overgang. De begrensninger, forutsetninger og forbehold som ligger bak de datakildene som har vært brukt er beskrevet i deltalj. Det beskrives også hvordan disse verdiene brukes videre til å beregne endring i jordkarbonlageret som konsekvens av arealbruksendring i følge IPCC. Resultatene er stratifiseret på

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klimasone og jordtype. Areal fra Landskogstakseringen blir brukt til rapportering av arealbruksendringer. Denne ny metodikken innebærer at definisjonen av SOC lageret endres relativt til tidligere metode. For å sikre at lagrene i jord, litter og dødved er konsistente og det ikke skjer overlapp samt for at metodikken for litter og død ved (DOM, dead organic matter) tilpasses klimasoner på liknende måte som SOC, inneholder denne rapport også informasjon om kopling mot standardverdier for DOM pools. Dette blir således en revidert metodikk også for disse lagre når det gelder arealendringer på mineraljord.

English

This publication presents a new methodology for reporting changes in soil organic carbon (SOC) as a consequence of land-use change (LUC) on mineral soil for use in the national greenhouse gas-inventory under UNFCCC. The methodology developed is based on a Tier 1 approach provided by the IPCC. It is based on the use of default reference SOC stock values (SOC_{REF}) provided for a combination of soil groups and climate zones. These default values have been generated by the IPCC based on a world soil database and are used in combination with a set of land-use dependent factors (management factors or stock change factors). By combining SOC_{REF} and management factors, the changes (resulting in a sink or source) in SOC after LUC are determined on the basis of the default conversion time established by the IPCC, which is 20 years and the assumption of changes occurring in a linear fashion (2006 IPCC Guidelines). Modern soil type maps of Norway with national coverage do not exist. Therefore, this report provides detailed descriptions of the alternative sources of information that have been used to define the default SOC_{REF} values that should be attributed to an area undergoing LUC. The limitations, assumptions, and constrains that the use of these data sources imply is described in this publication. The description on how the actual computation of the SOC change is done according to the IPCC guidelines is presented and the areal information used for studying LUC originates from the Norwegian National Forest Inventory. The result of these calculations is a change in SOC after LUC that is stratified by climate zone and soil group. To ensure consistent estimates (no double counting or overlaps), the method for litter and deadwood (DOM, dead organic material) was also updated to i) use IPCC default values and ii) stratification to climate zones, consistent with the IPCC default methodology. This report thus also documents the method used for estimating DOM changes after land use change on mineral soil.

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Contents

1 Background for methodology improvement 6
1.1 Previous method 6
1.1.1 Required changes 6
2 The Tier 1 methodology 8
2.1 Basic calculations following the 2006 IPCC Guidelines 8
2.2 SOC reference stocks 8
2.3 Stock change factors (SCFs) 9
2.4 Areas of LUC and transition time 10
3 Sources of information and their application 11
3.1 Stratification according to climate 11
3.2 Stratification according to IPCC-soil groups 13
3.2.1 Soil information on readily available maps 14
3.3 Designation of a SOC reference stock to the mapping units 19
3.3.1 Special considerations regarding organic soils 21
3.3.2 Special considerations regarding areas with sparse vegetation/bare rock (no soil) 22
3.3.3 Other specifications 22
3.5 Library of Stock Change Factors (SCFs) 22
3.6 Representativity of soil information for LUC areas 23
4 Resulting default SOC_{REF} map 25
5 Dead Organic Matter (DOM) 27
6 Conclusion 31
7 References 32
8 Appendix 1 Land-use definitions 34
9 Appendix 2 Supplementary material 35

List of abbreviations

DOM: Dead Organic Matter

FAO: Food and Agriculture Organization of the United Nations

IPCC: Intergovernmental Panel on Climate Change

JM-map: Map from the Norwegian Soil Mapping on agricultural land, “Jordsmonnkartlegging” in Norwegian

1991-map: Soil Map of Denmark, Finland, Norway and Sweden, Scale 1:2 000 000, from Rasmussen et al., 1991

LU: Land Use

LUC: Land-Use Change

NFI: National Forest Inventory

NIR: National Inventory Report

SOC: Soil Organic Carbon

SOC_{REF}: SOC Reference Stock

SCF: Stock Change Factor

UNFCCC: United Nations Framework Convention on Climate Change

WRB: World Reference Base for Soil Resources (in this report refers to the soil classification system provided by this entity)

1 Background for methodology improvement

Following an In-Country Review that took place in 2018, recommendations were given by the Expert Review Team to improve the current methodology used to estimate soil organic carbon (SOC) changes following land-use change (LUC) on mineral soil in the Norwegian National Inventory Report (NIR). Specific recommendations were to develop a methodology that i) avoids biases and ii) uses standard IPCC stratification. In the current project, the Tier 1 methodology described in the guidelines (IPCC 2006) for each category of land conversion to estimate changes on SOC in mineral soils has been examined and the necessary sources of information that allow its use have been identified.

1.1 Previous method

In the previous methodology, Norway reported SOC changes in the mineral soil due to LUC based on a set of national averages. For the land use (LU) categories Forest Land and Cropland based on soil profiles, for Grassland based on soil type combined with IPCC reference stocks, while for the remaining LU categories the following applied: an assumption was made for Settlements (following the 2006 IPCC Guidelines), Wetland uses a wetland-specific SOC reference stock provided by the guidelines and Other Land assumes no stock. The review of this methodology criticized mainly two points: 1) The assumption behind the current method for Forest Land, Cropland, and Grassland is that land-use conversions occur for each LU in equal proportion to the distribution of the SOC content within the LU. It is not possible to provide evidence that this assumption is true, and that the estimated change is therefore not biased. 2) The current calculation of SOC change is not stratified, therefore not complying with the IPCC good practice.

1.1.1 Required changes

In order to apply the 2006 IPCC Guidelines to calculate SOC changes in mineral soils subjected to LUC, it is necessary to calculate the SOC stocks at equilibrium for the current and previous LU category. For this purpose, the Tier 1 methodology applies a set of default SOC reference (SOC_{REF}) stocks according to a stratification based on climate and soil type. The methodology follows the procedure described by the 2006 IPCC Guidelines, however, we utilize the updated table 2.3., 2019 Refinement to the 2006 IPCC Guidelines, also shown in Fig.2 in this report and also updated values for some Stock Change Factors (SCFs, described in section 3.5). The updated SOC_{REF} values from the 2019 Refinement have been adopted after an evaluation, which concluded that: 1) the updated SOC_{REF} values from the updated table 2.3 arise from a larger database (1.6 times larger than the previous) and have a better geographic coverage; 2) it provides better estimates of uncertainty as compared to the previous 2006 IPCC Guidelines table in which default relative errors haven been shown to be too conservative (Batjes, 2011); 3) the updated table provides SOC_{REF} values for IPCC climate zone "Polar", which occurs in Norway, and which does not have values in the original table 2.3 (IPCC 2006). Updated values from the 2019 Refinement are also used for the DOM pool (see details in section 5).

After identifying the relevant SOC_{REF} for a given land area, the SOC_{REF} value needs to be adjusted by the relevant stock change factors (SCFs) that are presented in the corresponding tables (section 3.5) on each LU category to obtain the SOC stock at equilibrium. The most important change (from the previous method to that described in this report) is the stratification needed to follow the 2006 IPCC Guidelines by using their definitions of climate and grouping of soil type. It implies modifying the SOC_{REF} values from one value with national representation for a specific LU to a value that will be a function of pedoclimatic conditions. Norway does not have the necessary empirical data to ensure or document that the previous method is unbiased (section 1.1), therefore, we describe the Norwegian application of a Tier1 method that strictly follows the steps proposed by the 2006 IPCC Guidelines in this report.

The Norwegian National Forest Inventory (NFI) is used in the national GHG inventory under the UNFCCC to detect land-use conversions. Any new methodology must be combined with the NFI in a transparent way. A detailed account of the use of NFI in the Norwegian GHG inventory for the LULUCF sector is found in the National Inventory Report (NIR 2020) and in Breidenbach et al. 2020.

2 The Tier 1 methodology

2.1 Basic calculations following the 2006 IPCC Guidelines

The estimation of annual changes of soil organic carbon (SOC) stocks in mineral soils with a Tier 1 methodology is based on the following equation (Figure 1):

EQUATION 2.25

ANNUAL CHANGE IN ORGANIC CARBON STOCKS IN MINERAL SOILS

$$\Delta C_{Mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$

$$SOC = \sum_{c,s,i} \left(SOC_{REF_{c,s,i}} \bullet F_{LU_{c,s,i}} \bullet F_{MG_{c,s,i}} \bullet F_{I_{c,s,i}} \bullet A_{c,s,i}\right)$$

(Note: T is used in place of D in this equation if T is $\geq$ 20 years, see note below)

Figure 1. Equation for annual SOC stock change calculation in mineral soils, 2006 IPCC Guidelines, Vol.4, Ch. 2.

Here, changes in SOC are estimated for a finite period of time. Soil organic carbon is calculated for a specific condition in which it is considered to be at equilibrium (see assumptions below). This SOC at equilibrium is based on: a SOC reference stock (SOC_{REF}), a set of Stock Change Factors (SCFs) which account for land use, management and inputs of organic matter (F_{LU}, F_{MG}, F_I, respectively) and the area (A) in which all these parameters apply. Subscripts "*c*", "*s*" and "*i*" represent the climate zones, soil types, and set of management systems that are present in a country (respectively). Annual rates of SOC change are then estimated based on the difference in SOC stocks at two different time points in which certain conditions apply (i.e. the stratification: climate, soil type, management) divided by the time dependence.

In addition, the Tier 1 approach includes two important assumptions to report SOC changes following LUC:

1. Over time, SOC reaches an equilibrium based on soil, climate, LU, and management
2. SOC changes during the transition to a new SOC at equilibrium occur in a linear fashion

2.2 SOC reference stocks

Soil organic carbon reference stocks are a set of default estimates of SOC stocks in a mineral soil (0-30 cm), which represent a specific soil group within a climate region, provided in updated table 2.3 from the 2019 Refinement (Figure 2). In order to select the values that are representative for the area in which changes in SOC are estimated, it is necessary to have pedoclimatic information for the area in question.

TABLE 2.3 (UPDATED)
DEFAULT REFERENCE CONDITION SOIL ORGANIC CARBON STOCKS (SOC_{REF}) FOR MINERAL SOILS (TONNES C HA^{-1} IN 0-30 CM DEPTH) [1, 2]

IPCC Climate Zone [5]	IPCC soil class [6]		
	High activity clay soils (HAC) [7]	Low activity clay soils (LAC) [8]	Sandy soils (SAN) [9]
Polar Moist/Dry (Px - undiff)[13]	59 ± 41% (24)	NA	27 ± 67% (18)
Boreal Moist/Dry (Bx - undiff)[13]	63 ± 18% (35)	NA	10 ± 90% [4]
Cool temperate dry (C2)	43 ± 8% (177)	33 ± 90% [3]	13 ± 33% (10)
Cool temperate moist (C1)	81 ± 5% (334)	76 ± 51% (6)	51 ± 13% (126)
Warm temperate dry (W2)	24 ± 5% (781)	19 ± 16% (41)	10 ± 5% (338)
Warm temperate moist (W1)	64 ± 5% (489)	55 ± 8% (183)	36 ± 23% (39)
Tropical dry (T4)	21 ± 5% (554)	19 ± 10% (135)	9 ± 9% (164)
Tropical moist (T3)	40 ± 7% (226)	38 ± 5% (326)	27 ± 12% (76)
Tropical wet (T2)	60 ± 8% (137)	52 ± 6% (271)	46 ± 20% (43)
Tropical montane (T1)	51 ± 10% (114)	44 ± 11% (84)	52 ± 34% (11)
	Spodic soils (POD) [10]	Volcanic soils (VOL) [11]	Wetland soils (WET) [12]
Polar Moist/Dry (Px - undiff)[13]	NO	NA	NA
Boreal Moist/Dry (Bx - undiff)[13]	117 ± 90% [3]	20 ± 90% [4]	116 ± 65% (6)
Cool temperate dry (C2)	NO	20 ± 90% [4]	87 ± 90% [3]
Cool temperate moist (C1)	128 ± 14% (45)	136 ± 14% (28)	128 ± 13% (42)
Warm temperate dry (W2)	NO	84 ± 65% (10)	74 ± 17% (49)
Warm temperate moist (W1)	143 ± 30% (9)	138 ± 12% (42)	135 ± 28% (28)
Tropical dry (T4)	NA	50 ± 90% [4]	22 ± 17% (32)
Tropical moist (T3)	NA	70 ± 90% [4]	68 ± 17% (55)
Tropical wet (T2)	NA	77 ± 27% (14)	49 ± 19% (33)
Tropical montane (T1)	NA	96 ± 31% (10)	82 ± 50% (12)

Figure 2. SOC_{REF} stocks table (mean values with confidence intervals) from the 2019 Refinement to the 2006 IPCC Guidelines. Specifications corresponding to the footnotes can be found in the 2019 Refinement (Vol.4, Ch.2). Values for Wetland soils in this table correspond to those found in the 2013 Wetland Supplement (IPCC) table 5.2 (Ch.5).

To make use of the default SOC_{REF} values table (Figure 2), we consider the climatic information available for the reporting land area units (see section 3.1 for details). In Norway, more than 69% of the land area units belong to the cool temperate moist region (Table 1, section 3.1).

With regard to the soil groups defined in the default SOC_{REF} values table (Fig.2), also named IPCC soil groups in this report, a combination of different soil information sources has been compiled to be able to designate a SOC_{REF} stock to a specific land unit undergoing LUC. A detailed description of followed procedure is provided in section 3.

2.3 Stock change factors (SCFs)

The Stock Change Factors (SCFs) are a set of dimensionless default values that are used in Eq.2.25 (2006 IPCC Guidelines, see Fig.1) to calculate the SOC stock at equilibrium for a specific LU under a set of conditions. The 2006 IPCC Guidelines and the 2019 Refinement provide several tables in each

LU chapter and some general instructions that have been used in this report to provide a summary table of all these factors that are relevant for Norwegian conditions (section 3.5).

2.4 Areas of LUC and transition time

The parcels of land in which LUC is estimated for the yearly Norwegian Inventory Report (NIR) correspond to plots in the Norwegian National Forest Inventory (NFI) with use of the area representation for each plot. These plots have a size of 250 m² and within them a unique LU is defined (see Appendix 1 for LU definitions). NFI-plots may be sub-divided in the case where two land uses are observed. If LUC change is detected in a NFI-plot, this information is registered and the NFI-plot enters a transition category. Because the NFI-plots are georeferenced land-parcels in which it is possible to track changes on the areal unit over time, Norway uses an Approach 3 for Activity Data Collection (National Inventory Report (NIR) 2019 and Vol.4, Chapter 2, Box 2.1, 2006 IPCC Guidelines*)*. This implies the use of the following alternative formulation of Eq.2.25 from the 2006 IPCC Guidelines (shown in Fig.1):

Formulation B (Approaches 2 and 3 for Activity Data Collection)

$$\Delta C_{Mineral} = \frac{\sum_{c,s,p} \left[\left\{ \begin{array}{l} \left(SOC_{REF_{c,s,p}} \bullet F_{LU_{c,s,p}} \bullet F_{MG_{c,s,p}} \bullet F_{I_{c,s,p}} \right)_0 - \\ \left(SOC_{REF_{c,s,p}} \bullet F_{LU_{c,s,p}} \bullet F_{MG_{c,s,p}} \bullet F_{I_{c,s,p}} \right)_{(0-T)} \end{array} \right\} \bullet A_{c,s,p} \right]}{D}$$

Where:

p = a parcel of land representing an individual unit of area over which the inventory calculations are performed.

Figure 3. Alternative formulation of Eq.2.25 from the 2019 Refinement of the 2006 IPCC Guidelines (shown in Fig.1) that applies for the type of activity data available (Vol.4, Chapter 2, updated Box 2.1, 2019 IPCC Refinement). Terms in the equation refer to: SOC reference stock (SOC_{REF}) and Stock Change Factors which account for land use, management and inputs of organic matter (F_{LU}, F_{MG}, F_I, respectively) and the area (A) in which all these parameters apply. Subscripts "c", "s", and "p" represent the climate zones, soil types, and parcel of land in which the conditions apply (respectively). "D" refers to the time dependence of mineral SOC stock change factors, which is the default time period for transition between equilibrium SOC values; commonly 20 years.

With this alternative formulation (Figure 3), the SOC net change will be calculated at the level of each single unit of land, which in the Norwegian national submission to the UNFCCC (documented in NIR, 2020) is represented by the NFI-plots.

According to the 2006 IPCC Guidelines, areas that enter transient conditions from one LU to another are by default under LUC for a period of 20 years. This is considered the default time period for transition between equilibrium SOC values (as indicated in Eq. 2.25, shown in Figure 2 and also in Figure 3) and is therefore applied in this methodology.

The 2019 Refinement provide an excel spreadsheet exemplifying how calculations must be done according to the applicable formulation (2019 Refinement, Vol.4, Chapter 2, Box 2.2., Equation 2.25). We have used this new spreadsheet as a starting point for further calculations to ensure we follow the calculations as correctly.

3 Sources of information and their application

3.1 Stratification according to climate

A classification of climate, based on the regions defined by the 2006 IPCC Guidelines, can be carried out with the decision tree provided therein (Fig.3.A.5.2, Vol.4, Annex 3A.5). The required information for making the classification is: elevation, mean annual temperature (MAT), mean annual precipitation (MAP), the mean annual precipitation to mean annual potential evapotranspiration (PET) ratio (MAP:PET) and frost occurrence (based on a threshold of seven days per year where the minimum daily temperature is below zero). These parameters are available for the areal units in which land-use changes are registered (NFI-plots). The majority of the climate variables required for the decision tree were acquired from the seNorge national 1x1 km gridded datasets provided by The Norwegian Water Resources and Energy Directorate (NVE), The Norwegian Meteorological Institute, and Kartverket (Lussana et al., 2019). This includes daily mean temperature, daily minimum temperature, daily maximum temperature, daily precipitation, and daily actual evapotranspiration (AET). The time series is from 01/01/1957 to 31/12/2018 (the latest year is updated periodically). All values were aggregated to annual values (monthly values for temperature were also produced). Elevation for each plot was acquired from 10x10 m digital terrain models (DTM) provided by kartverket. The DTM dataset is additionally corrected with the median values from 1x1 m resolution DTMs, when the data is available. Temperature acquired on 1x1 km grid cells was adjusted for the higher resolution elevation grid of 10x10 m by using a lapse rate of -0.65°C per 100 meters in altitude. PET was not available from the seNorge datasets. It was therefore calculated using the Thornwaithe method in which mean monthly temperature and mean monthly daylight (hours) were used as input. Daylight hours are calculated using a solar calculator function from the R-package StreamMetabolism (Sefick, 2016) based on the NOAA Solar Calculator. The PET was replaced by AET for the instances where AET exceeded PET. AET is calculated from sophisticated hydrological models used in the seNorge datasets (Engeland, 2004), while the Thornwaithe method is an empirical model (Thornthwaite, 1948). As such the AET and Thornwaithe PET combined provide the most reliable PET estimates at the current time. The mean of the annual values over 30 years (1989-2018) were used as the climate reference from which the climate regions were determined using the 2006 IPCC climate region classification decision tree.

The results of applying the decision tree to all Norwegian NFI-plots is shown in Figure 4 and Table 1 below. There are no NFI plots with less than 35 days of frost per year AND with a MAT above 10°C. This excludes a large part of the decision tree.

Table 1. Area representation of Norway's IPCC climate regions based on NFI plots.

IPCC climate region	Area representation	
	(kha)	(%)
Boreal Dry	862	2.66
Boreal Moist	4 805	14.84
Cool Temperate Dry	273	0.84
Cool Temperate Moist	22 432	69.28
Polar Dry	5	0.02
Polar Moist	4 001	12.36
Total	32 378	100.00

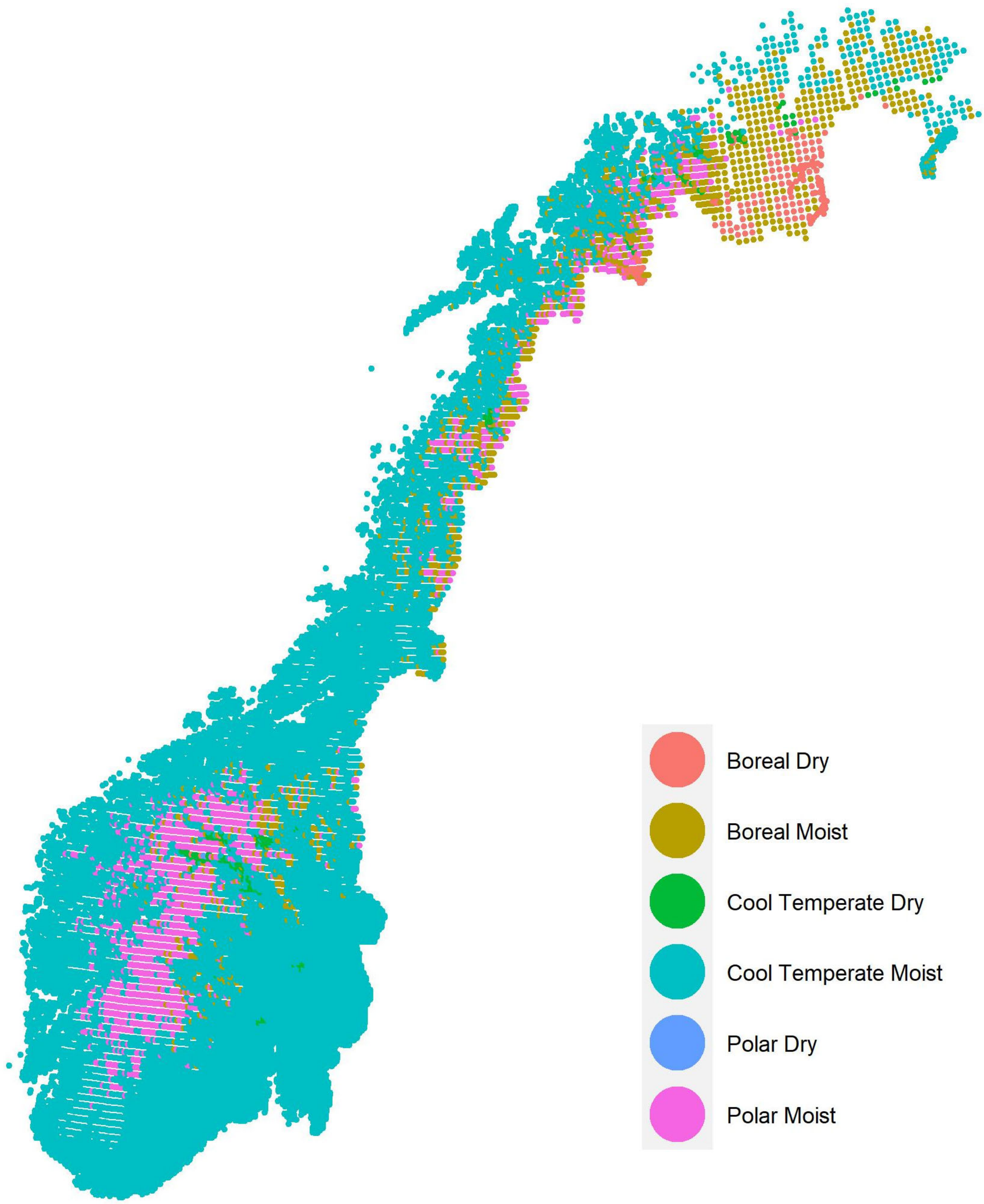

Figure 4. Map of Norway's NFI plots stratified according to the IPCC climate regions defined in the 2006 IPCC Guidelines.

In addition, specific climatic zones, which apply for the land use class transitions to and from Forest Land to report changes in the Dead Organic Matter (DOM) pool, have been used (Figure 5). These ecological zones originate from the 2006 IPCC Guidelines and are shown in the 2019 Refinement and the Forest Resources Assessment (FAO 2015), see section 5, table 8.

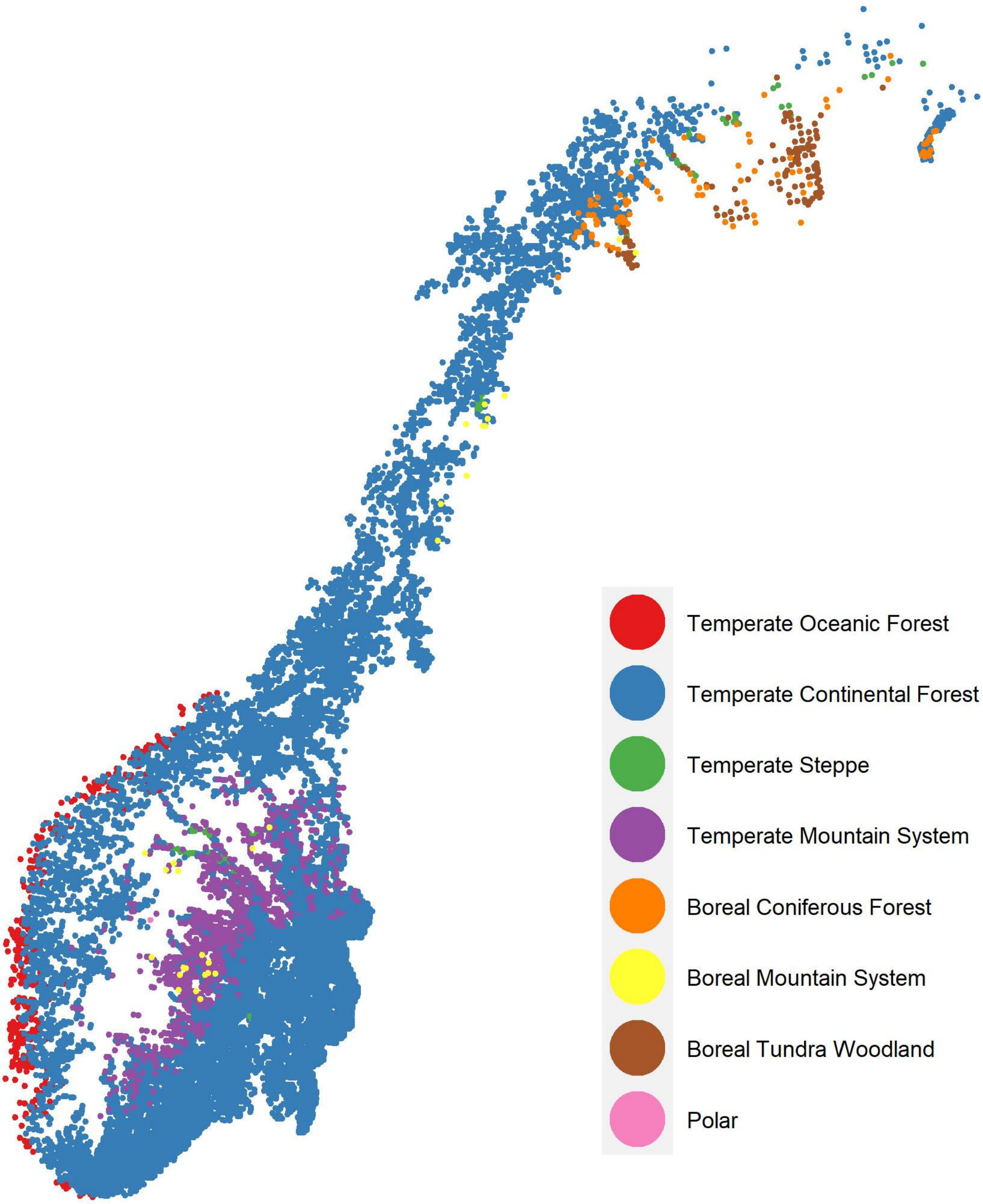

Figure 5. Map of Norway's NFI plots, which have been forest land, stratified according to the FAO ecological zones (2019 Refinement and Forest Resources Assessment, FAO, 2015). NFI plots which have not been forest land during the period of 1990-2019 are excluded, as land use information on a plot level prior 1990 is not available.

3.2 Stratification according to IPCC-soil groups

The soil groups included in the default SOC_{REF} values table 2.3 (Figure 2) are a combination of several soil types according to criteria such as mineralogy and weathering state, texture, and drainage. At the moment, Norway does not have a country-wide updated soil map or soil database, which would otherwise have been the most appropriate tool to find the relevant IPCC soil group for a specific land unit. To overcome this problem, we have investigated the possible and readily available sources of soil information that could be combined to provide a baseline. These are described below.

3.2.1 Soil information on readily available maps

3.2.1.1 The 1991 Nordic soil map (Rasmussen et al., 1991) and the Norwegian soil map (Låg, 1983)

A Nordic soil map published in 1991 (Rasmussen et al., 1991, hereafter referred to as the "**1991-map**") is the most recent and readily available source we have found covering the entire country (Appendix Fig. A1). This map is the result of a collaboration among soil scientists from the Nordic countries. The Norwegian part of this map, that is of interest for this project, originates from a soil-coverage map of Norway dated to 1983 and produced by J. Låg (Låg, 1983, Fig.3B, hereafter referred to as the "**1983-map**", Appendix Fig. A2), a Norwegian pedologist that gathered soil information for the National Atlas of Norway series (Norges Geografisk Oppmåling, 1983).

The 1983-map (Appendix Fig. A2) is not based on a systematic soil mapping, but rather on a compilation of different sources and field registrations describing soils primarily done in relation to the National Forest Inventory, but also from projects related to teaching and research at the Agricultural University of Norway (Line Tau Strand, pers. comm.). While a documentation of the compilation of the maps as we have them (1983 or 1991) is missing, we do know there is considerable amounts of systematic data behind it (see Appendix table A4 and references e.g. Låg 1985). This map consists of 24 categories or soil classes in which several soil types are listed according to their dominance for a specific area (6 classes: dominant (D, >50%), very large coverage (M, 30-50%), large coverage (GM, 20-30%), reduced coverage (N, 10-20%), limited coverage (L, 5-10%), very limited (F, <5%)). Therefore, it is rather indicating the probability to find a certain soil type in an area. The 1991-map is a later version of the 1983-map in which there is a total of 21 classes, since some classes from the 1983-map have been combined most likely due to their similarity. The correspondence between the soil classes found on both maps is presented in table 2.

Table 2. Correspondence between soil classes in the 1983-map and the 1991-map. Capital letters in brackets in the description of the 1983-map indicate the percentage range of coverage of a soil type: dominant (D, >50%), very large coverage (M, 30-50%), large coverage (GM, 20-30%), reduced coverage (N, 10-20%), limited coverage (L, 5-10%), very limited (F, <5%). The soil types in these maps correspond (with some modifications) to soil types defined according to the 1974 FAO classification.

Soil type coverage class correspondence between the 1991 and 1983 maps			
Class id nr. 1983 map	**Description (in Norwegian)**	**Class id nr. 1991 map**	**Description (as given in the English version of the 1991 map legend)**
1	isbreer (D), asonalt jordsmonn over alpin podsoleringsgrense (N)	1	glaciers incl. crudalpsols azonal soils above alpine podzolization boundary
2	asonalt jordsmonn over alpin podsoleringsgrense (D), lithosol (L), podsol (L)	2	crudalpsols incl. lithosols, podzols
3	sumpjordsmonn (D), podsol (GM), lithosol (L), rankerlignende jordsmonn (L)	45	dystric histosols, asso. podsols, incl. eutric histosols, lithosols, rankerlike soils
4	leirjodsmonn (D), podsol (N), brunjord (N), lithosol (L), sumpjordsmonn (L)	18	vertic and gleyic cambisols, incl. podsols, brown earths, lithosols, histosols
5	brunjord med høy basemetningsgrad (M), brunjord med lav basemetningsgrad (N), podsol (N), sumpjordsmonn (L), rendsina (F)	16	brown earths, asso. podsols, histosols, renzinas
6	brunjord med høy basemetningsgrad (GM), brunjord med lav basemetningsgrad (GM), podsol (GM), sumpjordsmonn (L), rankerlignende jordsmonn (L)	16	
7	brunjord med lav basemetningsgrad (M), podsol (N), lithosol (N), brunjord med høy basemetningsgrad (L), sumpjordsmonn (L), rankerlignende jordsmonn (L)	16	
8	lithosol (M), podsol (GM), brunjord (N), sumpjordsmonn (L), rankerlignende jordsmonn (L)	9a	lithosols, asso. podsols, incl. brown earths, histosols, rankerlike soils
9	lithosol (M), sumpjordsmonn (GM), rankerlignende jordsmonn (N), podsol (N), brunjord (L)	9b	lithosols, asso. histosols incl. rankerlike soils, podsols, brown earths
10	lithosol (M), podsol (GM), rankerlignende jordsmonn (N), sumpjordsmonn (L)	9c	lithosols, asso. podsols, incl. rankerlike soils, histosols
11	podsol, særlig jernpodsol med tynt til middels bleikjordlag på dyp	26	podsols, especially ferric podsols with thin to medium bleached layerin deep sedimentary deposits, incl. vertic and

	sedimentær jord (D), leirjordsmonn (L), sumpjordsmonn (L), brunjord (L)		gleyic cambisols, histosols and brown earths
12	podsol, særlig jernpodsol med tynt bleikjordlag (M), brunjord (GM), lithosol (N), sumpjordsmonn (L), leirjordsmonn (L)	23	podsols, especially ferric podsols with thin bleached layer, asso. brown earths, incl. lithosols, histosols, vertic and gleyic cambisols
13	podsol, særlig jernpodsol med tynt til middels bleikjordlag (M), lithosol (GM), brunjord (N), sumpjordsmonn (L), leirjordsmonn (L)	24	podsols, especially ferric podsols with thin to medium bleached layer, asso. lithosols, incl. brown earths, histosols, vertic and gleysic cambisols
14	podsol, særlig jernpodsol med tynt til middels bleikjordlag (D), lithosol (N), brunjord (N), sumpjordsmonn (L), leirjordsmonn (F)	32	podsols, especially ferric podsols with medium to thin bleached layer, incl. lithosols, brown earths, histosols, vertic and gleyic cambisols
15	podsol, særlig jernpodsol (D), brunjord (GM), sumpjordsmonn (L), saltjord (F)	31	podsols, especially ferric podsols, asso. brown earths, incl. histosols, saline soils
16	podsol, særlig humuspodsol på dyp jord (D), sumpjordsmonn (N), rankerlignende jordsmonn (L), leirjordsmonn (L), brunjord (L)	39	podsols, especially humic podsols in deep deposits, incl. histosols, rankerlike soils, vertic and gleyic cambisols, brown earths
17	podsol, særlig jern- og jernhumuspodsol (M), lithosol (GM), brunjord (N), sumpjordsmonn (N), rankerlignende jordsmonn (L)	40	podsol, especially humic and orthic podsols, asso. lithosols, brown earths, histosols, rankerlike soils
18	podsol, særlig med tykt til middels bleikjordlag, dels aurhelle (D), sumpjordsmonn (N), brunjord (L)	36	podsols, especially with thick to medium bleached layer and partly hardpan, incl. histosols, brown earths
19	podsol, særlig med tykt til middels bleikjordlag (D), sumpjordsmonn (N), lithosol (N), brunjord (L)	37	podsols, especially with thick to medium bleached layer, incl. histosols, lithosols, brown earths
20	podsol, særlig med tykt til middels bleikjordlag (D), lithosol (N), sumpjordsmonn (N), rankerlignende jordsmonn (L), brunjord (F)	38	podsols, especially with thick to medium bleached layer, asso. lithosols, incl. histosols, rankerlike soils, brown earths
21	podsol, særlig med tykt til middels bleikjordlag (M), lithosol (GM), sumpjordsmonn (N), rankerlignende jordsmonn (N), brunjord (F)	38	
22	podsol, særlig med tynt til middels bleikjordlag (M), brunjord (N), sumpjordsmonn (L), rankerlignende jordsmonn (L), leirjordsmonn (F)	25	podsols, especially with thin to medium bleached layer, asso. lithosols, incl. brown earths, histosols, rankerlike soils, vertic and gleyic cambisols
23	podsol, særlig med middels bleikjordlag (D), lithosol (N), brunjord	3	podsol, especially with thin to medium bleached layer, incl. lithosol, brown

	(L), sumpjordsmonn (L), rankerlignende jordsmonn (L), rendsina (F)		earths, histosol, rankerlike soils, rendzinas
24	podsol, særlig med tynt til middels bleikjordlag (D), sumpjordsmonn (N), lithosol (L), rankerlignende jordsmonn (L), brunjord (F)	4	podsols, especially with medium to bleached layer, incl. histosols, lithososls, rankerlike soils, brown earths

Despite the limitations evident for these maps due to their use of old classification schemes and the lack of transparent documentation of the mapping process (which are discussed in the next sections), they are the only available soil maps with national coverage at the moment, and therefore the only readily available source for a large share of the land area.

Background information, challenges and limitations

We have not been able to find a detailed protocol of how the 1983-map (Låg 1983) was compiled. However, we do know where much of the background data originated from and we do know that there was considerable variation both spatially and in the level of detail in this data. Systematic soil mapping of agricultural land started in 1980, before that only sporadic areas were mapped, ranging from farms to larger regions focusing on new cultivation of virgin land or areas in risk of flooding. Some regional soil maps such as the one for Ås municipality and for the region of Jæren in south west Norway (Semb & Skjeseth, 1975) mapped both agricultural and uncultivated areas. Låg listed some of the sources he used in a publication from 1980 (Låg, 1980), but nowhere does he state how these data were harmonized or weighted when making the national soil map. What we do know is that for the forest area the major source was soil observations done in connection with the National Forest Inventory. From 1954 to approx. 1989 the surveyors registered fairly detailed soil properties at each plot they visited. The protocol for the soil registration is given in (N.N., 1982) and includes observations on mineral/organic soil, soil profile type, parent material, soil depth, humus layer depth, texture, stones and boulders, groundwater table/drainage. Approximately 115000 NFI plots were registered covering 51900 km^2 of the productive forest area in Norway. Låg (1985) summarizes this information across 13 counties; at the time the forest inventories were typically carried out county by county. These observations and their exact location are archived at NIBIO. While these are, at least partly, digitized, they have never (to our knowledge) been subject to systematic quality control, analysis, or modelling for the purpose of creating a modern map of soil information and therefore not available for this project. The humus layer was sampled for chemical analyses on 7029 plots (Flaten, 1990; Steinnes et al., 1993). We have access to aggregated soil data from 13 forest inventory regions (counties) published between 1956 to 1960 (table A4 and list of reports in the Appendix), however these reports do not facilitate more detailed data than that available on the soil map when it comes to the way they are classified. With this information, and for some counties, it may be possible to refine the spatial distribution (i.e. to make two or more probability distributions for the recorded soil types) according to e.g. municipality or height above sea level. This was, however, not possible within the framework of this project.

Soil classification both nationally and internationally has developed considerably over the last 50 years and the translation of one system to another is far from straightforward, even worse when there are several different systems and versions to consider. Not all systems have had clear criteria and good protocols to guide the classification. Our challenge in this project was to relate the soil types as listed in the probability classes of the 1991-map to the IPCC default SOC reference values via modern soil classification systems (WRB) with the result shown in table A1 (Appendix).

The Norwegian Soil Mapping on agricultural land ("Jordsmonnskartlegging" in Norwegian, hereafter abbreviated as JM-map) has, since 1980, had well-documented protocols for their soil mapping and their accompanying soil classification. The soils were mapped according to nationally defined soil types (given names related to the localities where they were first described). These Norwegian soil types could be classified in the international classification system of preference, from 1980 to 1999 the Canadian System of Soil Classification (CSSC) was the most commonly used for both cultivated and forest soils. All the 1000 soils collected in the Norwegian forest soil database were described and classified according to the CSSC (Strand et al., 2016). The classification used for the 1991-map is, however, more obscure and does not translate well into any of the international soil classification systems used at that time, though it has a reference to the FAO-UNESCO system (FAO-UNESCO, 1974; FAO-UNESCO, 1990). The author of the map has made some amendments of the system to suit a more national soil classification tradition and the soil classes of the map also followed the simple soil classification protocol that was made for the forest inventory many years earlier (N.N, 1982). In this protocol, a fairly simple classification scheme is used, dividing the soils into three major soil classes, organic soils (e.g. defined by an organic layer of minimum 30 cm thickness), Podzols, and Brown earths. The Podzols were also divided into four subclasses according to the thickness of the eluvial (E-) horizon and also Podzol/Brown earths transitions were registered separately. The organic soils and the Podzols translate easily into Histosols (in some cases Gleysols, see section 3.3.1) and Cambisols respectively, according to WRB (WRB, 2015) and also the Podzol/Brown earths transition would translate into a Cambisol/Umbrisol. Most of the Podzols would also qualify as Podzols according to the WRB system, however, we should expect that many of these do not have a B horizon that fulfils the criteria for the spodic horizon and would most likely be classified as Arenosols (sandy soils) in a modern context (see footnote in Appendix Table A1). The emphasis of the E horizon thickness in the original field classification does not facilitate the identification of the sandy soils, since the reasons for having thick E horizons may be many and we cannot deduct texture and lack of a spodic horizon only from this observation. All the current international soil classification systems base their Podzol classification on the properties of the spodic/podzol B horizon or an accumulation index from the E to B horizon, not the E horizon properties and thickness alone. Combined with other observations on texture, parent material (mineralogy), landscape position/drainage, climate that would have been registered during the old forest inventory campaign, the E horizon could provide the information needed to distinguish which soils would better fit at "sandy" rather than "spodic" classification, however, this is an analysis that cannot be made in the timeframe of this project.

A challenge when using the 1991-map is that soil types are not given in a spatial context comparable to other data in for example the NFI, but mostly given as regional distributions of the probability for a limited number of soil types to occur. This information is difficult to use with modern data of point observations (NFI) and high spatial resolution (JM-map). While this is unsatisfying, the 1991-map with its soil type distribution approach, does provide a basis for illustrating the large-scale variability in soil types in a large and complex landscape. Some measures should be taken in the future to validate the 1991-map. Such evaluation is out of the scope of this project.

A detailed description of the digitizing process of these maps is provided in the Appendix 2 (section 2.1).

3.2.1.2 The Norwegian Soil Mapping on agricultural land (Jordsmonnskartlegging, JM-map)

Approximately 55% of the agricultural land in Norway is mapped by JM (Mathiesen et al., 2018). The JM-map entails mainly areas which are covered by the Cropland, and to some extent the Intensive Grassland (no-till cultivated grass pastures and closed pastures), definitions in the GHG Inventory of Norway (NIR 2021). This is therefore a source that targets specific LUs and does not provide country-wide coverage. However, it is a well-documented, updated, and systematic soil database and should therefore be used for all those LUC areas where its available. In this project, we have made use of the JM-dataset presented in Mathiesen et al. (2018). In addition, soil information here is provided according to the World Reference Base System for Soil Resources (WRB, 2015), which can be directly translated into the IPCC soil groups defined by Table 2.3 (Fig.2) without the need of any interpretations (see table 3 below).

3.3 Designation of a SOC reference stock to the mapping units

The selection of SOC_{REF} depends on the soil information available for a specific area subject to LUC. For those cases in which soil information is available from the JM-map, there will be a direct correspondence between the WRB-soil type defined by this database and one of the IPCC soil groups defined in the SOC_{REF} values table (Fig.2). The correspondence between the WRB-soil type and the IPCC soil group in this case is presented in table 3.

Table 3. WRB-system based soil types present in the Norwegian Soil Mapping on agricultural land (JM-map) and their correspondence with the IPCC soil groups from updated table 2.3 in the 2019 Refinement to the 2006 IPCC Guidelines. Confidence intervals are provided in Figure 2 or Table 2.3 of the 2019 Refinement (Vol.4 Ch.2).

		SOC_{REF} (t/ha)	SOC_{REF} (t/ha)	SOC_{REF} (t/ha)	SOC_{REF} (t/ha)
WRB soil group	**IPCC soil group**	**Cold temperate moist**	**Cold temperate dry**	**Boreal**	**Polar**
Anthrosol*	HAC	81	43	63	59
Arenosol	Sandy	51	13	10	27
Cambisol	HAC	81	43	63	59
Fluvisol†	HAC	81	43	63	59
Gleysol	Wetland	128	87	116	NO
Histosol#	-	N.A.	N.A.	N.A.	N.A.
Leptosol	HAC	81	43	63	59
Luvisol	HAC	81	43	63	59
Phaeozem	HAC	81	43	63	59
Planosol	HAC	81	43	63	59
Podzol	Spodic	128	NO	117	NO
Regosol	HAC	81	43	63	59
Stagnosol	HAC	81	43	63	59
Technosol	HAC	81	43	63	59
Umbrisol	HAC	81	43	63	59
Retisol/Albeluvisol	HAC	81	43	63	59

*Anthrosol: assumed to be most likely a reallocation of topsoil

†Fluvisol: most likely fluvial material of local HAC-origin

#Histosol: not included in this project since these soils are reported as organic soils

"NO" for the Spodic IPCC soil group under Cold Temperate Dry climate occurs because Podzols require high precipitation to form, therefore not found under dry climate. These soils are also not expected in the Polar zone, therefore also noted as "NO".

However, if the area undergoing LUC is located within a domain only covered by the 1991-map, another methodology is applied. The 1991-map defines a series of classes in which the different soil types are represented. These classes originate from the 1983-map in which soil types are listed according to a percentage range of coverage (see section 3.2.1.1, see table 2). For this reason, within a class from the 1991-map we have weighted the SOC_{REF} according to the percentage coverage of a specific soil type corresponding to a soil group from the updated IPCC table 2.3 (Fig.2). The information on the percentage coverage of each soil type was obtained from the 1983-map (Appendix, table A1, Fig.A2) since it was not specified in the 1991-map even though soil classes were almost identical.

As a first step, each soil type identified in the soil coverage classes from the 1983-map was translated into a WRB-soil type facilitating the correspondence between that soil type and the IPCC soil group from table 2.3 (Fig.2). This step is presented in table A1 in the appendix.

Secondly, SOC_{REF} values were calculated for each class in the 1991-map and provided in table 4. These values are obtained by weighing the contribution of each soil type (and thereby the corresponding IPCC soil group from the updated Table 2.3, Fig.2) in each class, based on the percentage coverage range provided by the original 1983-map (Appendix, table A1, Fig.A2). In order to calculate the weighted SOC_{REF} for each class the following assumptions are made:

1. The middle point of the percentage range is used to define the contribution of a soil type to the class and the remaining percentage up to 100% is allocated to the most dominant soil type within the class.
2. When more than one soil type is listed within a percentage range, the equal contribution of each soil type is assumed.
3. Classes nr. 16 and 38 in the 1991-map are the combination of classes 3 and 2 respectively in the 1983-map where percentage ranges are provided. Therefore, for these classes the SOC_{REF} calculated is the average of the original 1983-map classes that were combined.

An example of how the calculation is done is provided below.

<u>Weighted SOC_{REF} for cool temperate moist climate in class 23:</u>

A LUC plot on mineral soil corresponds to class 23 for that climate zone. This class then consists of 30-50% podsols, 20-30% cambisols, 10-20% leptosols, 5-10% gleysol, stagnosol/luvisol (see table A1 in Appendix). Therefore, the SOC_{REFs} from IPCC soil groups to be used for this class would be Spodic (podsol), HAC (cambisols, leptosols, and stagnosol/luvisol) and Wetland (gleysol). The calculation of the SOC_{REF} for class 23 would then be calculated as follows:

$SOC_{REF} = \sum((0.525*128)+(0.25*81)+(0.15*81)+((0.0375*128)+(0.0375*81))) = 107$ t/ha

Table 4. Weighted SOC reference stocks (from default values in the updated Table 2.3, 2019 Refinement of the 2006 IPCC Guidelines) for each soil type coverage class from the 1991-map with relative uncertainties (in %, at 95% confidence level). Only the IPCC listed uncertainties in the reference stocks for various IPCC soil types are taken into consideration in the weighted uncertainties. Significant uncertainties are expected in addition relating to the distribution of IPCC soil types to map classes (1991-map). The IPCC soil groups found in each class are listed (for further details on percentage coverage and soil types, see Appendix Table A1). SOC reference stocks are provided for the IPCC climate zones found in Norway. For those cases including the Wetland IPCC soil group it refers exclusively to mineral soils.

		SOC reference stocks (weighted) in t/ha			
Class id nr. 1991 map	**IPCC soil groups included (in order of prevalence)**	**Cool temperate moist***	**Cool temperate dry***	**Boreal**	**Polar**
1	HAC to a limited extent	12 ±5%	6 ±8%	9 ±18%	5 ±41%
2	HAC, Spodic	83 ±5%	41 ±8%	65 ±17%	33 ±39%
3	Spodic, HAC, Wetlands	117 ±11%	12 ±17%	105 ±75%	52 ±29%
4	Spodic, Wetland, HAC	123 ±11%	17 ±68%	111 ±72%	56 ±32%
9a	HAC, Spodic, Wetland	95 ±5%	34 ±10%	78 ±35%	39 ±31%
9b	HAC, Wetland, Spodic	96 ±5%	51 ±39%	80 ±27%	40 ±33%
9c	HAC, Spodic, Wetland	96 ±5%	36 ±17%	80 ±34%	40 ±33%
16	HAC, Spodic, Wetland	91 ±8%	37 ±14%	75 ±55%	37 ±37%
18	HAC, Spodic, Wetland	86 ±4%	41 ±10%	69 ±18%	35 ±36%
23	Spodic, HAC, Wetland	107 ±9%	22 ±14%	93 ±59%	47 ±28%
24	Spodic, HAC, Wetland	107 ±9%	22 ±14%	93 ±59%	47 ±28%
25	Spodic, HAC, Wetland	106 ±9%	23 ±6%	92 ±62%	46 ±28%
26	Spodic, HAC, Wetland	126 ±13%	4 ±45%	114 ±85%	57 ±41%
31	Spodic, HAC, Wetland	115 ±10%	18 ±32%	102 ±67%	51 ±37%
32	Spodic, HAC, Wetland	120 ±11%	14 ±42%	107 ±74%	54 ±32%
36	Spodic, Wetland, HAC	124 ±11%	16 ±72%	113 ±73%	56 ±41%
37	Spodic, Wetland, HAC	121 ±12%	13 ±45%	109 ±75%	54 ±29%
38	Spodic, HAC, Wetland	116 ±11%	18 ±42%	103 ±74%	51 ±31%
39	Spodic, Wetland, HAC	124 ±11%	16 ±72%	113 ±73%	56 ±41%
40	Spodic, HAC, Wetland	109 ±9%	24 ±25%	95 ±58%	48 ±28%
45	Wetland, Spodic, HAC	124 ±10%	62 ±85%	112 ±51%	56 ±41%

* Larger differences between SOC stocks in cool temperate dry and moist zones within the same class are most often caused by the dominant coverage of the Spodic IPCC soil group, which is not found in dry climate, therefore not contributing to the weighted SOC stock and its uncertainty.

3.3.1 Special considerations regarding organic soils

This project only concerns the reporting of SOC in mineral soils in areas affected by LUC. However, the sources of soil information that are being used also include information on organic soils.

The Norwegian NIR identifies organic soils based on three data sources (Table 6.11, National Inventory Report (NIR) of Norway, 2020). To keep consistency, **the designation of organic versus mineral soil on each areal unit provided by the NIR is respected in this methodology** (Appendix 2, section 2B). This implies potential cases of inconsistency in which the 1991-map defines an area dominated (or with some representation of) "sumpjordsmonn" (potentially an organic soil) while the NFI plot in the area may be defined as a mineral soil. According to the documentation available from the 1983-map (and thereby assumed applicable to the 1991-map), the designation of “sumpjordsmonn” refers to soils with an organic layer of at least 30 cm (Låg, 1976). No specifications regarding the decomposition stage or carbon and/or organic matter content are provided in this definition. Since the NFI designation should prevail (assumed to have better accuracy), in such a case the SOC_{REF} stock to be applied will be the one defined for the Wetlands IPCC soil group (Table 2.3, 2019 Refinement to the 2006 IPCC Guidelines, shown in Fig.2). This is because in the WRB classification Gleysols can have an organic (Histic) layer of up to 30 cm, indicating that within the “Wetlands” IPCC soil group, it is possible to have a mineral soil (such as Gleysol and therefore with restricted drainage conditions) with a relatively thick organic layer. In this way, the designation of the NIR is respected and at the same time the distinct characteristics of the soil due to restricted drainage are accounted for in the SOC_{REF}.

3.3.2 Special considerations regarding areas with sparse vegetation/bare rock (no soil)

Based on an expert assessment of the 1983- and 1991-maps, there was a general impression that mountainous areas with exposed bedrock, boulder fields and other surficial deposits were under-represented. This can have implications for SOC stock estimations, since these areas have negligible soil formation (if any). For this reason, the NFI registrations which provide specific information on the presence or absence of soil (variables defined as “vegetasjonstype/vegetation type” and “jorddybde/soil depth”, see definitions in the NFI field handbook, Viken, 2019) have been used. NFI plots registered with vegetation cover <50% (which also are registered to have more than 90% of bare rock), were considered to have a SOC stock equal to zero and therefore no changes will be reported. These cases correspond to the land use category “Other Land”.

3.3.3 Other specifications

Norway does not report emissions on Land converted to Flooded Land (therefore reported as “NE”, not estimated, NIR 2020). The land use category “Settlements” is treated in a specific way, as indicated by the guidelines, see next section for details.

3.5 Library of Stock Change Factors (SCFs)

To calculate the SOC stock, an equilibrium for each LU, the SCFs are used (Table 4) representing land use (F_{LU}), management regimes (F_{MG}) and inputs (F_I). These values originate mainly from the 2006 IPCC Guidelines and in cases of modifications, details are given in the table.

Table 5. Compilation of Stock Change Factors (SCFs) from the different LUs. Notation "NA" refers to "not applicable" and applies for Other Land, because a SOC_{REF} of 0 is assumed when conversion from or to this LU.

LU	Flu	Fmg	Fi
Cropland[1]	0.79	1.03	1.12
Grassland[2]	1	1.04	1
Settlements[3]	0.8	1	1
Other Land	NA	NA	NA
Managed Forest Land	1	1	1
Native Unmanaged Land	1	1	1

[1] Values for Cropland are averaged for every factor based on the different values provided by the 2019 Refinement to the 2006 IPCC Guidelines that are applicable in Norway. These refer to cool temperate, temperate, and boreal climate for moist and dry conditions (see Appendix table A2) [2] Values for Grassland are also averaged based on a revised table of factors (due to the revision of the Grassland definition, see Appendix table A3). [3]In transitions with conversions from and to Settlements, a product of SCFs equal to 0.8 is applied. This originates from the specifications provided in the 2006 IPCC Guidelines (Vol.4, Ch8 section 8.3.3.2), in which 20% of the SOC stock from the previous LU is assumed to be lost over 20 years. Conversions from Settlements to other LUs in which the previous LU is not known (at the beginning of the reporting in 1990, the land unit was a Settlement), it is assumed that the SOC stock at equilibrium is equal to the reference value times 0.8 as well. Currently, we do not have a differentiation of paved areas versus other sub-types under Settlements (such as parks, etc.) and we therefore apply a conservative approach assuming that all land under Settlements is paved over.

3.6 Representativity of soil information for LUC areas

The NFI plots (as described in 2.4) have a designated land cover class and some description of soil coverage and vegetation type. These characteristics are determined through field observations, or by scrutiny of detailed maps and aerial photographs, and can be considered as ground truth. However, it is not possible to extract soil type information from the NFI data.

As indicated before, there are two sources of soil type information that can be associated with the NFI plots and translated into the IPCC classes needed to apply the Tier 1 methodology:

1. The JM-map (Jordsmonnskartlegging, section 3.2.1) has a Minimum Mapping Unit (size of the smallest feature that is being reliably mapped) of 1 ha and covers approximately 55 % of agricultural land (the majority on croplands, and to a very limited extent, on grasslands, see 3.2.1.3) in Norway. Here, the WRB-classes can be extracted directly.
2. The 1991-map (sectiona 3.2.1), that covers all Norway, is generalized to a regional level, with soil mapping units consisting of percentage coverage of a number of soil types assigned to large areas (several 1000 sq.km).

If the JM-map exists on an NFI plot with its corresponding land-use class, the WRB-class can be associated. However, agricultural lands are most often located on the best soils and nearby forest may be different. A split sample plot with cropland on one part and e.g. forest on the other will use the detailed soil map (JM-map) on the cropland part, and the 1991-map for the forest part. Further, relatively few of the NFI plots are covered by the JM-map parcels (in 2020, 609 plots on mineral soils).

One of the biggest challenges behind the use of old soil maps is the diminished quality and low accuracy as compared to modern geographic information. Especially for this methodology, the 1991-map needs to be applied and used in parallel with more accurate and precise modern geographical information (JM-map, which is the result of a systematic soil survey). The 1991-map is considered to have a delineation accuracy alone of approx. 2 km. This makes its use difficult on the small land unit areal scale of the NFI-plot (250 m²) in which LUCs are registered. For these reasons, we have decided to use the soil information from the 1991-map at a spatial scale that takes into account the large inaccuracy behind it (see below).

Calculation of SOC_{REF}

To find soil type information with a fair degree of representativity for those NFI-plots where LUC occurs, we project a circle around the plot to define which soil types are representative for that land unit. The radius of this circle is different depending on the source map due to its different accuracy. For the JM-map, we use a circle of 14 m radius while for the 1991-map the radius is 6 km. The latter is defined as ~3 times the deviations observed between the 1991 map and modern topographic maps of Norway. The circle projected around the plots often contain several soil types (JM-map)/soil classes (1991-map). The SOC_{REF} for each soil type/class is identified in the corresponding table (according to the plot's IPCC climate zone and IPCC soil group, tables 3 and 4) and weighted with the area proportion of the circle.

Finally, an important detail regarding the organic versus mineral soil definition needs to be kept in mind: the designation of an NFI-plot as mineral or organic soil is respected, i.e. if the soil on the NFI-plot is registered as organic (see section 3.3.1), it will be reported following the organic soil methodology in the inventory. Further specifications regarding the procedure for differentiation between mineral and organic soils is provided in the Appendix 2 (section 2.2).

Table 6. Summary table of specifications regarding the calculation of SOC_{REF} in a land unit.

Bare rock	Derived from NFI registrations: scarce vegetation coverage and lack of soil. Plots with such registrations belong to "Other Land" (see 3.3.2)
Organic soil	Derived from NFI registrations (except on agricultural land) For agricultural land, information is derived from the JM-map or the areal resource map AR5 (Ahlstrøm et al., 2019). If >= 50 % of the plot is organic, it will be reported as organic soil. See Appendix 2, section 2B for further details. Note that neither the definition nor the emissions estimation on organic soils are part of the scope of this report.
Mineral soil	On agricultural land (as defined by JM, see 3.2.1) the WRB-class is found in the JM- map where it exists. All other mineral soils (regardless of land use) use the 1991-map (see section 3.3).

4 Resulting default SOC$_{REF}$ map

As a result of the processing of the maps, their soil type information and the definition of an IPCC climate zone associated to each plot, a map of SOC$_{REF}$ for plots with mineral soil has been produced (Figure 6, see section 3.6 for information on the procedure). This map should be interpreted with care as it does not present any measured values, only an approximated default value that is stratified according to a corresponding soil group and climate zone defined by IPCC. The map covers all LUs on mineral soils.

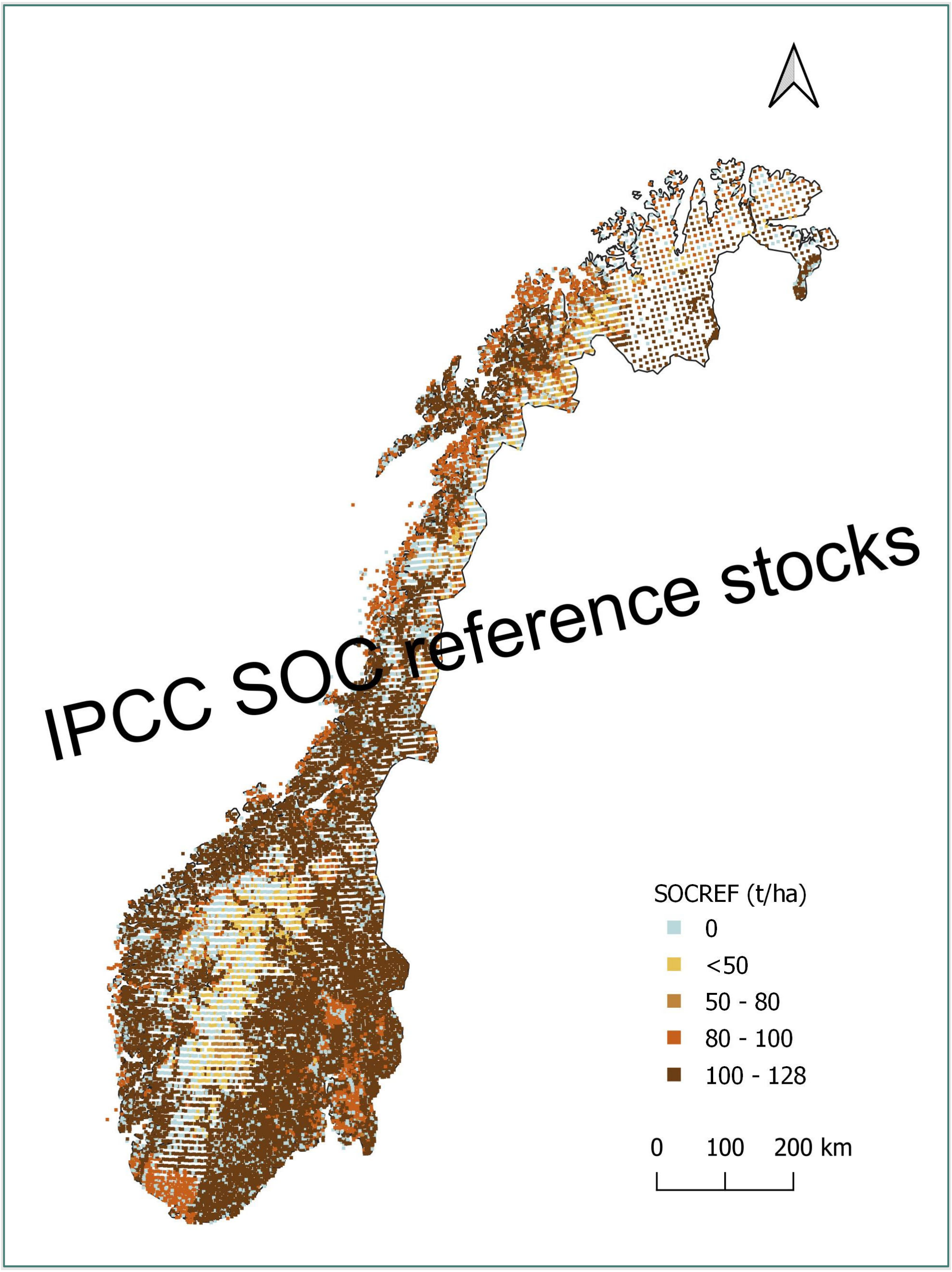

Figure 6. Map of SOC$_{REF}$ stocks (0-30 cm) for mineral soils in plots from the NFI. The values associated to each plot originate from the Tables 3 and 4 which are based on the updated Table 2.3 in the 2019 Refinement of the 2006 IPCC Guidelines. This map is therefore not showing measured values. The LUs Other Land, Settlements and Wetlands are represented in this map with a SOC$_{REF}$ equal to zero. Relative uncertainties for SOCref values are presented in Table 4. These uncertainty estimates do not cover neither the uncertainty related to the distribution of IPCC soil types in the soil map classes nor the spatial uncertainty in the map.

According to this map, a large majority of the plots fall within the interval with highest SOC_{REF} stock, which is above 100 tonnes/ha (Figure 7 and 7). As mentioned in previous sections most of the territory is covered by soil information from the 1991-map (~80%) meaning that features from this source are likely to have a strong influence on the SOC_{REF} map. In the 1991-map, the “Spodic” IPCC soil group dominates in more than half of the soil coverage classes (13 out of 21). In addition, the “Wetlands” IPCC soil group is also highly represented in the 1991-map soil classes (see section 3.3.1 for specifications on the soil type reflected here), occurring in all of them except two cases (Table 4). Both groups have the highest SOC_{REF} stocks in the list of default values (updated Table 2.3 2019 Refinement) within the IPCC climate zones that apply in Norway, and even more so in the Cool Temperate Moist climate zone, which is covering more than 69% of the country (Table 1). It is therefore not surprising, that a large part of the map in Figure 5 has high SOC_{REF} values.

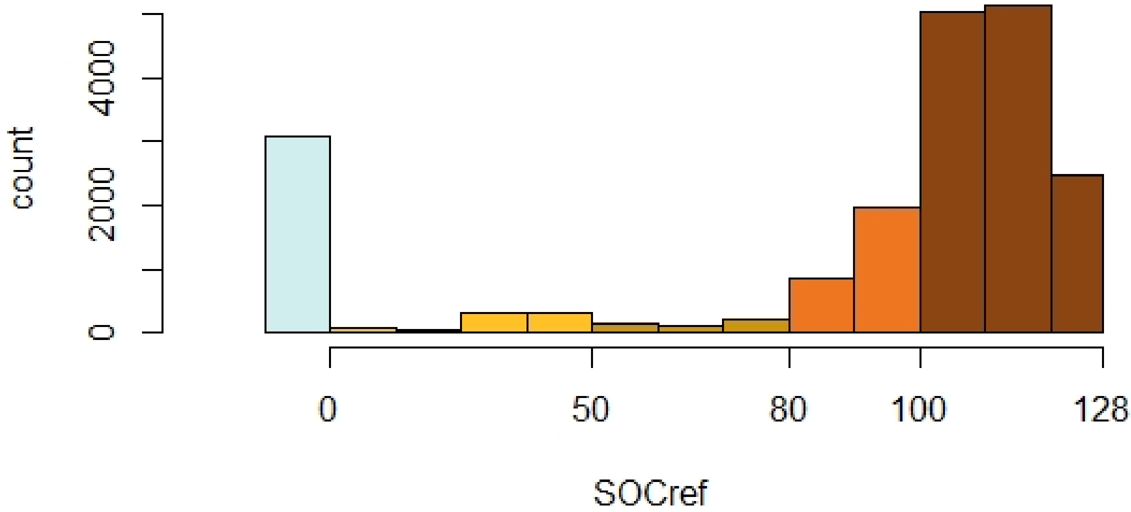

Figure 7. Histogram of all mineral soil plots to which a SOC_{REF} value has been assigned (in tonnes/ha). Colors of the histogram bins correspond to the colors of the five intervals provided in the map legend in Figure 5. The light blue column shows all occurrences in which SOC_{REF} equals zero.

5 Dead Organic Matter (DOM)

For LUCs to or from the LU class Forest Land, the loss and accumulation of dead organic matter (DOM) will have to be considered. By following the IPCC definitions of these pools, we avoid that pools of soil and DOM overlap. The pool definitions are shown in Table 7. For deforestation, the DOM pools are subject to "instantaneous oxidation" and the full reference carbon stock is regarded as an emission in the year of deforestation. For afforestation, the accumulation in DOM pools is assumed linear in 20 years after which the reference stock is reached and accumulation stops.

Table 7. Definition of reporting pools from the IPCC 2006 Guidelines. Vol. 4, Ch. 1.

TABLE 1.1
DEFINITIONS FOR CARBON POOLS USED IN AFOLU FOR EACH LAND-USE CATEGORY

Pool		Description
Biomass	Above-ground biomass	All biomass of living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds, and foliage. Note: In cases where forest understory is a relatively small component of the above-ground biomass carbon pool, it is acceptable for the methodologies and associated data used in some tiers to exclude it, provided the tiers are used in a consistent manner throughout the inventory time series.
	Below-ground biomass	All biomass of live roots. Fine roots of less than (suggested) 2mm diameter are often excluded because these often cannot be distinguished empirically from soil organic matter or litter.
Dead organic matter	Dead wood	Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps, larger than or equal to 10 cm in diameter (or the diameter specified by the country).
	Litter	Includes all non-living biomass with a size greater than the limit for soil organic matter (suggested 2 mm) and less than the minimum diameter chosen for dead wood (e.g. 10 cm), lying dead, in various states of decomposition above or within the mineral or organic soil. This includes the litter layer as usually defined in soil typologies. Live fine roots above the mineral or organic soil (of less than the minimum diameter limit chosen for below-ground biomass) are included in litter where they cannot be distinguished from it empirically.
Soils	Soil organic matter[1]	Includes organic carbon in mineral soils to a specified depth chosen by the country and applied consistently through the time series[2]. Live and dead fine roots and DOM within the soil, that are less than the minimum diameter limit (suggested 2 mm) for roots and DOM, are included with soil organic matter where they cannot be distinguished from it empirically. The default for soil depth is 30 cm and guidance on determining country-specific depths is given in Chapter 2.3.3.1.

[1] Includes organic material (living and non-living) within the soil matrix, operationally defined as a specific size fraction (e.g., all matter passing through a 2 mm sieve). Soil C stock estimates may also include soil inorganic C if using a Tier 3 method. CO_2 emissions from liming and urea applications to soils are estimated as fluxes using Tier 1 or Tier 2 method.

[2] Carbon stocks in organic soils are not explicitly computed using Tier 1 or Tier 2 method, (which estimate only annual C flux from organic soils), but C stocks in organic soils can be estimated in a Tier 3 method. Definition of organic soils for classification purposes is provided in Chapter 3.

For maximum consistency among soil, litter, and deadwood (DW) reference stocks which are used for calculating stock changes (for soil, see the other sections of this report), the DOM pools are defined as:

Litter: Following Table 7, fine woody material and the litter layer (as usually defined in soil typologies) is included. As we use IPCC default values for litter reference stocks (2019 Refinement, Vol. 4, Table 2.2), there should be no overlap with the soil pool (as these are also IPCC default). An estimate of fine woody litter is added using data made available from Canada (pers comm. Cindy Shaw): National Forest Inventory ground plots data (https://nfi.nfis.org/en/ground_plot) and the Forest Ecosystem

Carbon Database (https://cfs.nrcan.gc.ca/publications?id=25626). Reference stocks are selected for climatic zones using the zones given in the 2019 Refinement and the Forest Resources Assessment (FAO 2015) (Fig. 5, Table 8). The refence carbon stock values are given in Table 9.

Deadwood: Following Table 7, we use IPCC default values for reference carbon stocks (2019 Refinement, Vol. 4, Table 2.2). Climatic zones as for litter. The refence carbon stock values are given in Table 9.

Table 8. Ecological Zones (FAO, 2015, table 8) and IPCC Climate regions as used in the 2019 Refinement.

TABLE 4.1
CLIMATE DOMAINS (FAO, 2001), CLIMATE REGIONS (CHAPTER 3), AND ECOLOGICAL ZONES (FAO, 2001)

Climate domain		Climate region	Ecological Zone		
Domain	**Domain criteria**		**Zone**	**Code**	**Zone criteria**
Tropical	all months without frost; in marine areas, temperature > 18°C	Tropical wet	Tropical rain forest	TAr	wet: ≤ 3months dry, during winter
		Tropical moist	Tropical moist deciduous forest	TAwa	mainly wet: 3-5 months dry, during winter
		Tropical dry	Tropical dry forest	TAWb	mainly dry: 5-8 months dry, during winter
			Tropical shrubland	TBSh	semi-arid: evaporation > precipitation
			Tropical desert	TBWh	arid: all months dry
		Tropical montane	Tropical mountain systems	TM	altitudes approximately > 1000m, with local variations
Sub-tropical	≥ 8 months at a temperature > 10°C	Warm temperate moist	Subtropical humid forest	SCf	humid: no dry season
		Warm temperate dry	Subtropical dry forest	SCs	seasonally dry: winter rains, dry summer
			Subtropical steppe	SBSh	semi-arid: evaporation > precipitation
			Subtropical desert	SBWh	arid: all months dry
		Warm temperate moist or dry	Subtropical mountain systems	SM	altitude approximately 800 m-1000 m
Temp-erate	4-8 months at a temperature > 10°C	Cool temperate moist	Temperate oceanic forest	TeDo	oceanic climate: coldest month >0°C
			Temperate continental forest	TeDc	continental climate: coldest month <0°C
		Cool temperate dry	Temperate steppe	TeBSk	semi-arid: evaporation > precipitation
			Temperate desert	TeBWk	arid: all months dry
		Cool temperate moist or dry	Temperate mountain systems	TeM	altitudes approximately > 800 m
Boreal	≤ 3 months at a temperature > 10°C	Boreal moist	Boreal coniferous forest	Ba	coniferous dense forest dominant
		Boreal dry	Boreal tundra woodland	Bb	woodland and sparse forest dominant
		Boreal moist or dry	Boreal mountain systems	BM	altitudes approximately >600 m
Polar	all months <10°C	Polar moist or dry	Polar	P	all months <10°C

Climate domain: Area of relatively homogeneous temperature regime, equivalent to the Köppen-Trewartha climate group (Köppen, 1931).

Climate region: Areas of similar climate defined in Chapter 3 for reporting across different carbon pools.

Ecological zone: Area with broad, yet relatively homogeneous natural vegetation formations that are similar, but not necessarily identical, in physiognomy.

Dry month: A month in which Total Precipitation (mm) ≤ 2 x Mean Temperature (°C).

Table 9. Reference stocks (in tonnes C/ha) for the Litter and Deadwood (DW) pool by Ecological Zone (2019 Refinement, Vol.4,Ch.2, Table 2.2, which also provides minimum and maximum values for each pool). "N.A." denotes "not available". Litter values result from the sum of default litter values and fine woody biomass, the latter based on Canadian data.

Pool	IPCC_Climate_Zone	Ecological_zone_FAO	Broadleaf	Needleleaf
Litter	Boreal Dry	Boreal Tundra Woodland	31	69
Litter	Boreal Moist	Boreal Coniferous Forest	21	42
Litter	Cool Temperate Dry	Temperate Mountain System	7	8
Litter	Cool Temperate Moist	Temperate Mountain System	6	8
Litter	Cool Temperate Dry	Temperate Steppe	40	31
Litter	Cool Temperate Moist	Temperate Oceanic Forest	6	7
Litter	Cool Temperate Moist	Temperate Continental Forest	27	70
Litter	Polar Dry	Polar	N.A.	N.A.
Litter	Polar Moist	Polar	N.A.	N.A.
DW	Boreal Dry	Boreal Tundra Woodland	5.7	1.3
DW	Boreal Moist	Boreal Coniferous Forest	16.4	22.2
DW	Cool Temperate Dry	Temperate Mountain System	21.2	48.1
DW	Cool Temperate Moist	Temperate Mountain System	21.2	48.1
DW	Cool Temperate Dry	Temperate Steppe	26.2	8
DW	Cool Temperate Moist	Temperate Oceanic Forest	36.8	36.8
DW	Cool Temperate Moist	Temperate Continental Forest	23.6	22.1
DW	Polar Dry	Polar	5.7	1.3
DW	Polar Moist	Polar	16.4	22.2

Some considerations:

In using default values for both soil and DOM we assume that the carbon in the surface litter (soil horizon L) is included in litter whereas the carbon contained in the more humified organic horizons above the mineral soil (F, H) are included in soil. According to the IPCC 2006 Guidelines and the 2019 Refinement, the default values for litter do not include the carbon contribution from fine woody litter. These data are currently not available for Norway (hence Canadian data). In general, the numbers for both litter and deadwood are considered uncertain. Default values for litter (Table 9) for Boreal and for Cool Temperate Moist (< 800 m.a.s.l. and coldest month < 0 deg. C) are of the magnitude 40-70 tonnes carbon / ha. This is the same magnitude as the carbon stock for the Norwegian forest floors (i.e. the entire organic horizon including L, F, and H horizons) (Strand et al. 2016). This exemplifies the uncertainties involved.

6 Conclusion

After a thorough search through the available data sources that could allow the use of a Tier 1 methodology, we have concluded that old soil maps as well as a new use of climate data associated to NFI plots have been necessary to define the IPCC climate zones and soil groups on a country-wide basis. These are elements that have not been previously used in NIR-methodologies on the NFI-plot level, however, they provide valuable basic pedoclimatic information that has ultimately allowed the stratification of SOC stock data across LUs and regions. Despite the valuable inputs provided by the data sources used, when it comes to soil information, we emphasize the large uncertainties behind a very large part of the Norwegian territory. At the moment, Norway does not have a soil type map that covers the entire country and includes all LU classes. Information about soil is rather scattered on a LU-dependent way, and it is therefore likely that within the next years efforts in coordinating soil information in Norway could provide better information and even facilitate the reporting of SOC change after LUC with a Tier 2 methodology. The new methodology presented here is an improved approach as compared to the previous one as it strictly follows the requirements of IPCC methodology. It rests on a transparent stratification to soil type and climate zones, applies land use specific carbon stock change factors in the prescribed way (avoiding bias) and follows IPCC pool definition using default values.

Results (i.e. total sources/sinks from SOC as a consequence of LUC) from implementing this Tier 1 methodology are not included here, since they will be presented in the NIR 2021. While efforts to validate the data sources for at least some LUs (where data are available) will have to be a priority in the near future, it has not been a priority of this project due to time constraints.

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Appendix 1 Land-use definitions

Land-use is assessed by the National Forest Inventory (NFI) at more than 22,000 sample locations systematically distributed over the Norwegian land area. All land-use definitions are applied to a grain (a minimum size) of 0.1 ha; patches of land with a land-use smaller in extension than 0.1 ha are attributed to the land-use of an adjacent patch of land. Note that Norway applies land-use and not land-cover definitions.

Forest land (4A) is defined in the National Forest Inventory (NFI). The values used in the NFI are in accordance with the range of parameters in the definition from the Global Forest Resources Assessment (FRA) 2005. Forest land is land with tree crown cover > 10 %. The trees have to be able to reach a minimum height of 5 m at maturity in situ. Minimum area and width for forest land considered in the Norwegian inventory is 0.1 ha and 4 m. Forest roads are considered as settlements. The minimum area and width is consistent among all land-use categories in Norway. Young natural stands and all plantations established for forestry purposes, as well as forest land, which is temporarily unstocked as a result of e.g. harvest or natural disturbance, are included under forest land. All forest in Norway is managed either for wood harvesting, protection and protective purposes, recreation, and/or to a greater or lesser extent, hunting and berry picking. On more marginal and less productive forest land, the various management practices may be less intense, but still present. Hence, all forest in Norway is considered managed.

Cropland (4B) is defined as lands that are annually cropped and regularly cultivated and plowed. Both annual and perennial crops are grown. It also encompasses grass leys that are in rotations with annual crops, which may include temporarily grazed fields that are regularly cultivated. This category includes arable land that was previously annually cropped and regularly plowed but has since been abandoned. These areas remain in the cropland category until trees have regrown, making them unsuitable for plowing. All cropland is considered managed.

Grassland (4C) is defined in two sub-categories, intensive and extensive grasslands. 1) Intensive grasslands are areas utilized for grazing on an annual basis or for grass production without plowing. More than 50 % of the area should be covered with grass and it may be partly covered with trees, bushes, stumps, rocks etc. The grass may be mechanically harvested but the soil cannot be plowed. Intensive grassland with tree cover may be classified as grassland if grazing land-use is considered more important than forestry, even if the area meets the forest definition. According to the agricultural statistics used for determining grassland management practices, intensive grasslands include two management types; Closed pastures and No-till cultivated pastures. 2) Extensive grasslands include land areas with a significant C stock that do not fall into any of the other five land-use categories, for example, heath lands, other wooded land (i.e. land with sparse tree cover on mineral soil), and open areas. A large part of the extensive grassland area is open pastures (rangeland) and is grazed to some extent. All grassland (intensive and extensive) is considered managed according to these categories.

Wetlands (4D) are defined as lakes, rivers, mires, and other areas regularly covered or saturated by water for at least part of the year. Mires may be stocked by trees but with a tree coverage that does not meet the forest definition. All wetlands are assumed to be unmanaged except wetlands used for peat extraction and flooded lands caused by human constructed dams.

Settlements (4E) include all types of built-up land: houses, gardens, villages, towns, cities, parks, golf courses, sport recreation areas, power lines within forests, areas close to cabins (< 5m), industrial areas, gravel pits, and mines. All settlements are considered managed.

Other land (4F) is defined as waste land areas, such as bare rocks and ice, where there are no significant C pools.

Appendix 2 Supplementary material

Fig.A1. Soil map of the Nordic countries. Scale 1: 2 000 000. From Rasmussen et al., 1991. Two Finnish and two Swedish soil coverage classes were found within the Norwegian border. These were translated to corresponding Norwegian soil coverage classes after scrutinizing the different cases: Finnish codes 42 and 43 were translated into the Norwegian soil coverage class 45, while Swedish codes 21 and 33 were translated as Norwegian 24 and 36 soil coverage classes, respectively.

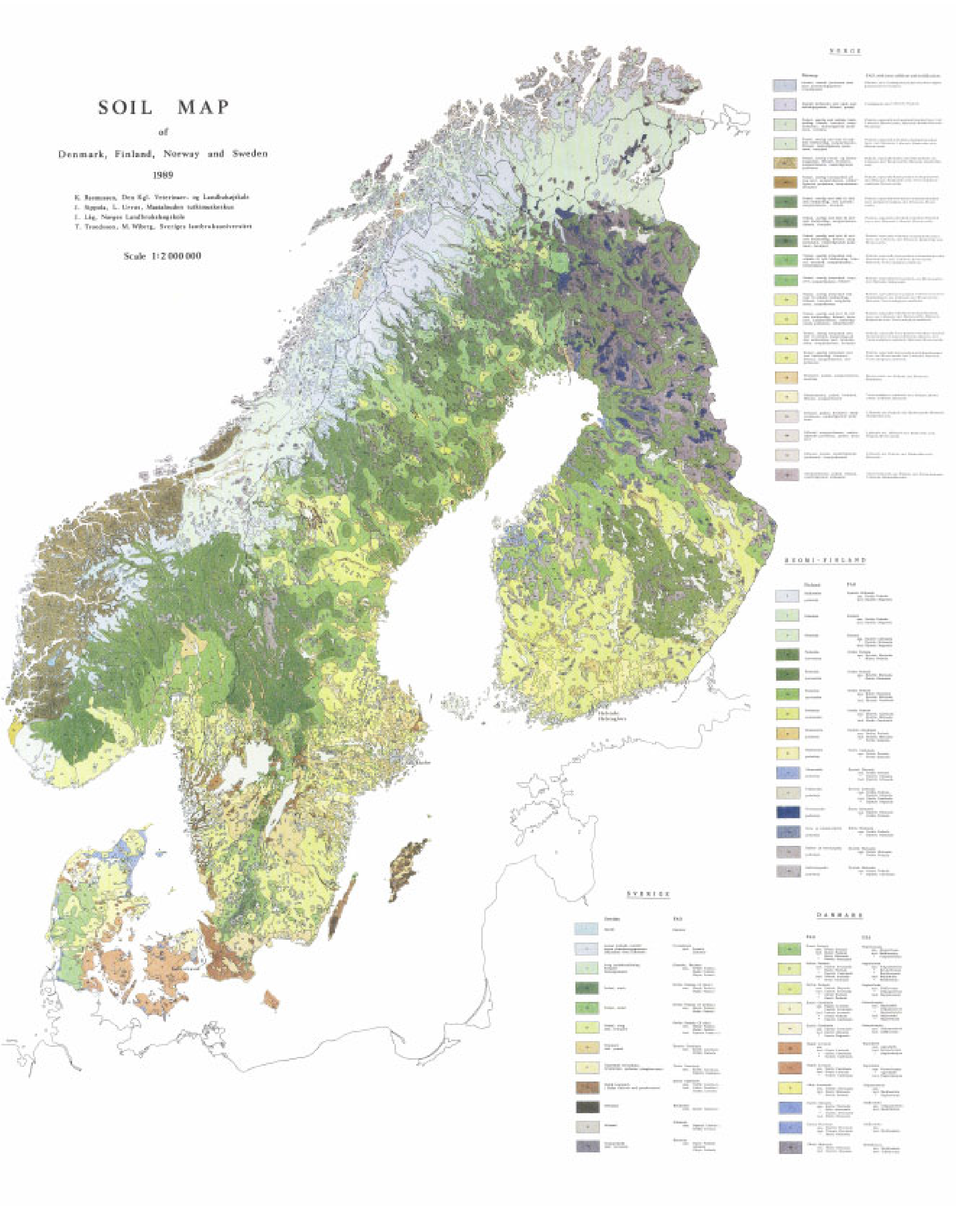

Fig.A2. Soil map of Norway from 1983, scale 1: 2 000 000. Author: J. Låg, Norges Landbrukhøgskole. A scanned version of this map was provided by Kartverket in November 2019.

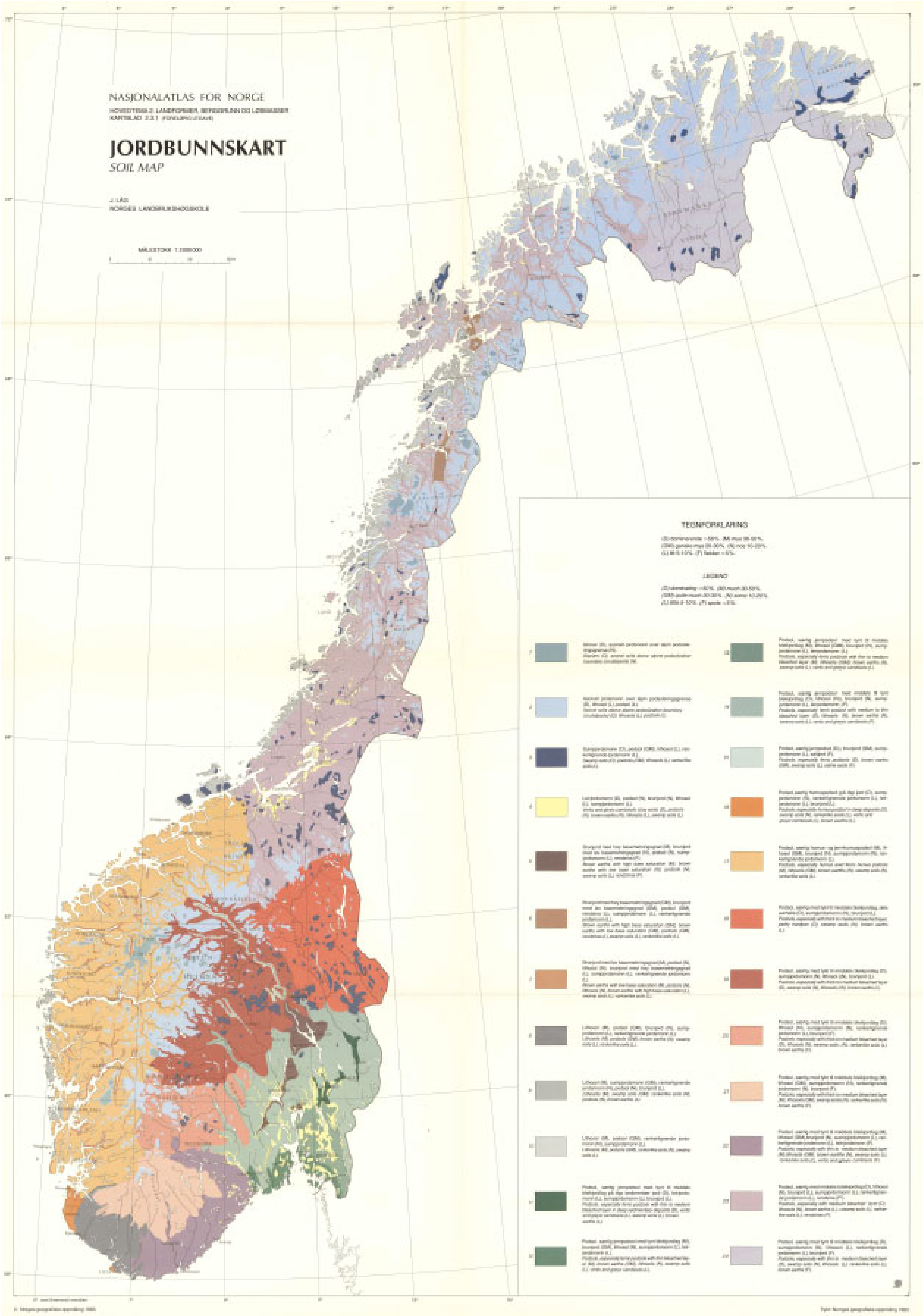

Table A1. Translation of soil types identified in each mapping unit (soil coverage class, in Norwegian) from the 1983-map and their correspondence with WRB-classifications soil types and IPCC soil groups described in table 2.3 from the 2006 IPCC Guidelines/2019 Refinement.

Class id nr. and coverage 1983 map	**Soil types within the mapping units**	**WRB-soil type (translated)**	**IPCC soil group (Table 2.3 in the guidelines)**
1			
D (Dominating >50%)	isbreer	glaciers	No soil
M (Much 30-50%)			
GM (Quite Much 20-30%)			
N (Some 10-20%)	asonalt jordsmonn	cryosols	HAC
L (Little 5-10%)			
F (Spots <5%)			
2			
D (Dominating >50%)	asonalt jordsmonn	cryosols	HAC
M (Much 30-50%)			
GM (Quite Much 20-30%)			
N (Some 10-20%)			
L (Little 5-10%)	lithosol, podsol	leptosols, podsol	HAC, Spodic
F (Spots <5%)			
3			
D (Dominating >50%)	sumpjordsmonn	gleysol/histosol*	Wetland (excluding organic soils)
M (Much 30-50%)			
GM (Quite Much 20-30%)	podsol	podsol	Spodic
N (Some 10-20%)			
L (Little 5-10%)	lithosol, rankerlignende jordsmonn	leptosol, leptosol	HAC
F (Spots <5%)			
4			
D (Dominating >50%)	leirjordsmonn	stagnosol/luvisol¥	HAC

M (Much 30-50%)			
GM (Quite Much 20-30%)			
N (Some 10-20%)	podsol, brunjord	podsol, cambisol	Spodic, HAC
L (Little 5-10%)	lithosol, sumpjordsmonn	leptosol, gleysol/histosol*	HAC, Wetland (excluding organic soils)
F (Spots <5%)			
5			
D (Dominating >50%)			
M (Much 30-50%)	brunjord med høy basemetningsgrad	cambisol	HAC
GM (Quite Much 20-30%)			
N (Some 10-20%)	brunjord med lav basemetningsgrad, podsol	cambisol, podsol	HAC, Spodic
L (Little 5-10%)	sumpjordsmonn	gleysol/histosol*	Wetland (excluding organic soils)
F (Spots <5%)	rendsina	leptosol	HAC
6			
D (Dominating >50%)			
M (Much 30-50%)			
GM (Quite Much 20-30%)	brunjord med høy basemetningsgrad, brunjord med lav basemetningsgrad, podsol	cambisol, podsol	HAC, Spodic
N (Some 10-20%)			
L (Little 5-10%)	rendsina, sumpjordsmonn, rankerlignende jordsmonn	leptosol, gleysol/histosol*, leptosol	HAC, Wetland (excluding organic soils), HAC
F (Spots <5%)			
7			
D (Dominating >50%)			
M (Much 30-50%)	brunjord med lav basemetningsgrad	cambisol	HAC
GM (Quite Much 20-30%)			
N (Some 10-20%)	podsol, lithosol	podsol, leptosol	Spodic, HAC
L (Little 5-10%)	brunjord med høy basemetningsgrad, sumpjordsmonn,	cambisol, gleysol/histosol*, leptosol	HAC, Wetland (excluding organic soil), HAC

	rankerlignende jordsmonn		
F (Spots <5%)			
8			
D (Dominating >50%)			
M (Much 30-50%)	lithosol	leptosol	HAC
GM (Quite Much 20-30%)	podsol	podsol	Spodic
N (Some 10-20%)	brunjord	cambisol	HAC
L (Little 5-10%)	sumpjordsmonn, rankerlignende jordsmonn	gleysol/histosol*, leptosol	Wetland (excluding organic soils), HAC
F (Spots <5%)			
9			
D (Dominating >50%)			
M (Much 30-50%)	lithosol	leptosol	HAC
GM (Quite Much 20-30%)	sumpjordsmonn	gleysol/histosol*	Wetland (excluding organic soils)
N (Some 10-20%)	rankerlignende jordsmonn, podsol	leptosol, podsol	HAC, Spodic
L (Little 5-10%)	brunjord	cambisol	HAC
F (Spots <5%)			
10			
D (Dominating >50%)			
M (Much 30-50%)	lithosol	leptosol	HAC
GM (Quite Much 20-30%)	podsol	podsol	Spodic
N (Some 10-20%)	rankerlignende jordsmonn	leptosol	HAC
L (Little 5-10%)	sumpjordsmonn	gleysol/histosol*	Wetland (excluding organic soils)
F (Spots <5%)			
11			

D (Dominating >50%)	jernpodsol[†]	podsol	Spodic
M (Much 30-50%)			
GM (Quite Much 20-30%)			
N (Some 10-20%)			
L (Little 5-10%)	leirjodsmonn, sumpjord, brunjord	stagnosol/luvisol[¥], gleysol/histosol*, cambisol	HAC, Wetlands (excluding organic soils), HAC
F (Spots <5%)			

12

D (Dominating >50%)			
M (Much 30-50%)	jernpodsol[†]	podsol	Spodic
GM (Quite Much 20-30%)	brunjord	cambisol	HAC
N (Some 10-20%)	lithosol	leptosol	HAC
L (Little 5-10%)	sumpjordsmonn, leirjordsmonn	gleysol/histosol*, stagnosol/luvisol[¥]	Wetlands (excluding organic soils), HAC
F (Spots <5%)			

13

D (Dominating >50%)			
M (Much 30-50%)	jernpodsol[†]	podsol	Spodic
GM (Quite Much 20-30%)	lithosol	leptosol	HAC
N (Some 10-20%)	brunjord	cambisol	HAC
L (Little 5-10%)	sumpjordsmonn, leirjordsmonn	gleysol/histosol*, stagnosol/luvisol[¥]	Wetlands (excluding organic soils), HAC
F (Spots <5%)			

14

D (Dominating >50%)	jernpodsol[†]	podsol	Spodic
M (Much 30-50%)			
GM (Quite Much 20-30%)			

N (Some 10-20%)	lithosol, brunjord	leptosol, cambisol	HAC, HAC
L (Little 5-10%)	sumpjordsmonn	gleysol/histosol*	Wetland (excluding organic soils)
F (Spots <5%)	leirjordsmonn	stagnosol/luvisol¥	HAC

15

D (Dominating >50%)	jernpodsol†	podsol	Spodic
M (Much 30-50%)			
GM (Quite Much 20-30%)	brunjord	cambisol	HAC
N (Some 10-20%)			
L (Little 5-10%)	sumpjordsmonn	gleysol/histosol*	Wetland (excluding organic soils)
F (Spots <5%)	saltjord	regosol	HAC

16

D (Dominating >50%)	humuspodsol	podsol	Spodic
M (Much 30-50%)			
GM (Quite Much 20-30%)			
N (Some 10-20%)	sumpjordsmonn	gleysol/histosol*	Wetlands (excluding organic soils)
L (Little 5-10%)	rankerlignende jordsmonn, leirjordsmonn, brunjord	leptosol, stagnosol/luvisol¥, cambisol	HAC, HAC, HAC
F (Spots <5%)			

17

D (Dominating >50%)			
M (Much 30-50%)	humuspodsol, jernhumuspodsol†	podsol	Spodic
GM (Quite Much 20-30%)	lithosol	leptosol	HAC
N (Some 10-20%)	brunjord, sumpjordsmonn	cambisol, gleysol/histosol*	HAC, Wetlands (excluding organic soils)
L (Little 5-10%)	rankerlignende jordsmonn	leptosol	HAC
F (Spots <5%)			

18

D (Dominating >50%)	podsol (dels med aurhelle)	podsol	Spodic
M (Much 30-50%)			
GM (Quite Much 20-30%)			
N (Some 10-20%)	sumpjordsmonn	gleysol/histosol*	Wetlands (excluding organic soils)
L (Little 5-10%)	brunjord	cambisol	HAC
F (Spots <5%)			

19

D (Dominating >50%)	podsol	podsol	Spodic
M (Much 30-50%)			
GM (Quite Much 20-30%)			
N (Some 10-20%)	sumpjordsmonn, lithosol	gleysol/histosol*, leptosol	Wetlands (excluding organic soils), HAC
L (Little 5-10%)	brunjord	cambisol	HAC
F (Spots <5%)			

20

D (Dominating >50%)	podsol	podsol	Spodic
M (Much 30-50%)			
GM (Quite Much 20-30%)			
N (Some 10-20%)	lithosol, sumpjordsmonn	leptosol, gleysol/histosol*	HAC, Wetlands (excluding organic soils)
L (Little 5-10%)	rankerlignende jordsmonn	leptosol	HAC
F (Spots <5%)	brunjord	cambisol	HAC
21			
D (Dominating >50%)			
M (Much 30-50%)	podsol	podsol	Spodic
GM (Quite Much 20-30%)	lithosol	leptosol	HAC

N (Some 10-20%)	sumpjordsmonn, rankerlignende jordsmonn	gleysol/histosol*, leptosol	Wetlands (excluding organic soils), HAC
L (Little 5-10%)			
F (Spots <5%)	brunjord	cambisol	HAC

22

D (Dominating >50%)			
M (Much 30-50%)	podsol	podsol	Spodic
GM (Quite Much 20-30%)	lithosol	leptosol	HAC
N (Some 10-20%)	brunjord	cambisol	HAC
L (Little 5-10%)	sumpjordsmonn, rankerlignende jordsmonn	gleysol/histosol*, leptosol	Wetlands (excluding organic soils), HAC
F (Spots <5%)	leirjordsmonn	stagnosol/luvisol[¥]	HAC

23

D (Dominating >50%)	podsol	podsol	Spodic
M (Much 30-50%)			
GM (Quite Much 20-30%)			
N (Some 10-20%)	lithosol	leptosol	HAC
L (Little 5-10%)	brunjord, sumpjordsmonn, rankerlignende jordsmonn	cambisol, gleysol/histosol*, leptosol	HAC, Wetlands (excluding organic soils), HAC
F (Spots <5%)	rendsina	leptosol	HAC

24

D (Dominating >50%)	podsol	podsol	Spodic
M (Much 30-50%)			
GM (Quite Much 20-30%)			
N (Some 10-20%)	sumpjordsmonn	gleysol/histosol*	Wetland (excluding organic soils)
L (Little 5-10%)	lithosol, rankerlignende jordsmonn	leptosol, leptosol	HAC, HAC

F (Spots <5%)	brunjord	cambisol	HAC

Notes: *gleysol/histosol: the original class «sumpjordsmonn» is translated into those two possible WRB soil types because the characteristics of these soils could meet the definition of both gleysoils (mineral soils) and histosols (organic soils) in some cases. The chosen correspondence with the IPCC soil group in this case is wetland, if the National Inventory Reporting database does not identify it as an organic soil. A more detailed explanation of this argumentation is provided in section 3.3.1 Special considerations for organic soils.

¥stagnosol/luvisol: the original class «leirjordsmonn» is translated into those two possible WRB soil types because the characteristics of these soils could meet the definition of both stagnosols and luvisols as well as the planosols and retisols/albeluvisols in the classification used in their agricultural land mapped by the Norwegian Agricultural Soil Mapping. This has, however, no implications for the IPCC soil group correspondence, since all these WRB-soil types belong to the High Activity Clay-soils IPCC soil group.

†jernpodsol: for this soil type (a ferric podsol), there were some indications that texture could have been an important parameter to characterize these soils, since classes where they dominate appear in areas with typically sandy soils. However, the information concerning the texture in areas where ferric podzols dominate is inconsistent and therefore we assume that the podsolization process is the most important factor for soil development in these cases and therefore they have been allocated to the Spodic group.

Table A2. Stock Change Factors applied for Croplands.

Cropland Stock Change Factors as provided in Table 5.5 from the 2019 Refinement (Vol.4, Ch5)						
Factor value type	**Level**	**Temperature regime**	**Moisture Regime**	**IPCC defaults**	**Average per factor value type**	**Relative Uncertainty (% of the mean)**
FLU	Long-term cultivated	Cool temperate/boreal	dry	0.77	0.79	6.88
			moist	0.7		
	Perennial/tree crop	Temperate/boreal	dry and moist	0.72		
	Set aside (20 yrs)	Temperate/boreal and tropical	dry	0.93		
			moist/wet	0.82		
FMG	Full	all	dry and moist/wet	1	1.03	9.88
	Reduced	Cool temperate/boreal	dry	0.98		
			moist	1.04		
	No-till	Cool temperate/boreal	dry	1.03		
			moist	1.09		
FI	Low	Temperate/boreal	dry	0.95	1.12	7.82
			moist	0.92		
	Medium	all	dry and moist/wet	1		
	High without manure	Temperate and boreal and tropical	dry	1.04		
			moist/wet	1.11		
	High with manure	Temperate/boreal and tropical	dry	1.37		
			moist/wet	1.44		

Table A3. Stock Change factors applying for grasslands in Norway (provided by Christophe Moni in May 2020). Estimated relative uncertainty for the F_{MG} is 11%.

Grassland type	Stock Change Factors		
	F_{LU}	F_{MG}	F_I
No-till cultivated grass pastures	1	1.14	1
Closed pastures	1	1	1
Open pastures	1	1	1
Coastal Heath	1	1	1

Table A4. The table summarizes data (collections of tables) from 13 old NFI surveys (in Norwegian). Each published set of tables are given after the table. In the notation in the table as well as the left column (descriptions) indications are given on potential ways to combine this old data with the current permanent plot NFI to get more spatially detailed data for the 1991 map.

		Telemark, 1956, Grenland	Agder, 1957	Sør Trøndelag, 1958	Østfold+Akerhus, 1959	Hedmark, 1961	Nord Trøndelag, 1961	Troms, 1962, x (nfi 1961, ikke 1960)	Vestfold, 1962	Hordaland, 1963	Møre Romsdal, 1962	Oppland, 1964	Buskerud, 1965	Nordland, 1966
	was the entire district surveyed?		x	x	x	x	x		x			x	x	
	number of plots (all surveyed variables)	3160	8150	6111	12283	27015	10846	2229	2789	1504	2573	13451	11529	4791
	number of plots (total, i.e. not for all variables)	12275	8150	6111	12283	27015	10846	2229+900	2789			13451	11529	
	ant tabeller / tables (=variables)	11	12	16	16	16	16	9	16	16	16	16	16	16
	jorddybde x takstområde (xx kommune, xxx år)	xx	xx	xx	xx	xx	xx	xxx				x	x	
	jorddypde								x	x	x			x
	humus x takstområde (xx kommune, xxx år)			xx	xx	xx	xx	xxx				x	x	
	humus								x	x	x			x
	humus x bonitet x jorddypde			x		x	x		x	x	x	x	x	x
	humus x bonitet x jorddypde x delfylke				x									
	humus x treslag x jorddypde			x		x	x		x	x	x	x	x	x
	humus x treslag x jorddypde x delfylke				x									
	jorddybde x bonitet	x		x		x	x	x	x	x	x	x	x	x
	jorddybde x bonitet x delfylke		x		x									
	jorddybde x bonitet x helling	x												
	jorddybde x vegetasjonstype	x		x		x	x		x	x	x	x	x	x
	jorddybde x vegetasjonstype x delfylke		x		x									
	jorddybde x treslag	x		x		x	x		x	x	x	x	x	x
	jorddybde x treslag x delfylke		x		x									
	jordart x jorddypde						x		x	x	x	x	x	x
	jordart (xd delfylke)	xd												
	jordart x helling									x				
	jordart x HOH (xx hoh)			xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx
	jordart x delfylke		x											
	jordart x partikkelst.fordeling			x	x	x	x	x	x	x	x	x	x	x
	partikkelst.fordeling (xd delfylke)	xd												
	partikkelst.fordeling x delfylke		x											
	jordart x stein+blok		x	x	x	x	x	x	x	x	x	x	x	x
	jordtype (xo overstyre kart)	xo						xoår	xo	xo	xo			xo
	jordtype x takstområde (xo kommune)					xx	xx					xx	xx	
	jordtype x HOH (xx hoh)			xx										
	jordtype x delfylke (xo overstyre kart)		xo											
	jordtype x delfylke x HOH (xx hoh)				xx									
	jordtype x bonitet	x		x		x	x	x	x		x	x	x	x
	jordtype x bonitet x delfylke		x		x									
	jordtype x bonitet x jorddypde			x		x	x		x	x	x	x	x	x
	jordtype x bonitet x jorddypde x delfylke		x		x									
	jordtype x vegetasjonstype (xxd delfylke) (xx approx wet)	xxd		xx		xx	xx	xx	xx	xx	xx	xx	xx	xx
	jordtype x vegetasjonstype x delfylke (xx approx wet)		xx		xx									
	jordtype x treslag (xd delfylke)	xd		x		x	x		x	x	x	x	x	x

	jordtype x treslag x vegetasjonstype x delfylke				x									
	jordtype x treslag x vegetasjonstype			x		x								
	jordtype x treslag x delfylke		x		x									

Noter til tabellen:

Fargekoder:

Rødbrun: humus

Grå: jorddybde

Blå: jordart

Hvit: partikkelst

Brun: jordtype

Den lysgrønne og rosa del av tabelle til høyre antyder der det største potensiale for å samkjøre data kan finnes (for eks. der hvor jordtype kan lokaliseres til en geografisk enhet).

Parametre:

Jorddybde	soil depth
Taksområde	survey district
Commune	municipality
Bonitet	site index
Del-fylke	sub-survey-district
År	year
Treslag	tree species
Helling	slope
Vegetasjonstype	vegetation type
Jordart	parent material
Partikkelstørrelsesfordeling	texture
Stein + blok	coarse fragments
Jordtype	soil type (coarse and non-modert scheme)
HOH	height above sea level

Publications:

J. Låg: An Inexpensive General Survey of the Norwegian Forest Soils

Acta Agric Scand 35:321-328, 1985. Jordundersøkelsens særtrykk nr. 333 (eller: 33(3)), 1985.

J. Låg. Taksering av norges skoger. Undersøkelse av jorda i skogene i Telemark fylke (nb deler).

Jordundersøkelsens særtrykk nr. 27, 1956.

J. Låg. Undersøkelse av jorda i skogene i Agder (nb hele).

Jordundersøkelsens særtrykk nr. 35, 1957.

J. Låg. Undersøkelse av jorda i skogene i Sør Trøndelag fylke (nb hele).

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J. Låg. Undersøkelse av jorda i skogene i Hedmark (nb hele).

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J. Låg. Undersøkelse av jorda i skogene i **Nord Trøndeland fylke (nb hele)**.

Særtrykk av «taksering av Norges skoger» Nord Trøndelag fylke 1961. Jordundersøkelsens særtrykk nr. 77, 1961.

J. Låg. Undersøkelse av skogjord i **Troms (nb deler)**.

Jordundersøkelsens særtrykk nr. 79, 1962.

J. Låg. Undersøkelse av jorda i skogene i **Vestfold fylke (nb hele)**.

Særtrykk av «taksering av Norges skoger» Vestfold fylke 1962. Jordundersøkelsens særtrykk nr. 81, 1962.

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Særtrykk av «taksering av Norges skoger» Deler av Hordaland fylke 1963. Jordundersøkelsens særtrykk nr. 85, 1963.

J. Låg. Undersøkelse av skogjord i **Møre og Romsdal (nb deler)**.

Særtrykk av «taksering av Norges skoger» Møre og Romsdal fylke 1962. Jordundersøkelsens særtrykk nr. 89, 1963.

J. Låg. Undersøkelse av jorda i skogene i **Oppland fylke (nb hele)**.

Særtrykk av «taksering av Norges skoger» Oppland fylke 1964. Jordundersøkelsens særtrykk nr. 98, 1964.

J. Låg. Undersøkelse av jorda i skogene i **Buskerud fylke (nb hele)**.

Særtrykk av «taksering av Norges skoger» Buskerud fylke 1965. Jordundersøkelsens særtrykk nr. 110, 1965.

J. Låg. Undersøkelse av skogjord i **Nordland (nb deler)**.

Særtrykk av «taksering av Norges skoger» Del av Nordland fylke 1965. Jordundersøkelsens særtrykk nr. 119, 1966.

Publications indicated in the above:

I særtrykket for hedmark nevnes en planlagt (?) publikasjon: «Jordbunnsbeskrivelse nr. 46. Medd. Fra Det norske Skogforsøksvesen. Nr. 59.»

I særtrykket for østfold, akershus nevnes en planlagt (?) publikasjon: «Jordbunnsbeskrivelse nr. 45. Medd. Fra Det norske Skogforsøksvesen. Nr. 54.»

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I særtrykket for agder nevnes en planlagt (?) publikasjon: «Jordbunnsbeskrivelse nr. 41. Medd. Fra Det norske Skogforsøksvesen. Nr. 49.»

I særtrykket for telemark nevnes en planlagt (?) publikasjon: «Jordbunnsbeskrivelse nr. 40. Medd. Fra Det norske Skogforsøksvesen. Nr. 45.»

Appendix 2.1. Digitizing Norwegian/Scandinavian 1:2M analog soil maps from 1983/1991

A detailed description of the digitizing process of both maps (the 1983-map and the 1991-map) is provided here. For the 1991-map, only the Norwegian part is within the scope of the digitizing.

Level of detail and accuracy

The main land of Norway is 324 000 km², of which approx. 1/3 is mountainous with little soil coverage. Compared to the varied and rough topography and geological variation in most parts of Norway, the analog maps have little detail. Overall, the maps divide Norway into >20 larger soil-type coverage regions, with some smaller distinct "anomalies" within. There are isolated features (polygons) down to approx. 4 km², which mainly represent distinct mountains and marchland.

Both maps are available as tiff files in full color with 300 dpi. The 1983-map was provided (scanned) by Kartverket (The Norwegian Mapping Authority) upon request from NIBIO, while the 1991-map was provided by I. Callesen (soil scientist at University of Copenhagen in Denmark).

The pixel size of the scanned maps is approx. 170 meters. The line width of boundaries drawn on the 1991-map is approx. 0.4 millimeters at 1:2M, 4-5 pixels in the tiff files, and 800 meters in the terrain. The 1983-map does not have lines separating the soil coverage classes, but uses quite distinct and dark colors to identify them. However, the printed 1983-map has some misalignment between printing colors or rasters, which results in the same delineation accuracy as the 1991-map.

The 1991-map was preferred for digitizing, since it is visually more comprehensive and the soil coverage-classes are in essence the same as in the original 1983-map (see section 3.1.2 for details). Further the cartography using lines, light colors, and soil-type coverage class numbers made it more legible in digitizing mode. The light color rasters were quite similar for some soil types. The possibility of doing automatic feature extraction was discarded due to the blurry character of the image files.

Georeferencing

QGIS was selected as georeferencing and digitizing tool, based on prior experience. The printed maps do not have information on datum or map projection used. A reasonable assumption is that datum was ED50 with projection UTM 33. The target coordinate system chosen was Euref89 UTM 33 (EPSG:25833), which is considered practical for small scale Norwegian maps. LAEA Europe (EPSG:3035) might be ideal, but would require more warping if the original was in fact UTM33.

Norway covers UTM zones 32 to 35, but the projection errors at the extremes (SW and NE parts of Norway) using modern transformation tools are far less than the line thickness of the original map. There are some visible paper bends in the scanned maps, which may affect the georeferencing accuracy.

An initial georeferencing of the 1991-map was done using Helmert transformation and only 7 distinct landmarks (target coordinates recorded from modern topographic map in Euref89/UTM33 at scale 1:100K) as control points. The reported accuracy of fit was 14 pixels, or more than 2 km. The result was homogenous all over Norway, with typical deviation of 1-2 km when checking against a modern map. Some larger deviations were observed at different locations. Using a polynomial transformation improved the reported accuracy, but not the result.

To check if the 1983-map would give a better result it was georeferenced. It has meridians at 2-degree intervals and the coordinates of some (~15) of these were transformed from ED50 degrees to Euref89/UTM33 and used as control points. The meridians are 2-3 pixels wide and the crossings in the image file were digitized with better precision than the landmarks. The reported accuracy of fit was

2 pixels, or about 0.4 km, which is very good. However, the deviations observed when checking against modern map were similar to the 1991-map.

Based on this, we decided to digitize the-1991 map. Improved georeferencing accuracy could be achieved using more land marks as control points, with the option to discard outliers. Further, the south, middle, and northern part of Norway could be referenced separately. When using this approach, the reported accuracy of fit was reduced to 7-8 pixels. The observed deviations were reduced accordingly, but large local deviations were still observed.

Looking in more detail at the deviations revealed that the local inaccuracies came from the rather imperfect drawing of the original maps. For example, the delineation of one fjord could fit perfectly, while another fjord only 50 km away was 2 km misplaced. The shape of some features were good generalizations of reality, while others were deformed. Both maps appeared to have parts with "sloppy" cartographic work. Compared to modern land cover maps the level of detail and accuracy is very low. However, the categorization of soil type provided as soil-type coverage classes is "unique". These qualities were important for the georeferencing and digitizing work, as well as the later use of the data.

Digitizing

The QGIS project for digitizing was set up in Euref89/UTM33 with the following elements:

- WMS with the official topographic maps of Norway at any scale.
- The national border of Norway (including offshore) as one line (ring) representing the area of interest.
- 3 versions of georeferenced 1991-map.
- 1 version of georeferenced 1983-map.

Three shapefiles for digitized simple features: 1) lines for polygon boundaries; 2) points with the soil-type coverage class code for any area; 3) polygons with soil-type coverage class code.

A process (a script using PostgreSQL with the PostGIS extension) creates the soil type map as a set of simple features polygons (no overlap and gaps) with soil type codes. In short, the shapefiles were imported and run through ST_Polygonize. The script could run at any stage and took only seconds. The resulting data were shown in QGIS, to keep track of progress, and help identify blunders.

Several principles were considered for digitizing:

- The data should be a true representation of the 1991 map, not trying to "improve" its geometric accuracy or thematic content.
- The lines should be within the boundaries (~4 pixel wide) of the scanned map, except where the 1991 map obviously conflicts with the real landscape.
- Soil-type coverage class polygons at the coast were extended to the nautical border, to cover islands not shown in the 1991-map.
- Lakes in the 1991 map should not be digitized.
- Where in doubt of soil-type coverage class or geometry the 1983-map should be consulted.

In the flat parts of Norway there were few obvious conflicts, but lines were to some extent adapted to follow rivers, lakes, valleys etc. in the modern topographic maps. In the fjord and mountain regions, there were many conflicts. The distance between fjords could be a few kilometers, with high mountains in between, while inaccuracy of 1991-map was 2-3 km as well. Thus, many adaptions were needed, in order to represent the intended "meaning" of the 1991-map. These adaptions were subjective, and not always obvious. They were also time-consuming, with need for zooming in and out to understand the maps. However, only one person did the digitizing, in order to keep judgment consistent.

Finally, in the 1991-map, the entire metropolitan area of Oslo was drawn as urban area, without soil type information. This cartography is not used any other place in Norway. Here, we digitized the soil classification from the 1983-map to override this anomaly.

We checked the resulting dataset in PostgreSQL for inconsistent coding or geometry using PostGIS functions.

Final version

When digitizing was complete, the result was systematically reviewed with different backgrounds. It was checked against the 1991-map for omissions or wrong soil categorization. It was also checked against the 1983-map, and any conflict was investigated. Finally, it was checked against modern topographic and land cover maps, and potential breach of principles were investigated.

Along the national border, there were small areas with soil-type coverage classes originating from the Swedish and Finish legends of the 1991-map. These were translated to Norwegian soil types, based on their descriptions and geographic location within the neighboring countries (see Appendix Fig.A1).

The dataset was overlaid with a land cover map (AR250) to exclude sea and lakes from the soil-type coverage class polygons.

The final version was provided as a set of ESRI Shape-datasets.

Appendix 2.2. Procedure for differentiation between mineral and organic soil in NFI-plots (provided by Rune Eriksen, October 2020)

SOC_{REF} på Landsskogtakseringens prøveflater.

Framgangsmåte ved beregning

Organisk eller mineraljord

Prioritering som følger

1 Registrering på prøveflata

2 Jordsmonnskart

3 AR5 kart

Registrering av mineraljord/torv finnes for alle flater på arealtypene; skog, annet tresatt areal og snaumark.

(med unntak av de som har arealanvendelse som gir "Settlements" f.eks. kraftlinjer)

For arealtypen kystlynghei er det ikke registrert mineraljord/torv, men det er en forutsetning for typen at det er mineraljord.

Der prøveflata ikke er oppsøkt i felt er mineraljord/torv bestemt ut fra kart og flybilder.

For beite og dyrka mark (som ikke har feltregistreringer) ble mineraljord/torv satt:

1 For Dyrka mark eller beite som er kommet til etter 1990, ble feltregistrering fra prøveflata før overgangen brukt.

2 Jordmonnskartet. Overlayet var gjort med sirkler med ca 14 m radius. (Det kartlagte arealet er stort sett fulldyrka, men det finnes også beite og overflatedyrka som er kartlagt)

For prøveflater (flatedeler) på dyrka mark ble prøveflata kodet som organisk hvis >= 50 % av sirkelens kartlagte areal var organisk (Histosol)

For prøveflater (flatedeler) på beite ble det gjort forutsetninger for kodingen:

Hel flate på beite brukte jordsmonnskartet dersom mer enn 304 m2 (halve sirkelen) var kartlagt (dvs at beitet må ha vært med i kartleggingsarealet)

Delt flate på beite brukte jordsmonnskartet dersom mer enn 500 m2 (82% av sirkelen) var kartlagt

3 AR5. Overlay med sirkler som for jordsmonnskartet. I analysen er ARTYPE (arealtype)og GRUNNF (grunnforhold) brukt

a Dyrka mark. Der det fantes ARTYPE 21 (fulldyrka) innenfor sirkelen, ble areal med grunnforhold = 45 (organisk) i % av arealet ARTYPE 21 brukt

b Dyrka mark. Der det ikke fantes ARTYPE 21 innenfor sirkelen ble ARTYPE 22 (overflatedyrka) og eller ARTYPE 23 (Beite) brukt på samme måte som over.

c Dyrka mark. Der det ikke fantes ARTYPE 21,22,23 innenfor sirkelen ble alle artyper (som har grunnforhold registrert) brukt.

d Manuell gjennomgang av 7 flater som hadde blitt bygget ned etter 1990. Grunnforhold fra original ØK (økonomisk kartverk).

Beite etter samme prinsipp som over, men med ARTYPE 22 og 23 som første prioritet.

SOC_{REF}

Data med SOC_{REF} pr jordtype og klimasone ligger i to lookuptabeller;

lskov_1990_jmkart_lu

lskov_1990_jordkart91_lu

Data med flateid og klimasone ligger i tabellen;

lskov_1990_klimasone_ipcc

Beregning av SOC_{REF}

Det er laget to view (spørringer) som beregner SOC_{REF} på alle prøveflater

lskov_1990_socrefjm_v

lskov_1990_socrefj91_v

For alle forekommende jordtyper (med unntak av Histosol) finner man en SOC_{REF} i lookuptabell for riktig klimasone og vekter dette med arealet

for jordtypen innenfor sirkelen (j91 - r = 6 km, jm - r=14 m)

Til slutt et view som plukker SOCREF fra riktig kart og for prøveflater i relevante landuseklasser med mineraljord.

lskov_1990_socref_fid_luc_v

Dette viewet inneholder alle forekommende kombinasjoner av flateid, landuseclass og mito (mineraljord/torv) samt SOCREF fra riktig kart.

Jordsmonnskartet er brukt for Dyrka mark og beite - der det finnes etter samme kriterier som beskrevet under tilordning til mineraljord/torv over.

Prøveflater med vegetasjonstype '0' (uten vegetasjon) og som ikke har treregistreringer er kodet som Landuseclass 'Other', og får SOCREF=0

Øvrige flater på mineraljord (utenom Settlements og vann) får beregnet SOCREF basert på jordtyper og klimasone

1 For Dyrka mark og beite brukes jordtyper fra jordmonnskartet der de finnes. Kriteriene for å bruke jordsmonnskartet er som for å finne mineraljord/torv over

NIBIO
NORSK INSTITUTT FOR
BIOØKONOMI

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.

Forsidefoto: Romstad/Namsos kommune – Førsvoll/Rennesøy kommune - Hølonda/Melhus kommune – Elvestad/Hobøl kommune. Fotograf: Oskar Puschmann

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