2. Additional Indicators of Climate Resilience

2.1. Carbon storage and sequestration in vegetation

2.1.1 Carbon storage and sequestration in vegetation per unit area per unit time

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Total carbon storage and sequestration in vegetation per unit area per unit time	**Climate Resilience**
Description and justification	Accounting for C stored in soil and vegetation in an urban area can provide an indication of the condition of natural green spaces, total free surface area and total quantity of vegetation in the area examined. Measures of C storage and sequestration also provide a tangible connection to climate change mitigation, and the impacts of local land use, planning and management decision-making. It is important to note the substantial variation in C sequestration and storage capacity of different types of NBS.
Definition	Total amount of carbon (tonnes) stored in vegetation, described per unit area and unit time
Strengths and weaknesses	+ The modelling tool can be used to model potential effects of changes to be made or situation if changes were not made by creating parallel scenarios of the same area with different tree inventories + The inventory can be created from maps and sample measurements - Access to reliable and accurate data may be limited - Analyses may require an external laboratory
Measurement procedure and tool	There are several tools for modelling carbon in trees including the U.S. Forest Service Forest Inventory and Analysis Database, such as the suite of i-Tree tools (USDA Forest Service, 2019). The i-Tree Eco model inputs a database of city trees with information on location, size and species to a geographic information system platform. Alternatively, an estimate of C storage or sequestration in above-ground vegetation can be manually determined

	using a similar approach to the i-Tree Eco application. First, each above-ground vegetation polygon in a digital cartographic dataset can be classified per light detection and ranging (LiDAR) data as, e.g., herbaceous vegetation (grasses and non-woody plants), shrub (woody bushes and trees with mean height typically <2 m), tall shrub (woody bushes and trees with mean height generally 2-5 m), or tree (trees >5 m in height) after Davies, Edmonson, Heinemeyer, Leake, & Gaston (2011). Davies et al. (2011) recommend surveying to ground-truth map data and classification estimates. Species-specific allometric equations are available from the scientific literature to estimate above-ground dry weight biomass of the classified vegetation, and carbon storage calculated using conversion factors also available from the scientific literature. Where there are multiple equations for a given species, the equations can be combined to obtain a general result. Total above ground tree biomass can be converted to C storage using conversion factors based on tree type. The dry-weight of above-ground biomass of each class of vegetation along with the mean C content can also be determined via laboratory analysis.
Scale of measurement	District to regional scale
Data source	
Required data	Requires data on extent of vegetation cover & characteristics of vegetation (e.g., type, age and height), land use, air quality data, and meteorological and other local information for modelling. These can be obtained from forest inventory analysis (FIA), a national land cover database (NLCD) or databases for housing density mapping. Users may need permission to gain access to national databases unless the data are open (freely available).
Data input type	Quantitative
Data collection frequency	Annually to enable tracking of changes to C storage and sequestration with time before and after NBS implementation
Level of expertise required	Moderate – requires understanding of the C storage concept, and ability to combine and apply allometric equations and modelling tools
Synergies with other indicators	Used for evaluating C storage necessary for *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 sample collection, e.g., air quality measurements
Additional information	
References	Davies, Z.G., Edmonson, J.L., Heinemeyer, A., Leake, J.R., & Gaston, K.J. (2011). Mapping an urban ecosystem service: quantifying above-ground carbon storage at a city-wide scale. Journal of Applied Ecology, 48, 21125-1134. Fong, W.K., Sotos, M., Doust, M., Schultz, S., Marques, A., & Deng-Beck, C. (2015). Global Protocol for Community-Scale Greenhouse Gas Emission Inventories. Washington, D.C.: World Resources Institute. Retrieved from https://www.wri.org/publication/global-protocol-community-scale-greenhouse-gas-emission-inventories Intergovernmental Panel on Climate Change (IPCC). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston, S., Buendia, L., Miwa, K., Ngara, T., & Tanabe, K. (Eds.). Hayama, Japan: Institute for Global Environmental Strategies (IGES). Retrieved from https://www.ipcc-nggip.iges.or.jp/public/2006gl/. Intergovernmental Panel on Climate Change (IPCC). (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team, R.K. Pachauri and L.A. Meyer (Eds.). Geneva, Switzerland: IPCC. United States Department of Agriculture (USDA) Forest Service. (2019). i-Tree Eco Manual. Northern Research Station, USDA Forest Service. Retrieved from https://www.itreetools.org/resources/manuals/Ecov6_ManualsGuides/Ecov6_UsersManual.pdf