List of indicators by ES, indicating brief methodology and reference.

Category Ecosystem Service	Soil Ecosystem services	Soil indicator	Units	Description	Methods	Reference
Provisioning	Provision of food, fibre and fuel	Crop yield	kg/ha	Weight of any economic product per unit of land area harvested	Fischer (2015)	Fischer (2015) https://doi.org/10.1016/j.fcr.2014.12.006
		Wood production	kg/ha	Weight of any economic product per unit of land area harvested	Fischer (2015)	Fischer (2015) https://doi.org/10.1016/j.fcr.2014.12.006
		Vegetation richness	species number	Number of total plant species, diversity and number per surface	Liu et al. (2022)	Liu et al. (2012) https://doi.org/10.1016/j.agee.2022.107935
		Vegetation cover	%	Percentage of soil which is covered by green vegetation, obtained by satellite/aerial images		
	Provision of water	Soil gravimetric moisture	%	Mass of water contained in mass of soil.	Determination of gravimetric soil moisture, weighing a soil sample before and after drying	Porta, J., M. López-Acevedo, and R. Rodríguez. 1986. "Técnicas y Experimentos En Edafología." In , 282. Col.legi Oficial d'Enginyers Agrònoms de Catalunya, Barcelona.
		Soil water at field capacity	%	Mass of water contained in soil after a pressure of -33 kP		
		Soil water at wilting point	%	Mass of water contained in soil after a pressure of -1500 kP		
		Soil water holding capacity	%	Mass of water that soil is able to retain in its natural state	ISO 11274 (2019)	ISO 11274 (2019) https://www.iso.org/es/contents/data/standard/06/82/68256.html
	Provision of raw materials	Rock fragments and gravels	%	Percentage of rocks fragments and gravels (>2mm) in a soil after sieving	Sieving and weighting	Taubner et al. (2009). https://doi.org/10.1002/jpln.200800085
		Sand content	%	Percentage of particles of a size between 0.05-2 mm in a soil after sieving by 2 mm	Laser analyser	Mukhopadhyay et al. (2019). https://doi.org/10.1016/b978-0-12-813912-7.00014-4.
		Silt content	%	Percentage of particles of a size between 0.05-0.002 mm in a soil after sieving by 2 mm	Laser analyser	Mukhopadhyay et al. (2019). https://doi.org/10.1016/b978-0-12-813912-7.00014-4.
		Clay content	%	Percentage of particles of a size < 0.002 mm in a soil after sieving by 2 mm	Laser analyser	Mukhopadhyay et al. (2019). https://doi.org/10.1016/b978-0-12-813912-7.00014-4.
Regulating	Flood regulation and erosion control	Aggregates size distribution floating	%	This method analyses the aggregate stability and size distribution by their ability to mantain their shape when they are subjected to artificially induced forces	Díaz et al. (1994)	Diaz, E. et al. (1994). https://doi.org/10.1016/0016-7061(94)90069-8
		Aggregates size distribution > 2000 mm	%			Diaz, E. et al. (1994). https://doi.org/10.1016/0016-7061(94)90069-8
		Aggregates size distribution 250 to 2000 mm	%			Diaz, E. et al. (1994). https://doi.org/10.1016/0016-7061(94)90069-8
		Aggregates size distribution 53 to 250 mm	%			Diaz, E. et al. (1994). https://doi.org/10.1016/0016-7061(94)90069-8
		Aggregates size distribution < 53 mm	%			Diaz, E. et al. (1994). https://doi.org/10.1016/0016-7061(94)90069-8
		Mean weight diameter MWD	mm			Diaz, E. et al. (1994). https://doi.org/10.1016/0016-7061(94)90069-8
		Bulk density	g/cm3	Calculated by dividing the volumen of voids (pore space), by the volumen of solids (soil particle)	ISO 11272 (2017)	ISO 11272 (2017). https://www.iso.org/standard/68255.html
		Soil porosity	%	Calculated by dividing the volume of pore space by the volume of soil particles	Scanning by RX-CT	Blake and Hartge (1986)
		Soil structure assessment	Dimensionless	Soil 3D-arrangement in space	Scanning by RX-CT	
	Climate regulation	Total organic carbon	g/kg	Concentration of organic carbon in soil	Dry combustion and determination by elemental analyser	ISO 10694 (1995). https://www.iso.org/es/contents/data/standard/01/87/18782.html?browse=ics
		Carbon stocks	ton/ha	Mass of total organic carbon stocks in per soil area	Dry combustion and determination by elemental analyser	ISO 10694 (1995). https://www.iso.org/es/contents/data/standard/01/87/18782.html?browse=ics
		C/N ratio	Dimensionless	Mass of total carbon divided by mass of total nitrogen	Dry combustion and determination by elemental analyser	ISO 10694 (1995). https://www.iso.org/es/contents/data/standard/01/87/18782.html?browse=ics
		Particulate organic carbon	g/kg	Concentration of particulate organic carbon in soil	Physical fractionation of Soil Organic Matter and determination by elemental analyser	Cambardella & Elliot (1992). https://doi.org/10.2136/sssaj1992.03615995005600030017x
		Inorganic carbon	g/kg	Concentration of particulate inorganic carbon in soil	Volumetric method	ISO 10693 (1995). https://www.iso.org/es/contents/data/standard/01/87/18781.html
		CO2	mg/kg ·h	Emission of CO_2 from soil	Measurement of GHG emissions will be done under laboratory conditions with soil incubations at fixed air temperature and soil moisture conditions. Soil samples will be incubated for a week. Different gas samples will be taken during the incubation period. Determination will be done with a gas analyser.	Moreno-Barriga et al., 2017. https://doi.org/10.1016/j.geoderma.2017.04.017
		N_2O	mg/kg ·h	Emission of N_2O from soil		
		CH_4	mg/kg ·h	Emission of CH_4 from soil		
	Water purification and soil contamination reduction	Total As	mg/kg	Total concentration of all these elements in soil.	Extraction with aqua regia. Measurement by ICP-MS	ISO 11466 (1995). https://www.iso.org/standard/19418.html
		Total Cd	mg/kg			
		Total Co	mg/kg			
		Total Cr	mg/kg			
		Total Cu	mg/kg			
		Total Hg	mg/kg			
		Total Pb	mg/kg			
		Total Ni	mg/kg			
		Total Sb	mg/kg			
		Total V	mg/kg			
		Total Zn	mg/kg			
		As bioavailable	mg/kg	Bioavailable concentration of all these elements in soil.	Soils with pH > 6: DTPA soil extraction, 1:2 v/v. Soils with pH < 6: EDTA soil extraction, 1:5 v/v. Measurement by ICP-MS.	Álvaro-Fuentes J. et al. 2019. Handbook of plant and soil analysis for agricultural systems (1.0). Zenodo. https://doi.org/10.5281/zenodo.2553445
		Cd bioavailable	mg/kg			
		Co bioavailable	mg/kg			
		Cr bioavailable	mg/kg			
		Hg bioavailable	mg/kg			
		Pb bioavailable	mg/kg			
		Ni bioavailable	mg/kg			
		Sb bioavailable	mg/kg			
		V bioavailable	mg/kg			
		NO_3^-	mg/kg	Nitrates content in soil	Extraction with deionized water in a 1:10 soil:extractant ratio and measured by ion chromatography.	Keeney, D. R., & Nelson, D. W. (1982). Nitrogen-Inorganic Forms. In A. L. Page (Ed.), Methods of Soil Analysis, Agronomy Monograph 9, Part 2 (2nd ed., pp. 643-698). Madison, WI: ASA, SSSA.
		Total pesticides	ng/g	Total pesticides content in soil	QUECHERS method. Pesticide extraction with one or several solvents. Cleaning the sample to avoid interferences. Determination by LCMS/MS and GC-HRMS.	Mol et al. (2008). https://doi.org/10.1021/ac801557f Silva et al. (2019). https://doi.org/10.1016/j.scitotenv.2018.10.441
		Microplastics	particle/kg	Microplastic content in soil	Sequential extraction by NaCl and $ZnCl_2$. Identification by microscope and/or FTIR.	Corradini et al. (2019) http://doi.org/10.1016/j.scitotenv.2019.03.368
	Nutrient cycling	Total nitrogen	g/kg	Concentration of nitrogen in soil	Measurement by Elemental Analyzer in dry and grounded sample.	Keeney, D. R., & Nelson, D. W. (1982). Nitrogen-Inorganic Forms. In A. L. Page (Ed.), Methods of Soil Analysis, Agronomy Monograph 9, Part 2 (2nd ed., pp. 643-698). Madison, WI: ASA, SSSA.
		$NH4^+$	mg/kg	Concentration of ammonium in soil	Extraction with 2M KCl in a 1:10 soil:extractant ratio and colorimetrically measured.	Keeney, D. R., & Nelson, D. W. (1982). Nitrogen-Inorganic Forms. In A. L. Page (Ed.), Methods of Soil Analysis, Agronomy Monograph 9, Part 2 (2nd ed., pp. 643-698). Madison, WI: ASA, SSSA. Kandeler, E. and Gerber, H. (1988) Short-Term Assay of Soil Urease Activity Using Colorimetric Determination of Ammonium. Biology and Fertility of Soils, 6, 68. https://doi.org/10.1007/BF00257924
		P Available	mg/kg	Bioavailable concentration of phosphorous in soil	OLSEN extraction (0.5 M $NaHCO_3$ solution adjusted at a pH of 8.5). Measurement by ICP-OES.	ISO 11263 (1994) https://www.iso.org/standard/19241.html
		SO_4^{2-}	mg/kg	Concentration of sulphates in soil	SO_4^{2-} is extracted with deionized water in a 1:10 soil extractant ratio and measured by ion chromatography.	Hem, J.A., G.K. Rutherford, and G.W. VanLoon. 1983. Determination of chloride, nitrate, sulphate and total sulfur in environmental samples by single-column ion chromatography. Talanta 30:677-682. Schmalz et al. (2001) https://doi.org/10.1002/1522-2624(200110)164:5%3C577::AID-JPLN577%3E3.0.CO;2-I
		Exchangeable Ca	mg/kg	Concentration of exchangeable Ca in the cation exchange complex	$BaCl_2$ extraction. Measurement by ICP-MS	ISO 23470 (2018). https://www.iso.org/es/contents/data/standard/06/87/68765.html
		Exchangeable Mg	mg/kg	Concentration of exchangeable Mg in the cation exchange complex	$BaCl_2$ extraction. Measurement by ICP-MS	ISO 23470 (2018). https://www.iso.org/es/contents/data/standard/06/87/68765.html
		Exchangeable K	mg/kg	Concentration of exchangeable K in the cation exchange complex	$BaCl_2$ extraction. Measurement by ICP-MS	ISO 23470 (2018). https://www.iso.org/es/contents/data/standard/06/87/68765.html
		Exchangeable Na	mg/kg	Concentration of exchangeable Na in the cation exchange complex	$BaCl_2$ extraction. Measurement by ICP-MS	ISO 23470 (2018). https://www.iso.org/es/contents/data/standard/06/87/68765.html
		Cation exchange capacity	cmol/kg	Concentration of cations in the cation exchange complex	$BaCl_2$ extraction. Measurement by ICP-MS	ISO 23470 (2018). https://www.iso.org/es/contents/data/standard/06/87/68765.html
		Sum of bases	mg/kg	Concentration of basic cations in the cation exchange complex	$BaCl_2$ extraction. Measurement by ICP-MS	ISO 23470 (2018). https://www.iso.org/es/contents/data/standard/06/87/68765.html
		Oxalate extractable Al	mg/kg	Concentration of non-crystaline and poorly crystaline Al in soil	Acid ammonium oxalate method. Measurement by ICP-OES	Ross, G. J. and Wang C. 1993. Extractable Al, Fe, Mn, and Si. pp. 239-246. In: Carter, M. R. (ed), Soil Sampling and Methods of Analysis, Canadian Society of Soil Sciences, Lewis Publishers, Ann Arbor, MI..
		Oxalate extractable Fe	mg/kg	Concentration of non-crystaline and poorly crystaline Fe in soil	Acid ammonium oxalate method. Measurement by ICP-OES	Ross, G. J. and Wang C. 1993. Extractable Al, Fe, Mn, and Si. pp. 239-246. In: Carter, M. R. (ed), Soil Sampling and Methods of Analysis, Canadian Society of Soil Sciences, Lewis Publishers, Ann Arbor, MI..
		B bioavailable	mg/kg	Concentration of bioavailable B in soil	Hot water extraction (50°C, soil:solution ratio 1:5)	Bingham, F.T. (1982) Boron. In: Page, A.L., Ed., Methods of soil Analysis Part-2 Chemical and Mineralogical Properties, American Society of Agronomy, Madison, 431-448
		Cu bioavailable	mg/kg	Concentration of bioavailable Cu in soil	Soils with pH > 6: DTPA soil extraction, 1:2 v/v. Soils with pH < 6: EDTA soil extraction, 1:5 v/v. Measurement by ICP-MS.	Álvaro-Fuentes J. et al. 2019. Handbook of plant and soil analysis for agricultural systems (1.0). Zenodo. https://doi.org/10.5281/zenodo.2553445
		Fe bioavailable	mg/kg	Concentration of bioavailable Fe in soil		
		Mn bioavailable	mg/kg	Concentration of bioavailable Mn in soil		
		Mo bioavailable	mg/kg	Concentration of bioavailable Mo in soil		
		Zn bioavailable	mg/kg	Concentration of bioavailable Zn in soil		
		pH	Dimensionless	Soil pH	Glass electrode in a 1:5 (V/V) suspension of soil in H_2O or $CaCl_2$ (LUCAS methodology)	ISO 10390 (2021) https://www.iso.org/standard/75243.html
		Electrical conductivity	dS/m	Soil electrical conductivity	Metal electrodes in aqueous extract of soil (1:5 V/V)	ISO 11265 (1994). https://www.iso.org/standard/19243.html
	Provision of genetic resources and biochemicals	Firmicutes abundance via PLFAs	nmol/g	Abundance of each specific microorganism group	Determine the changes in the microbial community structure in the analysis of the phospholipid fatty acids (PLFAs)	Malosso et al. 2004. https://doi.org/10.1016/j.soilbio.2003.09.004
		Actinobacteria abundance via PLFAs	nmol/g			
		Gram+ bacteria abundance via PLFAs	nmol/g			
		Gram- bacteria abundance via PLFAs	nmol/g			
		Bacterial abundance via PLFAs	nmol/g			
		Arbsucular mycorrhizal fungi abundance via PLFAs	nmol/g			
		Zygomicota abundance via PLFAs	nmol/g			
		Ascomycota and Basidiomycota abundance via PLFAs	nmol/g			

		Unspecific fungal abundance via PLFAs	nmol/g			
		Fungi abundance via PLFAs	nmol/g			
		Unspecific microbial abundance via PLFAs	nmol/g			
		Total PLFA	nmol/g	Total abundance of active microorganisms		
		Prokaryotes and fungi		Abundance of identifyed prokaryotes and fungi	DNA extracted with DNeasy PowerSoil Pro Kit (Qiagen) (Töwe et al., 2011). DNA quantification with Qubit® 2.0 Fluorometer (Invitrogen, Thermo Fisher Scientific) and quality with Nanodrop1000TM (Invitrogen, Thermo Fisher Scientific). Amplification and sequencing of 16S rRNA and ITS genes with Illumina Nextseq 2 x 300 bp using for 16S rRNA gene the primer set forward (515F; GTGYCAGCMGCCGCGGTAA) and reverse (806R; GGACTACNVGGGTWTCTAAT) (Apprill et al., 2015; Parada et al., 2016). For ITS gene, a mixture of six forward primers (in equimolar concentration) analogous to ITS3 and a degenerate reverse primer analogous to ITS4 (ITSmix3/ ITSmix4) according to Tedersoo et al. (2014) will be used.	Apprill et al. (2015) http://doi.org/10.3354/ame01753 Parada et al. (2016) https://doi.org/10.1111/1462-2920.13023 Tedersoo et al. (2014) https://doi.org/10.1126/science.1256688 Töwe et al. (2011) https://doi.org/10.1016/j.mimet.2010.12.028
		Metagenomics			Sequencing libraries on Illumina NovaSeq 6000 (PE 2 x 150 bp, two S4 flow cells, or eight lanes). The reads will be merged with corresponding reads of the previous run ("top-up") after they passed initial quality checks. The initially expected overall yield ill be 16-20 B fragments or 4800-6000 Gb; the final yield (after merging) will be as 13.8 B fragments or 4181 Gb. The actual average insert size will be 245 bp (SD = 42 bp) as inferred by bbmerge.sh with default settings on adapter-trimmed reads.	Mueller et al. (submitted) https://gitlab.com/rcmueller/tree-soil-microbiomeinterplay-under-drought
		Protists diversity, richness and abundance		Diversity, richness and abundance of identifyed protists	DNA extraction. Amplification and sequencing of 18S rRNA gene with Illumina Nextseq 2x300 using the primer set forward (Euk575Fngs; ASCYGYGGTAAYWCCAGC) and reverse (Euk895Rngs; TCHNHGNATTTCACCNCT).	Guerra et al. (2021) https://doi.org/10.1126/science.abd7926
		Nematodes		Abundance of identifyed nematodes	Extraction from100 cm^3 of soil using automated zonal centrifuging (Hendrickx centrifuge technique). • The nematode suspension will be transferred to a counting dish to determine the number of nematodes microscopically. Subsequently, the nematodes will be collected on a membrane filter (0.8 µM) by vacuum filtration (600mbar). • The filter with nematodes will be destroyed by bead-beating (30 Hz, 2 times 1 min). The resulting powder will be used as a soil sample to extract DNA. • For each nematode DNA extract, a library prep will be made by applying a two-step amplification process (Waeyenberge et al., 2019). • The first PCR reaction will be executed with 12.5 mL of 2X KAPA HiFi HotStart ReadyMix, 0.75 µM of each primer elongated with the Illumina adapter overhang nucleotide sequence (5'-TCGTCGGCAGCGTCAGATGTGTATAAGAGACAG-3' for a forward primer and 5'-GTCTCGTGGGCTCGGAGATGTGTATAAGAGACAG-3' for a reverse primer), 2 µL DNA extract, andMilliQ water up to a volume of 25 µL. • IlluminaMiSeq PE300 platform(2 x 300 bp) will be used.	Hendrickx, G. (1995). An automatic apparatus for extracting free-living nematode stages from soil. Nematologica, 41, 308. Waeyenberge et al. (2019) https://doi.org/10.3390/d11040052
Supporting	Hosting biodiversity	Mesofauna		Identification of soil mesofauna	• Collection of undisturbed soil cores in the field using a soil core sampler (4 cm diameter and 0-20 cm depth). • Separation of the two depth levels 0-10 and 10-20 cm using a spatula. • Placing the soil cores directly into the beakers that suit to the Kempson/MacFayden extractor or in plastic bags or containers properly labelled. • Transport the samples to the laboratory in cool boxes with cool packs. • In the lab, microarthropods will be extracted by behavioural methods using a Kempson or MacFadyen high-gradient extractor (Kempson et al., 1963; MacFadyen, 1961). • Keep at 4ºC and extract the animals as quickly as possible. (Do not store for longer than 2 weeks). • Total extraction period is usually 10 days.	Macfadyen, A.. 1953. Notes on methods for the extraction of small soil arthropods. J. Anim. Ecol. 22: 65–78. Kempson, D., Lloyd, M. and Ghelardi, R.. 1963. A new extractor for woodland litter. Pedobiologia 3: 1–21.
		Earthworms and macrofauna		Identification of soil earthworms and macrofauna	• The standard method for sampling earthworms and other macrofauna is digging and hand-sorting of the upper soil layer. A chemical expellant is used to irritate earthworms in deeper soil layers. • By this method they are forced to leave the soil. The active agent in mustard, allyl isothiocyanate (AITC; mustard oil) will be used as described in ISO 23611-1:2018. • Once soil fauna sampling is finished, return soil back into the pit and leave the place in a tidy state. • In the following, the systematic procedure is described and explained in two steps: 1. Hand-sorting of soil samples in the field. 2. Chemical expelling of deep burrowing earthworms at the same sampling point in the field. • Excavate a square pit with an area of 25x25 cm and a depth of 20 cm • Separate 0-10 cm (earthworms and macrofauna) and 10-20 cm (earthworms only) and place the 2 soil samples on 2 different plastic sheets • Collect earthworms and macrofauna out of the excavated soil, roots, litter etc. by hand-sorting and picking up with plastic tweezers/forceps • Earthworms will be rinsed in tap water, put on tissue paper for carefully drying, then fixed in a 1:1 solution of 4% formalin and 96% ethanol until stop moving and collected in labelled test tubes with 4% formalin • Other macrofauna will be collected in labelled test tubes with 70% ethanol • Add 2.5 L AITC solution into the pit to expel deep	Bouche, M. B. (1977) Strategies lombriciennes. In Soil Organisms as Components of Ecosystems (eds. V. Lohm and T. Persson), Proc. 6th Int. Soil Zool. Coli., Ecol. Bull. (Stockholm), 25, 122–132. ISO 23611-1 (2018) https://www.iso.org/standard/70449.html Sims, R. W. & Gerard, B.M. (1999). Earthworms: Notes for the identification of British species. 4th Edition. Published for The Linnean Society of London & The Estuarine & Coastal Sciences Association by Field Studies Council, Montford Bridge, Shrewsbury. Pp. 169.
		Viable and non-viable cells		Identification of viable and non-viable cells	• Amicrobial propidiummonoazide (PMA)-based approach will be used to distinguish viable fromdead bacteria, followed by DNA extraction using the DNeasy Powersoil Pro kit. • Subsequently, DNA will be quantified using a Qubit® 2.0 Fluorometer and assessed for quality with a Nanodrop1000TM, followed by purification using Amicon Ultra 0.5 mL Centrifugal Filters 30 K NMWL.	Li et al. 2017. https://doi.org/10.1038/s41598-017-02516-3 Manfredini et al. 2023 https://doi.org/10.1093/jambio/lxad169

		Microarthropods by metabarcoding		Identification of microarthropods	• DNA will be extracted with the PowerMax DNA extraction kit. Ten nanograms of DNA will be used as a template for triplicated PCR reactions to amplify Cytochrome Oxidase I BF3 region using two sets of primers, BF3 + BF2 and III_B_F + FoI-degen-rev. • PCR reactions will be carried out for 25 cycles with regular primers, plus an additional 5 cycles in which barcodes will be added in excess. Corresponding PCR products will be bead-purified and pooled equimolarly. Pooled libraries will then receive Illumina sequencing adapters via ligation and sequenced using the Illumina NovaSeq Platform. • Obtained sequences will be quality-curated and dereplicated using USEARCH. DNA sequences will be translated into proteins using Prodigal. and taxonomically identified against the nr-NCBI database + MEGAN and abundance tables generated with USEARCH. • Diversity will be defined as the number of different Zero-centric OTUS and community composition assessed using a Multivariate Analysis of Variance.	Elbrecht V et al. 2019 https://doi.org/10.7717/peerj.7745 Ceja-Navarro et al. 2021 https://doi.org/10.1186/s40168-021-01042-9
		IR spectroscopy		IR spectroscopy-based model estimate soil biological indicators	• Soil samples (100g) will be sieved by 2 mm-mesh and dried at 60°C max. • Images of all soil cores will be acquired with a HySpex VNIR-1600 (further denominated as VNIR; 410–990 nm) and a HySpex SWIR-320 m-e (further denominated as SWIR; 970–2500 nm) hyperspectral line scanner camera. • For each ground sample, reflectance spectral measurements (over the 350–2500 nm wavelength range with 2151 bands at a spectral resolution of 1 nm with an average band sampling interval of ~ 2 nm) using the ASD FieldSpec-Pro spectroradiometer that is equipped with an 8°-fore optic will be collected.	Steffens et al. (2021). https://doi.org/10.1038/s41598-021-95298-8