Required data	
Data input type	Quantitative
Data collection frequency	
Level of expertise required	High
Synergies with other indicators	
Connection with SDGs	-
Additional information	
References	http://webcache.googleusercontent.com/search?q=cache:http://bcodata.whoi.edu/LaurentianGreatLakes_Chemistry/bs116.pdf

8.15.3 Soil carbon to nitrogen ratio

Project Name: UNaLab (Grant Agreement no. 730052)

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Soil carbon to nitrogen ratio (C/N)	**Climate Resilience** **Green Space Management**
Description and justification	The respective quantities of carbon and nitrogen in soil is critical to soil microbial activity and a fundamental indicator of biogeochemical cycling in ecosystems. Changes to soil C/N ratio impacts nutrient cycling in soils and the structure and function of plant communities, thereby affecting ecosystem service functions. Soils with higher C/N ratio are better able to buffer soil and water N pollution, because soils with greater C/N ratio generally exhibit slower rates of N mineralisation and nitrification, and greater capacity for N immobilisation (Groffman et al., 2006). The accumulation of C and N in urban green space soils is determined both by the length of time following urbanisation that an area is managed as a green space and the structural composition of green space vegetation. Factors such as the presence of

trees, an understory, and surface litter are key to soil C and N accumulation. Urban green space soils under tree canopies have been shown to have significantly greater soil C and N content and higher C/N ratios compared with grassed areas (Livesley et al., 2015). Planting and placement of trees within urban green spaces should facilitate accumulation of understory vegetation and litter to promote high C/N ratios and C and N storage in soils.

Soil microorganisms require C and N in a ratio of about 24:1 to support metabolic processes (USDA-NRCS, 2011). The majority of N in soil is present in organic form. Organic N is mineralised to ammonium (NH_4^+) via organic matter breakdown, then, under oxygenated conditions, oxidised to nitrate (NO_3^-). Plants are able to take up both NH_4^+ and NO_3^-, with some evidence for direct plant uptake of organic N, particularly in N-limited environments. Microbiological uptake of all forms of N is called immobilisation because the N is taken up or 'immobilised' in microbial biomass. Nitrogen mineralisation/ immobilisation reactions in soil are dependent upon the total N content and the C/N ratio. If decomposing organic material contains more N than microorganisms need for cell growth (i.e., where C/N < 24:1), surplus nitrogen is excreted as NH_4^+. Conversely, if decomposing organic materials contain less N than required by soil microorganisms for cell growth (i.e., C/N >24:1), the soil microorganisms must acquire additional N from the soil. In the longer term, this can lead to reduced soil fertility due to a deficit of N.

Management of urban landscapes can disrupt C and nutrient cycling through irrigation, litter removal, fertiliser or mulch addition, or other practices. Studies have shown that soil C/N ratios of urban green spaces increase with time since green space establishment, or with the duration of altered management intensity (Golubiewski, 2006; Livesley et al., 2015). Understanding the C/N ratio can promote C storage whilst maintaining adequate soil fertility, as well as management of soil N to minimise leaching of nitrate (NO_3^-) to local waterbodies and/or gaseous losses (i.e., as N_2, N_2O, NO, NH_3).

Nitrogen accumulates in soil through fixation of atmospheric N to organic forms. Soil organic matter is typically 5-6% N, so N levels in soil closely follow soil organic matter content. The N content of soil parent materials is low because N does not form stable minerals.

Soil N pools:

- Gaseous: N_2, N_2O, NO, NH_3
- Mineral N: NH_4^+, NO_2^-, NO_3^- (<2% of total N but very important)

	• Fixed N: NH_4^+ trapped in vermiculite-like clays (4-8% of total N) • Organic N: 80-95% of total soil N, needs to be mineralised prior to biological uptake Soil N moves between pools via a series of reactions. Soil organic matter is mineralised to form ammonium (NH_4^+). In the presence of oxygen, the NH_4^+ undergoes nitrification to form nitrate (NO_3^-). Both NH_4^+ and NO_3^- are forms of N available for plant and microbial uptake. Excess NH_4^+ in soil may be bound to soil clay minerals. If not taken up by plants or microorganisms, soil nitrate (NO_3^-) may be lost from the system by leaching to local waterways or through volatilisation as N2, N_2O, NO or NH_3 gas.
Definition	The ratio between the total mass of carbon and the total mass of nitrogen in soil
Strengths and weaknesses	+ Physical sampling and laboratory analysis of soil C and N yields accurate information, with improved accuracy of estimated C and N content of soil with increasing sampling intensity + Combustion-based analytical methods are relatively simple and widely applicable - Small changes in soil C may be difficult to quantify in carbonate-rich soils, in which case multiple analytical steps may be required to obtain reliable measurements - Soil sample collection is relatively labour-intensive; analyses typically require an external laboratory (rather than analysed in-house)
Measurement procedure and tool	The most reliable and accurate method of determining soil C and N content is field sampling followed by laboratory analysis. Sampling is performed using a measuring tape (for establishment of sampling transect or grid), soil corer, and plastic bags. Soil cores should be taken to a depth of at least 0.3 m, and up to 1.0 m depth depending on the rooting depth of local vegetation. Combustion is an accurate, commonly used analytical technique to quantify C and N in soil. A carbon-nitrogen combustion analyser can provide measures of total carbon, total organic carbon and total inorganic carbon (after sample acidification), total nitrogen, and C/N ratio.
Scale of measurement	Plot scale
Data source	
Required data	Site characteristics, including maps of soil type, topography, and vegetative cover. Average soil bulk density (in kg/m^3; can be measured or estimated based on

	soil type). Obtainable from local municipality, department of environment, geological survey.
Data input type	Quantitative
Data collection frequency	Annually, including at a minimum measurement before and after NBS implementation
Level of expertise required	Low to Moderate – field sampling Moderate – combustion analysis in laboratory conditions High – soil sample pre-treatment for determination of organic C content
Synergies with other indicators	Similar method used to determine *Carbon removed or stored per unit area per unit time* indicator
Connection with SDGs	SDG 11 Sustainable cities and communities, SDG 13 Climate action, SDG 15 Life on land
Opportunities for participatory data collection	Participatory data collection is feasible through soil sample collection
Additional information	
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8.15.4 Soil carbon decomposition rate

Project Name: PHUSICOS – According to Nature (Grant Agreement no. 776681)

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Soil carbon decomposition rate	**Climate Resilience Green Space Management**
Description and justification	Indicators of Carbon Sequestration in Soil sub-criterion will assess the carbon sequestration in soil.
Definition	Decomposition of Carbon is a part of the Carbon cycle and is essential for recycling the finite matter that occupies physical space in the biosphere. Decomposition is the process by which organic substances are broken down into simpler organic matter. One can differentiate abiotic from biotic decomposition (biodegradation). The former means "degradation of a substance by chemical or physical processes, e.g., hydrolysis" (Water Quality Vocabulary. IShaO 6107-6:1994). The latter means "the metabolic breakdown of materials into simpler components by living organisms", typically by microorganisms.
Strengths and weaknesses	
Measurement procedure and tool	Model/Sampling/Survey
Scale of measurement	%
Data source	
Required data	
Data input type	Quantitative
Data collection frequency	