London Group Meeting 2024
Issue Paper: Soil Health

System of Environmental Economic Accounting: Soil Health

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1 Introduction

This document sets out the implementation plan to develop a system of environmental economic accounting – otherwise, referred to as natural capital accounting (NCA) – for soil quality in the United States (U.S.). A strategy to develop a U.S. system of natural capital accounts across a broad set of natural resources is described in the National Strategy to Develop Statistics for Environmental-Economic Decisions (released in January 2023 and hereafter referred to as the "National Strategy). The strategy outlines a plan for an all-of-government approach to increase the understanding of the economic value of the nation's environmental and natural resources to provide linkages with the current U.S. system of national accounts (SNA). The soils account appears in the National Strategy as a Phase III account with a research period beginning in 2023, a prototype account appearing in 2029, and core statistical series inclusion (finalized methods) by 2035.

The U.S. Department of Agriculture's (USDA) Economic Research Service (ERS) is coordinating the department's efforts to develop NCA. The ERS, in conjunction with the Natural Resources Conservation Service (NRCS), the Farm Service Agency (FSA) and the U.S. Forest Service (FS), will lead in the development of the soils accounts and contribute to the accounting of soils-related ecosystem services in other accounts. To the degree possible, these accounts will follow standards set out in the United Nation's System of Environmental-Economic Accounting (SEEA) framework.

This implementation plan contains many acronyms, so as a quick reference we offer definitions of the acronyms in Table 1.

Table 1. Nomenclature

Acronym	Definition
NCA	Natural capital accounting
SNA	System of national accounts
USDA	U.S. Department of Agriculture
ERS	USDA, Economic Research Service
NRCS	USDA, Natural Resources Conservation Service
USFS	USDA, U.S. Forest Service
FSA	USDA, Farm Service Agency
SEEA	System of environmental-economic accounting
SSURGO	Soil Survey Geographic database
STATSGO	State Soil Geographic database
NRI	Natural Resources Inventory
FIA	Forest Inventory and Analysis

2 The Importance of Soils Accounts

Soil health is the foundation of the food system and productive farming practices in the U.S. Fertile soils provide essential nutrients to plants and other living organisms.

A healthy soil is a living, dynamic ecosystem, teeming with microscopic and larger organisms that perform many vital functions including converting decaying matter to plant nutrients; controlling plant disease; controlling insect and weed pests; improving soil structure, and ultimately improving crop production.

Healthy soils also contribute to mitigating climate change by maintaining or increasing its carbon content. Today, the Earth's soils store about 2500 gigatons of carbon – that's more than three times the amount of carbon in the atmosphere and four times the amount stored in living plants and animals (Cho, 2018). Moreover, soils remove about 25 percent of the world's fossil fuel emissions each year. The amount of carbon that are absorbed by soils and length in which the carbon can be stored is mostly determined by how the land is managed.

Soil health is defined as the continued capacity of soil to function as a vital living ecosystem. Soil does this by performing five essential functions: (i) regulating water; (ii) sustaining plant and animal life; (iii) filtering and buffering potential pollutants; (iv) cycling nutrients: and, (v) providing physical stability and support (Natural Resources Conservation Service, 2023).

Current soil health research has determined how best to manage soil in a way that improves its functions. The four principles of to manage soils are: (i) maximize the presence of living roots; (ii) minimize disturbance; (iii) maximize soil cover; and, (iv) maximize biodiversity (Natural Resources Conservation Service, 2023a).

The U.S. has an intimate history with soil health. In the 1930s, a series of droughts combined with poor soil management led to the Dust Bowl in the Great Plains. Severe soil erosion and horrific dust storms wreaked havoc for nearly a decade. In reaction to the Dust Bowl, Congress passed the Soil Conservation and Domestic Allotment Act, which directed the Secretary of Agriculture to establish the Soil Conservation Service as permanent agency in the USDA. The Soil Conservation Service offered technical and financial assistance to farmers to adopt better soil conservation and management practices. In 1994, Congress changed the name of the Soil Conservation Service to the Natural Resources Conservation Service to reflect the broadening scope of the agency's mission.

According to the National Science and Technology Council (2016), soil is one of the least recognized types of natural resources (as opposed to water, air, or forests), and the benefits of soils are more likely to be recognized after they have been degraded (through erosion) or after extreme events.

New pressures on soil resources have emerged with the co-development of new crop varieties and the expansion of high-yield agriculture into more arid regions (National Science and Technology Council, 2016). These new developments threaten soil resources that formerly had been managed less intensively. Moreover, as urban populations continue to expand, the demand for housing development has increased the amount of impervious land covers that present challenges for soil and water management.

Soil degradation is the process of rendering a soil incapable for providing its expected level of ecosystem services. Degradation reduces the availability of soils for food and fiber production, water filtration and storage, carbon sequestration, and other important ecosystem services (National Science Technology County, 2016). Often, degraded soils can be remediated through improved management practices and soil amendments. Changes in management can halt or reverse soil organic matter losses. Examples of management include land use change from cropland to perennial grass cover associated with the Conservation Reserve Program (Gebhart et al., 1994).

Soil loss can be construed as the most extreme type of soil degradation. Soil loss occurs primarily through wind and water erosion. The estimated rate of erosion on the cropland in the U.S. is, on average, about 4.6 tons per acre per year (National Resource Inventory, 2017). The estimated losses are not evenly distributed across the U.S., and some areas of the country experience losses of twice that amount.

According to the Rockefeller Foundation (2021), the external costs of soil erosion in the U.S. are an estimated $67 billion per year.

3 U.S. Federal Data on Soils

The primary source of soil information is the Soil Survey Geographic database (SSURGO), which is accessible through the USDA’s Web Soil Survey. Maintained by the NRCS, the database contains hundreds of estimated properties of soil landscapes and components that cover over 90 percent of the continental U.S. (Natural Resources Conservation Service, 2023b). The State Soil Geographic database (STATSGO) provides a smaller set of estimated properties for the entire country.

NRCS also maintains the Natural Resources Inventory (NRI), which is a longitudinal survey of the nation’s land-use characteristics. Current NRI estimates cover the contiguous states, Hawaii, Alaska, and parts of the Caribbean. Information collected includes land cover and use, water and wind erosion, wetland characteristics, and soil properties. However, NRI is principally a land-use database, not a soil-property database, therefore it lacks detailed information on soil characteristics.

The U.S. Forest Service leads the Forest Inventory and Analysis (FIA) program, which produces an annual survey of U.S. forests and forest soils. In addition, FIA reports on land-cover change, carbon sequestration, and the effects of pollution and wildfires.

Several public-private collaborations aggregate and analyze soil data. For example, the International Soil Carbon Network (ISCN) is a platform to integrate global data on soil carbon measures. ISCN partners with the U.S. Global Change Research Program (USGCRP) and the National Ecological Observatory Network (NEO).

Other federal agencies including the Environmental Protection Agency (EPA), the Department of Energy (DOE), and others host databases applicable to soils properties and quality. Other sources include the Soil Moisture Active-Passive (SMAP) satellite, which is designed to measure soil moisture to a depth of five centimeters.

An important component of a planned interagency approach to measuring and managing soil resources will be the coordination of these disparate datasets across Federal agencies to ensure that the data is discoverable, accessible, and usable for purposes of information acquisition and analysis to inform policy decisions.

4 State of Work on Soils

4.1 Literature Review

Before exploring soil health measurements within the SEEA framework, we start here by offering a non-exhaustive review of the peer-reviewed literature on soil health from an applied economics perspective.

Several studies over the past couple of decades have explored the value of soil health based on U.S. federal government conservation programs and farm-level adoption of soil health practices, including conservation tillage and cover cropping, among others. Conservation tillage, or minimum tillage, is broadly defined as a farming practice that involves leaving no less than 30 percent of plant residue on the soil after harvest (U.C. Sustainable Agriculture Research and Education Program, 2017). This practice reduces the volume of soil disturbance, thereby preserving surface residues, which enhances soil aggregation, promotes biological activity, and increases the water holding capacity and infiltration rates.

Cover cropping is broadly defined as a farming (or gardening) practice in which a farmer grows a seasonal soil cover crop (grasses, legumes, and forbs) between the planting of two cash (commodity) or forage crops (USDA Economic Research Service, 2024). Cover cropping helps to slow soil erosion, improve soil health, enhance water availability, smother weeds, control pests and diseases, and increase biodiversity (Clark, 2015).

Chen et al. (2021), using remotely-sensed tillage practice data, explored the effects of conservation tillage on county average corn (maize) and soybean yields across 646 counties within 12 states of the Corn Belt region of the U.S. They found no evidence that conservation tillage negatively affects yields, and they found that conservation tillage can mitigate the impact of drought on soybean yields.

Chen et al. (2022), using remotely-sensed cover crop practice data, found that U.S. Midwest counties with higher cover crop acreage had statistically lower soil erosion level, but the magnitudes of the estimated effects were modest.

In a follow-up study, Chen et al. (2023), using remotely-sensed tillage practice data and the Iowa Farmland Values Survey, found that an increase in no-till adoption rates had a statistically significant positive effect on county-level agricultural land values.

Won et al. (2024) found that counties with higher cover crop adoption rates tend to have lower levels of crop insurance losses due to prevented planting. The resulting reduction in prevented planting risk also becomes larger with longer term, multiyear cover crop use.

Adler et al. (2020) examined the impact of cover crops on crop production and soil nutrient loss in conjunction with conservation tillage systems (i.e., no-till or reduced tillage) based on a two-year field experiment in Missouri. They found that cover crops were an effective tool for reducing discharge and soil nutrient loss.

Blanco-Canqui et al. (2015) studied the cumulative effects of cover crops on soil physical properties based on a fifteen-year field experiment of cover crops in Kansas. They found that cover crops significantly impacted soil physical properties by increasing soil organic matter concentration.

Analysis by Schoengold et al. (2015) found that recent disaster and indemnity payments are associated with an increase in the use of no-till and a decrease in the use of conservation tillage. Their findings show the unintended impacts of changes to agricultural policies (disaster payments and crop insurance) on the use of on-farm conservation practices.

Dominati et al. (2010) presented a framework for soils natural capital and ecosystem service quantification. They're framework consists of five components. One, soil natural capital as characterized by standard soil properties. Two, the processes behind soil natural capital formation, maintenance, and degradation. Three, anthropogenic and natural drivers of soil processes. Four, providing and regulating soil ecosystem service. Five, human needs fulfilled by soil ecosystem services.

Brady et al. (2015) devised economic values associated with soil ecosystem services in agriculture. To estimate the economic value of soils, they used an economic production function approach based on the assumption of profit maximization. They fit the model with data from long-term field experiments within different sites in Europe and the U.S.

Pieralli (2017) developed a non-monotonic economic measure of soil quality. The method uses linear programming to obtain a measure of soil quality based on aggregating quantitative soil characteristics. The modeling results indicate that soil carbon and clay content have a negative marginal effect on soil quality when concentrations of soil carbon cross a certain threshold.

Oldfield et al. (2019) conducted a meta-analysis of the relationship between soil organic matter and crop yields. They argue that although soil organic matter is a key determinant of soil health, its relationship with crop yield is ambiguous due to differences in soils, climates, and farming systems. They found that yields for maize and wheat were on average greater with high concentrations of soil organic carbon; however, the yield increase levels off at about two percent soil organic carbon.

In a follow-up study, Oldfield et al. (2020) examined the relationship between soil organic matter on crop growth. Specifically, they found that high concentrations of soil organic matter (SOM) led to greater crop productivity (measured as aboveground biomass) up to a threshold of five percent, after which productivity declined across all treatment types. They conclude that improvements to soil properties did not translate to gains in productivity at the highest level of SOM, implying that there is a SOM threshold to crop productivity.

Wood and Blankinship (2022) offered a comprehensive overview of how to define "soil health." They review three common indicators: the Comprehensive Assessment of Soil Health, the Soil Health Institute's Tier 1 indicators, and the USDA Soil Health Indicators. Based on this review, they develop a framework for an improved understanding of soil health measurement, including directional accuracy, quantified outcomes, functional forms, and links to management. Moreover, they argue for new ways to conceptualize soil health measurements, including innovative measures beyond field scale observations, innovative measures for natural ecosystems, and aggregating data across multiple sources, among others.

A report by the Rockefeller Foundation (2021) estimated that the external costs of soil erosion in the U.S. is about US$67 billion per year. Similarly, A European Commission analysis found that soil erosion has outstripped soil formation across the European Union, and the costs of soil loss was estimated to be about US$ billion per year (Panagos et al., 2015). Based on these findings, Obst (2015) argued that soil health should be better integrated into the System of Environmental Economic Accounting.

Raffeld et al. (2024) examined how increasing interest in voluntary soil carbon markets have led to new soil carbon measurement, reporting, and verification (MRV) protocols by carbon registries. They explored two types of methods for measuring soil carbon – fixed-depth and equivalent soil mass – using data from the University of California, Davis's Century Experiment and the University of Wisconsin Madison's Wisconsin Integrated Cropping Systems Trial. They concluded that the equivalent soil mass measure, sampled to 60 cm, should be considered the best practice for quantifying the change in soil organic carbon stocks on an annual basis.

Guerra et al. (2024) developed a framework for a national assessment of soil biodiversity to better understand the current state and trends of soil biodiversity, identify the main drivers of change, estimate impacts of soil biodiversity loss, and explore the potential pathways for conservation and sustainable governance.

4.2 SEEA Framework

Despite the advance in soil science research from a natural capital perspective, the soils accounts remain an underdeveloped part of the SEEA framework (Obst, 2015).

Nonetheless, guidance for accounting for soil resources is offered in the SEEA central framework (United Nations, 2014). The SEEA framework identifies the many dimensions of soils research. For example, soil resources can provide information on the area and volume of soils lost due to erosion or made unavailable by changes to land cover. However, the central framework posits that accounting for soil types, nutrient content, carbon content, and other characteristics is more relevant for a detailed examination of the health of soil systems.

The SEEA framework offers characterizations of soil resources needed for the establishment of a soils account. The framework offers the following observations, which are abbreviated here for the sake of exposition.

1. Different types of soil are defined in reference to their components and properties.
2. Various soil types can be defined using information on different combinations of soil components and properties.
3. Soil resources are measured through a series of inventory processes or surveys.
4. Measures of soil quality or value can be developed using a range of approaches.
5. The availability of the suite of measures varies between and within geographic boundaries.

The central framework suggests that an initial accounting exercise should include measures of the area and volume of soil resources. Table 2, derived from the central framework, offers a potential starting point for account entries of soils as a physical asset.

Table 2. Physical asset account for the area of soil resources (acres or hectares)

	Type of soil resource	**Total area**
Opening stock of soil resources		
Additions to stock		
Change to land cover		
Change to soil quality		
Change to soil environment		
Total additions to stock		
Reductions in stock		
Change to land use		
Change to soil quality		
Change in soil environment		
Total reductions to stock		
Closing stock of soil resources		

In terms of the accounting entries, the central framework advocates that the focus be placed on the area of different soil types at the beginning and end of the accounting period. Different scopes of soil resources may be measured depending on the purpose of the analysis. For example, an analysis of carbon sequestration in soils may be appropriate.

The table makes a distinction between additions and reductions due to changes in land cover. For example, a loss of soil resources for agriculture because of urban expansion. Other deviations include changes to soil quality (e.g., compaction or acidification), and changes to the soil environment (e.g., desertification or land clearing).

In addition to the asset account, there may be further interest in tabulating types of soil resources by type of land use or land cover at a particular point in time. Such an approach may help to determine whether various types of land use are being undertaken on high-quality or marginal soils.

The central framework suggests a second stage in accounting, which entails measuring the volume of soil resources. Such an approach may enable an assessment of the extent of erosion and the impact of major disasters such as flooding or drought in addition to an assessment of soil depletion. A model asset account for volume of soil resources is offered in Table 3.

Similar to the asset account for the area, the table is structured to show the opening and closing volumes and the changes in the volume of the soil. The table can account for the movement of soil through natural processes (such as wind or water) in which soil is lost in one area but deposited in a different area. Soil erosion, on the other hand, could be considered a reduction in the stock. The soil resources can be classified by soil type; however, it may be meaningful to structure the changes in volume by geographic region or by land use. Changes in the volume should be recorded when soil is excavated and moved for various reasons such as for building levies and dykes, for land reclamation, or for road construction. According to the central framework, the loss of top layers of soil due to extraction should be recorded as permanent reductions in soil resources.

Table 3. Physical asset account for the volume of soil resources (acres or hectares)

	Type of soil resource	**Total volume**
Opening stock of soil resources		
Additions to stock		
Soil formation and deposition		
Upward reappraisals		
Reclassifications		
Total addition to stock		
Reductions in stock		
Extractions		
Soil erosion		
Catastrophic losses		
Downward reappraisals		
Reclassifications		
Total reductions to stock		
Closing stock of soil resources		

4.3 Other Aspects in Accounting for Soil Resources

In the SEEA central framework, soil resources are accounted for in the physical supply and use tables for the energy resource accounts. The energy accounts record the movement of soil resources for construction, land reclamation, landscaping, and other economic activities. These entries may or may not record movements of soil as part of dredging operations or movements of contaminated soil for treatment.

In addition to the physical asset accounts listed in the previous subsection, the flow of individual elements in the soil, such as soil carbon and soil nutrients (nitrogen, phosphorous, and potassium) can be recorded as part of a material flow accounting. The recording of nutrient balances can help account for the overall function of soil resources as a biological system. However, the current central framework does not fully describe the overall state or condition of soil resources, change in the health, or soils' capacity to provide benefits.

In the central framework, the value of soil resources is tied directly to the value of land. Therefore, if the land and soils accounts are to be separated, then connections may need to be between changes in the combined value of land and soil, and the separate accounts should consider changes in the associated income earned from the use of the soil resources.

4.4 Recent Research on Capital Accounting for Soil Resources

A recent research paper developed by Robinson et al. (2017) sought to create a comprehensive accounting framework for soil resources. The authors identify the following threats to soil resources caused by degradation:

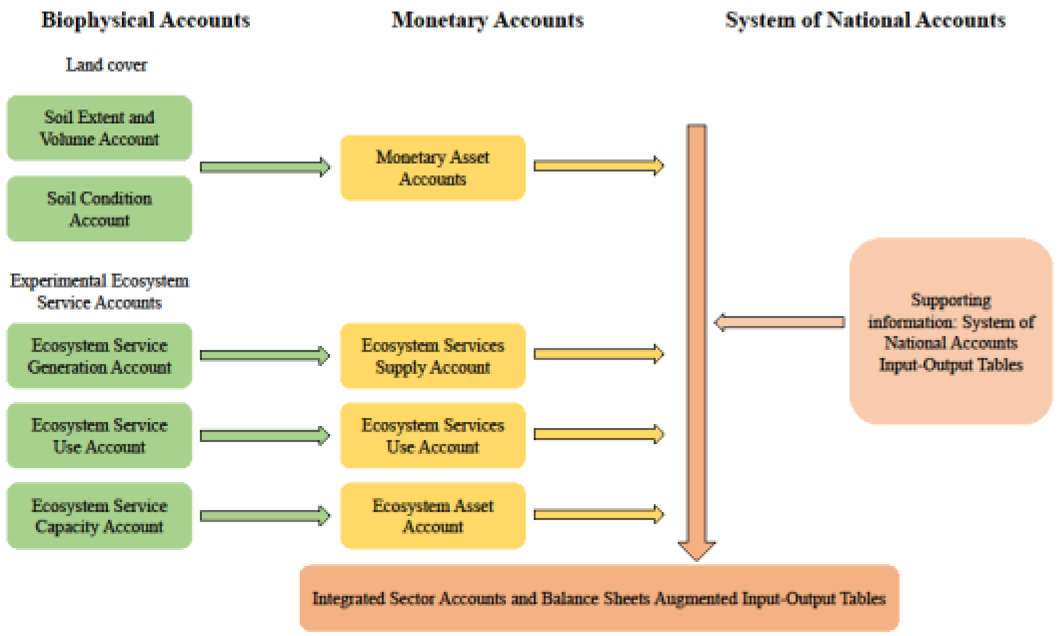
1. Soil erosion by water;
2. Soil erosion by wind;
3. Decline in soil organic matter;
4. Soil compaction;
5. Sealing;
6. Contamination;
7. Salinization;
8. Desertification;
9. Flooding and landslides; and,
10. Decline in soil biodiversity.

The authors posit that soil should be construed as a non-depreciating growth substrate. As such, costs need to be recorded for soil degradation and the value recorded for its ecosystem services. Given this framework, soil resources can be measured by state-and-change.

The Food and Agriculture Organization of the United Nations (2015) define soils as "any material within [two meters] of the Earth's surface that is in contact with the atmosphere, excluding living organisms, areas with continuous ice not covered by other material, and water bodies deeper than [two meters.]"

Unlike the SEEA Central Framework, Robinson et al. (2017) advocate for using land use cover for reporting instead of soil classification type. They argue that it is easier to record changes to soil stock, extent, and condition as reported by land cover. Moreover, the authors contend that this classification type is more relevant to policy as it easier to measure the impacts of management interventions by land cover type. Hence, the authors propose a top-level division defined by land cover, and then subdivide soils according to characteristics such as organ carbon content.

Figure 1. Conceptual overview of soils account for the SEEA Central Framework

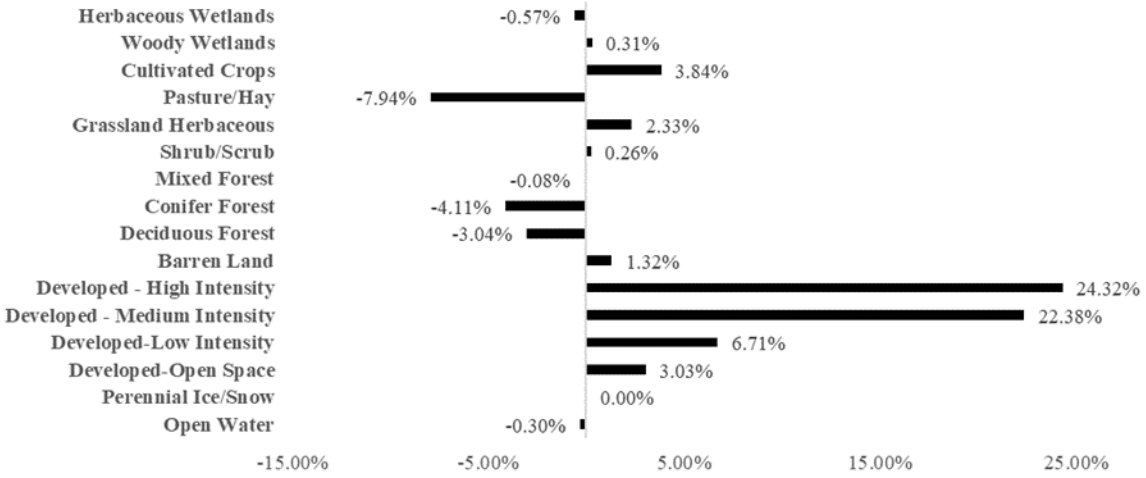


Source: Figure recreated by the authors based on Robinson et al. (2017).

A conceptual overview of Robinson et al.'s (2017) proposed soil account, within the SSEA Central Framework, is offered in Figure 1. Their conceptualization is that soil accounts will inform ecosystem service accounts, by providing a biophysical assessment of natural resources with a connection to economic activity. The economic contributions of the assets are to be converted to monetary accounts to augment input-output tables or form satellite accounts to the System of National Accounts. As stated above, the soil extent is measured by land use, with subdivisions including grassland and woodland, among others. Within subdivisions, a second layer of analysis could apply soil properties such as soil organic content.

Figure 2 illustrates the change to land cover in the U.S. between 2001 and 2016 among sixteen classes. The classes in the figure do not align with the SEEA Central Framework's aggregate classes of land cover, but the data can be converted as such with additional geospatial analysis. As displayed in the figure, cultivated cropland increased by nearly four percent over this period, whereas herbaceous wetlands and pastureland have declined by nearly one and eight percent. During the same period, there have been major increases in developed lands, largely associated with urban sprawl. Tree covered areas, including mixed forests, conifer forests, and deciduous forests declined by approximately seven percent in total.

Figure 2. Net percentage land-cover change in the conterminous U.S. (2001-2016)



Notes: This graph illustrates the net percentage land-cover change in the conterminous U.S. between 2001 and 2016. The percentage change is calculated based on seven epochs of land-cover data.
Source: This figure was created by the authors based on calculations from (Homer et al., 2020).

4.5 Soils Account Proposed Method

Following Robinson et al. (2017), the U.S. land cover data can be calculated according to the SEEA Central Framework. This proposed calculation would benefit from annual land cover data, which would provide a finer assessment of land cover change through time. However, periodic assessments – that is, land cover change data spanning longer than one year – may be necessary to derive finer grain spatial data on land cover.

Once the land cover data assessment is complete, an extent account table will be constructed. An example from Robinson et al. (2017), based on 25 member states of the European Union (E.U.) from the years 2000 to 2012, is offered in Table 4. Such an assessment would be carried out based on U.S. land cover change with the latest years of land cover data. The additions to stocks would be divided into managed and unmanaged with artificial surfaces and cropped systems placed in the managed category. Woodlands would be challenging to divide as some are managed and some are not, so additional consultation with the U.S. Forest Service would be required to determine how to classify the changes to woodlands and forests, particularly the ones involving semi-natural ecosystems.

Examples of soil measurement and the relationship to soil cycles is offered in Table 5. The table is based on the E.U.'s LUCAS ("land use and coverage area frame survey") model. The table indicates what measures are available to account for soil cycles and threats and in which years LUCAS survey that the data is available. Such an example can be used to match data between SSURGO and the U.S. Geological Survey's National Land Cover Database (NLCD). NLCD data is based on Landsat satellite imagery (U.S. Geological Survey, 2019).

Finally, a soil state and change account – otherwise called a mass account – would be constructed. This analysis would account for changes due to soil degradation and policy intervention that reduce it. The monitoring of soil cycle would require data on the carbon cycle, nutrient cycles, soil production, erosion cycles, and the water and energy balance (Robinson et al., 2017). Moreover, soils are susceptible to change by land use and land use change and pollution. One of the primary goals of the soils account is to assess the impact of these changes to the condition of soil resources and the effect on the economy.

An example of the soils mass account is offered in Table 6. This table is derived from the work of Robinson et al. (2017) and accounts for changes to soil stocks based on the SEEA central framework's fourteen defined categories of land use. The authors accounted for changes to soil stocks among 25 members of the E.U. between the years 2000 and 2012. During this period, they found gain in soil stocks across six categories (herbaceous crops, wood crops, multiple crops, grassland, tree covered areas, and shrub covered areas). Conversely, they found losses in soil stocks for sparsely natural vegetated areas and barren lands. What is unclear from Table 6 is if cropped areas are permanently gaining or losing soil, and determining the rates of soil stock changes is occurring is difficult (Robinson et al., 2017).

Table 2. Example of extent account for change in land cover assets (2000-2012)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEEA Classes	Artificial surfaces (including urban and associated areas)	Herbaceous crops	Woody crops	Multiple or layered crops	Grassland	Tree covered areas	Man-grove	Shrub covered areas	Shrubs and/or herb, vegetative, aquatic or reg. flooded	Sparsely natural vegetated areas	Terrestrial barren land	Permanent snow or glaciers	Inland water bodies	Coastal water bodies and intertidal areas
CORINE classes	1x	21x	22x	24x	231, 321	31x, 324		322, 323	41x	333	331, 332, 334	335	51x	42x, 52x
Opening area km2 of resources (2000)	99128	941447	88041	410037	383142	1270472	NA	143195	76508	17298	5054	1	55996	2106
Additions to stock														
Managed expansion	8354		1596											
Natural expansion														
Upward reappraisal														
Total additions to stock	8354		1596			4049						0	815	19
Reductions in stock														
Managed regression		-8676		-2921										
Natural regression														
Downward reappraisal														
Total reductions in stock		-8676		-2921	-1228			-1186	-565	-74	-182			
Closing area km2 (2012)	107482	932801	89636	407116	381913	1274521	NA	142009	75942	17225	4872	1	56811	2125

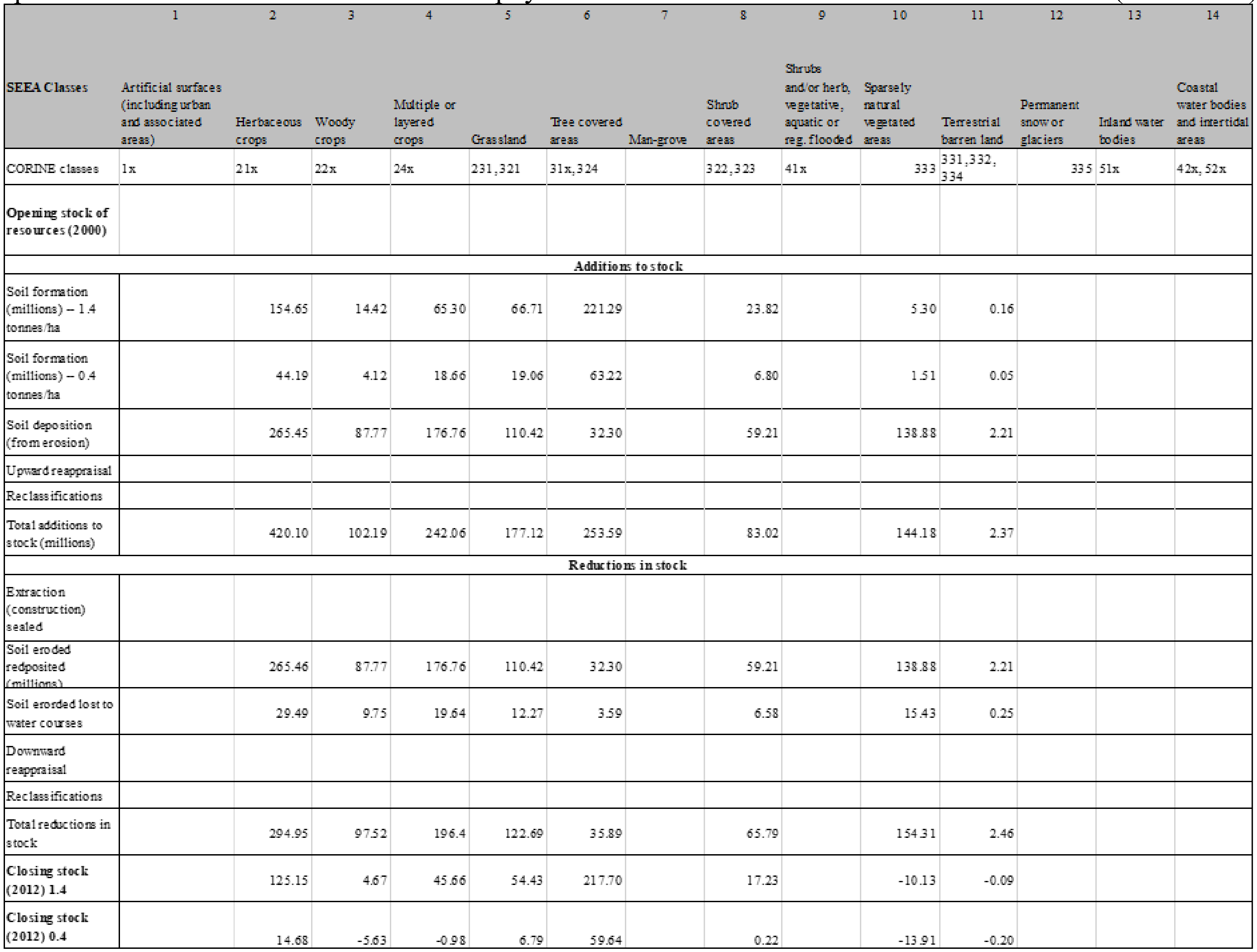
Notes: This table is derived from Robinson et al. (2017). The numbers in this table represent the change in land cover assets for the EU25 (2000-2012). The land cover assets are based on the classification system within the SEEA Central Framework. The term CORINE denotes the “coordination of information on the environment.” It is an inventory of European land cover split into 44 different land cover classes.

Table 3. Example of soil measurements and the relation to the primary soil cycles and threats

	Soil cycles				Soil threats											LUCAS sample year			
Soil parameters measured in LUCAS	**Carbon cycle**	**Nutrient cycle**	**Water and energy balance**	**Soil formation/erosion**	**Soil erosion by water**	**Soil erosion by wind**	**Decline in soil organic matter in peat**	**Decline in soil organic matter in mineral soils**	**Soil compaction**	**Sealing**	**Contamination**	**Salinization**	**Desertification**	**Flooding and landslides**	**Decline in soil biodiversity**	**2009**	**2015**	**2018**	**2021**
Soil organic carbon (SOC)	+	+		+	#	#	#	#	#						#	++	++		++
Soil inorganic carbon (SIC)	+	+														++	++		++
pH	+	+					#	#			#	#				++	++		++
Texture, and coarse fragments	+	+	+	+	#	#	#	#	#							++	++		
NPK		+														++	++		++
CEC		+														++	++		++
EC		+										#					++		++
Sulphate sulphur, Na		+									#								++
Heavy metals											#					++		++	
Nitrate nitrogen		+									#							++	++
Organic pollutants											#							++	++
Thickness of peat					#	#													++
Soil erosion	+	+		+	#	#													++
Soil bulk density	+	+			#	#			#					#				++	++
Soil moisture	+	+			#	#			#					#				++	++
Soil biodiversity															#			++	++
Land cover									#	#	#	#	#			CORINE Databse			
Extent accounts									*	*	*	*	*	*	*				
Mass accounts	*	*	*	*	*	*	*	*											

Notes: This table is derived from Robinson et al. (2017) based on the LUCAS database. LUCAS denotes the "land use and coverage area frame survey." The symbol "+" indicates that the data is available for the Soil cycles categorization and the indicated soil parameter measured in LUCAS. The symbol "#" indicates the data is available for the Soil threats categorization and the indicated soil parameter measured in Lucas. The symbol "++" indicates the survey year in which the soil parameter was measured. Finally, the symbol "*" indicates that the data can be used in either the Extent accounts or Mass accounts.

Table 6. Example of mass account for soil stock and biophysical account table for soil formation and erosion (2000-2012)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEEA Classes	Artificial surfaces (including urban and associated areas)	Herbaceous crops	Woody crops	Multiple or layered crops	Grassland	Tree covered areas	Man-grove	Shrub covered areas	Shrubs and/or herb, vegetative, aquatic or reg. flooded	Sparsely natural vegetated areas	Terrestrial barren land	Permanent snow or glaciers	Inland water bodies	Coastal water bodies and intertidal areas
CORINE classes	1x	21x	22x	24x	231,321	31x,324		322,323	41x	333	331,332, 334	335	51x	42x, 52x
Opening stock of resources (2000)														
Additions to stock														
Soil formation (millions) – 1.4 tonnes/ha		154.65	14.42	65.30	66.71	221.29		23.82		5.30	0.16			
Soil formation (millions) – 0.4 tonnes/ha		44.19	4.12	18.66	19.06	63.22		6.80		1.51	0.05			
Soil deposition (from erosion)		265.45	87.77	176.76	110.42	32.30		59.21		138.88	2.21			
Upward reappraisal														
Reclassifications														
Total additions to stock (millions)		420.10	102.19	242.06	177.12	253.59		83.02		144.18	2.37			
Reductions in stock														
Extraction (construction) sealed														
Soil eroded redposited (millions)		265.46	87.77	176.76	110.42	32.30		59.21		138.88	2.21			
Soil erorded lost to water courses		29.49	9.75	19.64	12.27	3.59		6.58		15.43	0.25			
Downward reappraisal														
Reclassifications														
Total reductions in stock		294.95	97.52	196.4	122.69	35.89		65.79		154.31	2.46			
Closing stock (2012) 1.4		125.15	4.67	45.66	54.43	217.70		17.23		-10.13	-0.09			
Closing stock (2012) 0.4		14.68	-5.63	-0.98	6.79	59.64		0.22		-13.91	-0.20			

Notes: This table is derived from Robinson et al. (2017). The numbers in this table represent the change in land cover assets for the EU25 (2000-2012). The land cover assets are based on the classification system within the SEEA Central Framework. The term CORINE denotes the “coordination of information on the environment.” It is an inventory of European land cover split into 44 different land cover classes.

5 Future Development of Soils Accounts within the U.S. System of Environmental-Economic Accounts

Soils accounts will be developed alongside of land, water, and forest accounts and complement other accounts including "Wetlands and peatlands," "Urban greens space," and "Grasslands, deserts, and tundra," among others. Together, these accounts will provide a more complete overview of the nation's natural capital assets.

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