	(e.g., through policies, directives, urban development plans or strategies).
Scale of measurement	Municipality; country
Data source	
Required data	Local risk assessment for natural and climate hazards; local development plans
Data input type	Semi-quantitative
Data collection frequency	Annually
Level of expertise required	Moderate
Synergies with other indicators	The indicator can be assessed in conjunction with *Disaster resilience* indicator. It is directly related to all indicators the *Natural and Climate Hazards* indicator group and encompasses them and their impacts for a holistic urban development.
Connection with SDGs	SDG 9 Industry, innovation and infrastructure, SDG 11 Sustainable cities and communities, SDG 13 Climate action
Opportunities for participatory data collection	No opportunities identified
Additional information	
References	Tyszka, T. and Zielonka, P. *Large risks with low probabilities: Perceptions and willingness to take preventive measures against flooding*. IWA Publishing, 2017, pp. 105-118.

5.15 Mean annual direct and indirect losses due to natural and climate hazards

Project Name: RECONECT (Grant Agreement no. 776866)

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Mean annual direct and indirect losses due to natural and climate hazards	**Natural and Climate Hazards**
Description and justification	The losses due to natural and climate hazards can be calculated for any area. The calculation is usually based on models in order to account for natural variation of the hazards. The mean annual losses are often referred to as

	the risk of the hazard and the indicator is within hydrometeorological risks most often denoted *Expected Annual Damage*. The indicator is a key input into any economic assessment of the feasibility of a project aimed at hydro-meteorological risk reduction because the project costs should be balanced against the calculated reduction of *EAD* in e.g., a cost-benefit analysis.
Definition	The definition of EAD is given as (e.g., (Zhou et al., 2012)): $$EAD = \int_A \int_p D(p)dpdA$$ where *D(p)* denotes the damage that occurs at an annual frequency *p* and *A* denotes the area in question. The equation assumes that there is no damage for events occurring more often than once per year.
Strengths and weaknesses	While in principle it is a simple metric it is in reality difficult to assess because of relatively high inherent uncertainties. The uncertainties are mainly related to calculation of how the hazard is exposing assets in the area and how much value the assets have to humans before and after being exposed to the hazard.
Measurement procedure and tool	There is typically a distinction between direct and indirect costs and tangible and intangible costs (Merz et al., 2010). Direct costs are costs related to the direct impact of the hazard, e.g., destruction of buildings and infrastructure, while the indirect costs are a consequence of the hazard, but not directly e.g., disruption of public services, relocation of citizens etc. Tangible costs can be assessed based on an economic market while intangible costs are all other costs, e.g., loss of life, psychological distress, damage of cultural heritage, and loss of trust in authorities. Using the definition above it is assumed that also intangible costs are assigned an economic value, but in some cases key intangible costs are reported as numbers of humans affected (Kreibich et al., 2017). Use of this approach should be aligned with the indicator *Number of people adversely affected by natural disasters each year*.
Scale of measurement	Typically the area is considered without consideration of the economic activity in the surrounding area and only considering costs during and shortly after the hazard occured. However, there are exceptions where larger scale (often positive) impacts as well as improved economic productivity post-event are included in the analysis, e.g., Hallegatte et al., 2011.
Data source	

Required data	Hazard maps as a function of the frequency of the hazard(s). Typically this will be in the form of raster og shape files in a GIS environment. Value maps covering the area showing what assets can be exposed and what cost is associated with exposure, typically as a function of key characteristics of the hazard. For water hazards this could be e.g., inundation depth and/or duration of exposure. This data should be available in the same format as the hazard maps
Data input type	Quantitative
Data collection frequency	The data should in principle be collected every time there is a) a change in the land use that affects the value maps, and b) new information about the hazards become available.
Level of expertise required	Medium to high.
Synergies with other indicators	This indicator is related to several other indicators, in particular to *Number of people adversely affected by natural disasters each year* and to the indicator group on Health and Wellbeing.
Connection with SDGs	The connection is closest to SDG 1 (target 1.5) and SDG 11 (several targets) (Sørup et al, 2019).
Opportunities for participatory data collection	A participatory approach to establishing the value maps will both increase the awareness of the indicator and improve the accuracy of the assessment.
Additional information	
References	Hallegatte, S., Ranger, N., Mestre, O., Dumas, P., Corfee-Morlot, J., Herweijer, C., Wood, R.M., 2011. Assessing climate change impacts, sea level rise and storm surge risk in port cities: A case study on Copenhagen, Climatic Change. https://doi.org/10.1007/s10584-010-9978-3 Hammond, M.J., Chen, A.S., Djordjević, S., Butler, D., Mark, O., 2015. Urban flood impact assessment: A state-of-the-art review. Urban Water J. 12, 14–29. https://doi.org/10.1080/1573062X.2013.857421 Kreibich, H., Baldassarre, G. Di, Vorogushyn, S., Aerts, J.C.J.H., Apel, H., Aronica, G.T., Arnbjerg-nielsen, K., Bouwer, L.M., Bubeck, P., Caloiero, T., Chinh, D.T., Cortès, M., Gain, A.K., Giampá, V., Kuhlicke, C., Kundzewicz, Z.W., Llasat, M.C., Mård, J., Matczak, P., Mazzoleni, M., Molinari, D., Dung, N. V, Petrucci, O., Schröter, K., Slager, K., Thieken, A.H., Ward, P.J., Merz, B., 2017. Adaptation to flood risk : Results of international paired flood event studies. Earth's Futur. 5, 953–965. https://doi.org/10.1002/2017EF000606 Merz, B., Kreibich, H., Schwarze, R., Thieken, a., 2010. Review

	article "assessment of economic flood damage." Nat. Hazards Earth Syst. Sci. 10, 1697–1724. https://doi.org/10.5194/nhess-10-1697-2010 Sørup, H.J.D., Fryd, O., Liu, L., Arnbjerg-Nielsen, K., and Jensen, M.B. 2019. An SDG-based framework for assessing urban stormwater management systems. Blue-Green Systems, Blue-Green Systems, 1, 1, 102-118. DOI: 10.2166/bgs.2019.922. Zhou, Q., Mikkelsen, P.S., Halsnæs, K., Arnbjerg-Nielsen, K., 2012. Framework for economic pluvial flood risk assessment considering climate change effects and adaptation benefits. J. Hydrol. 414–415. https://doi.org/10.1016/j.jhydrol.2011.11.031

5.16 Risk to critical urban infrastructure

Project Name: CONNECTING Nature (Grant Agreement no. 730222)

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Reduction of inundation risk for critical urban infrastructures (probability-economic) (Applied and EO/RS combined)	**Natural and Climate Hazards**
Description and justification	Metrics are based on the quantification of infrastructure that has a reduced risk of flooding due to NBS implementation. Ultimately, this relates to a reduced economic cost of flooding, or increased health & wellbeing of communities due to reduced stress levels associated with flooding or risk of flooding. It should be noted that, if NBS is poorly designed or well-designed but poorly constructed, it has the potential to lead to increased local flooding risk for some areas. Advances in remote sensing technology and new satellite platforms such as ALOS sensors have widened the application of satellite data, for instance to validate flood inundation models. Flood modelling based on remote sensing rainfall data will be useful for developing regional flood early-warning and flood mitigation systems in flood hazardous areas. Reduction in flood-risk by nature-based solutions simulation can be used to: • Support the development of strategic plans for NBS implementation to reduce flood risk and comply with Flood Risk Management; • Predict the impact of individual NBS projects;