

NBS soil interventions

This section presents **6 factsheets dedicated** to **NBS Soil Interventions**, detailing Permeable surfaces, organic soil amendments, farming practices and land management techniques.

PERMEABLE SURFACES

CARDIMED	1. SURFACE UNSEALING
<i>Picture not available.</i> Synonyms: De-sealing; De-sealed area; Deculvering; unsealing surfaces, demineralization. Description: Surface unsealing encompasses a variety of techniques aimed at removing impermeable surfaces to enhance water infiltration and reduce runoff. It involves the removal of impervious layers, such as asphalt or concrete, to restore natural permeability of soil or replace them with permeable surfaces. By creating pathways for water to penetrate into the soil below, these techniques mitigate stormwater issues and contribute to environmental sustainability. Furthermore, desiling surfaces can improve soil health, stimulate vegetation growth, and bolster overall ecosystem resilience.	
Main challenges targeted	Air quality, Soil restoration & protection, Societal benefits
Regulation and Maintenance Services	Permeability restoration, Create or restore habitat, Restore degraded areas Mitigate desertification, Reduce changes on soil characteristics, Stabilize soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilize water retention, Rehabilitate polluted soil, Improve carbon sequestration, Reduction of greenhouses gases emissions, Enhance dry deposition of aerosol particles, Provide thermal regulation / cooling
Cultural Services	Aesthetic value, Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Preserve cultural and historic heritage, Facilitate education, Reduce undesired behaviours, activities and vandalism, Support social cohesion and justice, Support environmental awareness,, Increase stakeholder engagement, Increase physical health, Promote mental health, Reconnect people with nature, Promote health habits
Provisioning Services	Promote artificial aquifer recharge / preserve groundwater supply
Other Services	Not applicable
Replicability	★ ★ ★
Design & planning	Standard equipment typically used in road construction for regular asphalt can also be utilised for surface unsealing projects. This includes machinery and tools necessary for excavation, levelling, and laying materials.
Operation and maintenance	Not applicable
Combinations with other	Porous/Pervious asphalt (for an integrated management of

NBS	stormwater runoff). Bioretention cell (rain garden), Bioswale and Filter drain (for reducing the runoff going to these systems, improving stormwater source control and enhancing overall biodiversity of the approach - an integrated rainwater management strategy). Terracing (for enhancing slope stability and maximising the available land for water infiltration).
Supportive units & smart tech	<i>Not applicable</i>
CAPEX	10 - 30 €/m ² . Main type of costs: Equipment and materials (demolition machinery, hand tools and other) Labour (replacement materials of the paved surface, demolition and removal of the sealants).
OPEX	<i>Not applicable</i>
By-product(s):	<i>Not applicable</i>

ORGANIC SOIL AMENDMENTS

CARDIMED	COMPOST APPLICATION
<i>Picture not available.</i> Synonyms: Community composting; Compost heap; Compost application facility; Soil improvement and conservation; Soil enhancement; Soil amendment; Gentle remediation options; Soil management; Improved soil; Xeriscaping. Description: There are various techniques to produce organic compost, and numerous sources contribute to its production, including urban allotments, livestock, restaurants, markets, fruit stores, and industrial processes. However, the true transformation occurs when it's applied to the soil. Compost application is a game-changer for soil health and fertility. Through compost application, the soil's microbiota is enriched, and its physical characteristics are improved, such as its ability to retain water, which is crucial for plant growth. When spread onto the land, compost enriches soil structure, infuses it with essential nutrients, and nurtures robust plant growth.	
Main challenges targeted	Soil restoration & protection, Societal benefits
Regulation and Maintenance Services	Erosion regulation, Reduce flood risk, Permeability restoration, Create or restore fauna, Reduce changes on soil characteristics, Stabilize soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilize water retention
Cultural Services	Social relations (related to recycling activity of organic waste and its valorization), Facilitate education, Support social cohesion and justice, Support environmental awareness, Reconnect people with nature
Provisioning Services	Nutrient cycling , Soil formation, Promote natural aquifer recharge / preserve groundwater supply, Promote artificial aquifer recharge / preserve groundwater supply, Provide nutrition sources for birds and insects, Production of biomass, Nutrient recovery, Sustainable food production
Other Services	Contribute to new or existing business, Reduced costs in comparison

	with other solutions, Favour green economy (reuse of local by-products)
Replicability	★ ★ ★
Design & planning	Assess soil needs: soil quality analysis to determine nutrient deficiencies and ph levels. Calculate application rates: based on size of the area, soil's requirements and composition of the compost. Application timing: typically during the growing season or before planting. avoid applying compost during heavy rain or when the ground is frozen. Proper application method: The method chosen depends on factors like soil structure, plant type, and etc. Some methods are: topdressing, incorporation into the soil, or as a mulch. If incorporating compost into the soil, ensure thorough mixing to distribute nutrients evenly and prevent clumping. Consider local context: slope, proximity to water bodies, and regulations regarding compost application to minimise potential runoff and environmental hazard.
Operation and maintenance	Operational activities: (Monitor moisture Levels) Water the area if necessary to help activate microbial activity and facilitate nutrient uptake by plants. (Rotate application areas) Rotate compost application areas to ensure all proper distribution and resting time between applications. (Follow best practices) local agricultural extension services or composting organisations to maximise effectiveness and minimise risks. Others: Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements. Safety protocols and training (to prevent accidents and ensure compliance with safety regulations). Track legal and regulatory compliance. Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	Green corridors , vegetated pergolas and agroforestry (for maintaining the soil quality and sustainability). Sludge treatment wetland (to obtain compost).
Supportive units & smart tech	Advanced soil health monitoring , (for assessing impact and optimising compost management practices).
¹ CAPEX	<i>Not available.</i> Main type of costs: Equipment and materials (compost material, storage facilities, equipment for spreading compost or manual labour and vehicles); Permits, fees and administrative (regulatory compliance and consulting fees); Transportation and delivery; Labour.
OPEX	<i>Not available.</i> Main type of costs: Permits, fees and administrative.

¹ It depends on the type of crop, the amount of compost required (depth and size of area), and the application method.

By-product(s):

Not applicable

CARDIMED

MULCHING APPLICATION

Picture not available. **Synonyms:** weeds management; Mulch; Soil improvement and conservation; Soil enhancement; Soil amendment; Gentle remediation options; Soil management; Improved soil; Soil moisture management, Retaining stubble and green manuring; Xeriscaping. **Description:** Mulching application is a technique that involves placing a layer of material (mulch) over the soil around plants, which can be organic (such as straw, compost, or bark) or inorganic (such as plastic or fabric). This material acts as a protective cover that offers various benefits, such as soil moisture conservation, erosion reduction, weed control, soil T regulation, and soil health improvement. Mulch serves the dual purpose of retaining moisture and suppressing weed growth in dry, hot conditions, but it must be managed carefully to avoid waterlogging and rot in wet, cold climates. Mulching is commonly used in agriculture, gardening, and horticulture to maintain a more conducive environment for plant growth and to reduce the need for irrigation and the use of herbicides.

Main challenges targeted

Biodiversity & renaturalization, Rainwater management & flood protection, Soil restoration & protection

Regulation and Maintenance Services

Erosion regulation, Reduce flood risk, Reduce combined sewer overflows
Reduce landslides, Reduce urban runoff, Stormwater source control, Permeability restoration, Create or restore habitat, Create or restore fauna
Create or restore flora, Reduce harmful impacts to fauna & flora, Forest creation and/or restoration, Develop resilience of green spaces, Reduce changes on soil characteristics, Stabilize soil / substrate, Improve soil fertility / biodiversity, Improve carbon sequestration

Cultural Services

Facilitate education, Support environmental awareness

Provisioning Services

Promote natural aquifer recharge / preserve groundwater supply, Provide nutrition sources for birds and insects, Nutrient recovery

Other Services

Contribute to local employment, Increase land/property monetary value, Reduced costs in comparison with other solutions, Reduced carbon footprint

Replicability



Design & planning

Materials used for mulching vary depending on the type of mulch. For mineral mulch, options include sand, pozzolana, gravel, and slate. Raw organic mulch includes flax flakes, hay, and hemp glitter. Wood mulch encompasses maritime pine bark, wood chips, wood pellets, bagasse, fragmented rameal wood, and non-composted wood mulch. **Depth of application** varies depending on the mulch material, ranging from 5-18 cm. The most common **type of mulch to be anchored** is hay or straw. The primary **anchoring methods** include mulch tiller, netting, manual anchoring with spade or peg and twine.

Operation and maintenance	Operational activities: Inspect mulched areas, monitor weeds and pest, assess the effectiveness of the mulch (application, coverage, durability, etc.) and adapt management or mulch type accordingly. Maintenance activities: Remove or integrate mulch materials as required. Appropriately gather and dispose of synthetic mulch material after its intended use. Manage undesirable weeds and pests. Others: Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements. Safety protocols and training (to prevent accidents and ensure compliance with safety regulations). Track legal and regulatory compliance. Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	Bioretention cell (rain garden) (for promoting moisture retention and weed suppression, reducing the need for frequent watering, which is especially relevant for young rain gardens). Agroforestry and Urban micro forest (for maintaining the soil quality and sustainability). These NBS can also act as a source of organic material for Mulching application. Permeable surfaces (for moisture regulation, weed control, enhanced water infiltration).
Supportive units & Smart tech	Smart irrigation systems (supply and optimization of irrigation). Remote sensing, computer vision and advanced precision agriculture equipment (for supporting informed decisions and optimising mulch distribution and coverage). Biodegradable mulch films (for weed suppression and moisture retention benefits while degrading naturally over time). Solar panels (for reducing energy costs and enhancing overall sustainability). Advanced soil health monitoring (for assessing impact and optimising mulch management practices).
² CAPEX	0.75 - 2 €/m². Main type of costs: Equipment and materials (mulch material, equipment for spreading mulch or manual labour, wheelbarrows and rakes); Labour (clearing and levelling the area); Transportation and delivery.
OPEX	0.15 - 0.5 €/m² y. Main type of costs: Labour (mulch replacement, weed control, inspections and repairing damaged areas).
By-product(s):	<i>Not applicable</i>

FARMING PRACTICES

<u>CARDIMED</u>	COVER CROPS
	Synonyms: Green manure, Soil enhancement; Soil amendment; Gentle remediation options; Soil management; Improved soil; Soil moisture management, Conservation agriculture; Agroecology practices; Sustainable farming practices;

² the cost varies depending on the type of mulching chosen, the size of the covered area, encompassing both material costs and installation expenses

Climate-smart agricultural techniques (CSA,). **Description:** Cover crops are crops planted primarily to cover and protect the soil, rather than for harvesting and sale. These crops are typically planted between main crop seasons or alongside cash crops. The primary purpose of cover crops is to improve soil health and fertility, prevent erosion, and suppress weeds. Indeed, cover crops are an important part of sustainable and regenerative agricultural practices aimed at maintaining and enhancing the long-term health and productivity of the land. Picture source: Ledda

Main challenges targeted	Biodiversity & renaturalization and Societal benefits
Regulation and Maintenance Services	Erosion regulation, Improve quality of surface water, Improve quality of groundwater, Reduce flood risk, Reduce sediment flow into drainage systems, Reduce combined sewer overflows, Reduce landslides, Reduce urban runoff, Stormwater source control, Permeability restoration, Create or restore habitat, Create or restore fauna, Create or restore flora, Support pollination, Reduce harmful impacts to fauna & flora, Forest creation and/or restoration, Connect green spaces; Develop resilience of green spaces, Support free movement of species, Provide nesting and breeding habitat, Refuge for farm and wild animals, Stabilize soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilize water retention, Improve carbon sequestration, Enhance dry deposition of aerosol particles, Provide thermal regulation / cooling
Cultural Services	Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Preserve cultural and historic heritage, Facilitate education, Support environmental awareness; Increase stakeholder engagement, Increase physical health, Promote mental health, Reconnect people with nature, Promote health habits
Provisioning Services	Nutrient cycling , Soil formation, Production of biomass, Nutrient recovery, Promote natural aquifer recharge / preserve groundwater supply, Harvest, store and treat rainwater, Provide nutrition sources for birds and insects, Sustainable food production
Other services	Contribute to local employment, Increase land/property monetary value, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products), Reduced carbon footprint
Replicability	★★★★
Design & planning	Plants selection: consider factors such as climate, soil type, cropping sequence, and desired benefits such as nitrogen fixation, weed suppression, erosion control. Main categories of plants: grasses, including grains such as oats, barley, or wheat, as well as warm-season grasses like millets, sorghums, and sudangrass; brassicas, this group consists of leafy broadleaf plants with a large taproot, such as radishes, turnips, and other related species; legumes, any species capable of forming nodules on its roots and fixing excess soil nitrogen,

	such as clovers, peas, and vetches. Residue removal and weed control , creates optimal conditions for cover crop germination and growth. Seeding depth from 0.5-2.5 cm. When species with different seeding depths are mixed together, there are several strategies that can be used to aid in the successful establishment of each species. It is recommended to sow cover crops at a seeding rate ranging from 265-290 Kg per ha depending on the species.
Operation and maintenance	To properly define the termination time of the cover crops e.g biomass quantity and quality (in terms of C/N ratio). Optimised plants density and species selection or mixing. Different species for different agro-ecological objectives. Others: Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements. Safety protocols and training (to prevent accidents and ensure compliance with safety regulations). Track legal and regulatory compliance. Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	Crop rotation and Agroforestry (for improving soil quality, reduction of erosion, water and moisture retention, and suppressing weeds)
Supportive units & Smart tech	Advanced precision agriculture equipment (for precise planting and management in line with field variability). Advanced soil health monitoring (for assessing impact and optimising cover crop management practices).
CAPEX	20 - 180 €/ha. Main types of costs: Equipment and materials (cover crop seed); Labour (preparing the soil and seeding the cover crops)
OPEX	<i>not available</i> . Main types of costs: Labour (soil management, fertilisation and weed control).
By-product(s):	<i>not applicable</i>

<u>CARDIMED</u>	CROP ROTATION
<i>Picture not available.</i> Synonyms: Crop Diversification; Soil enhancement; Soil amendment; Gentle remediation options; Soil management; Improved soil; Conservation agriculture; Agroecology practices; Sustainable farming practices; Climate-smart agricultural techniques (CSA). Description: Crop rotation is an agricultural practice involving the systematic alternation of different crops on the same land over time to enhance soil health, increase yields, and manage pests and diseases sustainably. It's based on varying crop types planted in successive seasons, contributing to improved crop and soil health, and overall agricultural sustainability. Rotation patterns may vary based on local conditions and crops grown, but the core principle remains consistent: alternating crops to maintain and improve land health while maximising productivity.	
Main challenges targeted	Biodiversity & renaturalization, Societal benefits, Soil restoration & protection

Regulation and Maintenance Services	Reduce water withdrawals, Improve quality of surface water, Improve quality of groundwater, Avoid / reduce salinity in groundwater, Efficient water treatment (effluent of WWTP), Efficient water treatment (agricultural runoff), Reduce flood risk, Reduce agricultural runoff, Permeability restoration, Mitigate desertification, Coastal restoration & protection/ Promote resilience against natural disasters, Stabilize soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilize water retention, Rehabilitate polluted soil, Improve carbon sequestration, Reduction of greenhouses gases emissions
Cultural Services	Aesthetic values, Facilitate education, Support environmental awareness
Provisioning Services	Production of biomass, Provide raw material, Nutrient recovery, Sustainable food production
Other Services	Increase land/property monetary value, Contribute to new or existing business, Reduced costs in comparison with other solutions, Reduced carbon footprint, Reduced water footprint
Replicability	★ ★ ★
Design & planning	Plants with similar pest and disease susceptibilities must be separated by an appropriate time interval. Rotate crops from different plant families, such as brassicas (cabbage, broccoli, cauliflower, etc.), solanaceae (tomato, potato, eggplant, etc.), cucurbits (cucumber, squash, melon, etc.), alliaceae (onion, garlic, leek, etc.), and leguminosae (peas, lentils, beans, etc.), etc. Rotate heavy nitrogen-consuming crops with nitrogen-fixing crops or cover crops. Rotate crops with different root systems, such as taproots (carrot, beet, radish, etc.), fibrous roots (lettuce, spinach, celery, etc.), and tubers (potato, sweet potato, yam, etc.). Plan cover crop planting strategically to avoid leaving soil bare or periods where nutrients are released without active plant growth Harvesting time determines the sequence of crops in a rotation. For instance, autumn-sown crops require a clear area in summer and/or autumn for necessary cultivation, limiting them to succeeding crops harvested by summer's end. Conversely, summer-sown crops like winter brassicas typically follow vegetables or green manures that were cultivated over winter, freeing up the land earlier than spring-sown crops. Segment the crop allotment into equal-sized sections, with an additional area designated for perennial crops.
Operation and maintenance	Operational activities: Maintain healthy soil (including chemical balance, drainage, vitality, biological health, fertility, nutrient cycling, tillage, organic matter, and soil cover to prevent erosion). The frequency and amount of watering are adjusted according to rainfall and evaporation rates, crucial for maintaining soil and plant health. Adjusting the timing of harvest, either earlier or later, based on the ripeness and quality of the crops. Maintenance activities: Control and management of weeds, diseases and pests. Adding or removing mulch

	as necessary, based on the T and moisture levels of the soil. Others: Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements. Safety protocols and training (to prevent accidents and ensure compliance with safety regulations). Track legal and regulatory compliance. Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	Compost application, Mulching application and Cover crop (for improving soil quality, reduction of erosion, water and moisture retention, and suppressing weeds)
Supportive units & smart tech	Weather stations data (for optimising planting and harvesting schedules to maximise rotation benefits). Remote sensing (satellite imagery and aerial drones for assessing rotation success, identifying areas for improvement and thus supporting informed decisions and optimising crop rotation management). Advanced precision agriculture equipment (for optimising planting, fertilisation, rotation and crop yields). Solar panels (for reducing energy costs and enhancing overall sustainability). Advanced soil health monitoring (for assessing impact and optimising crop rotation management practices). Decision support systems (for enabling data-driven decision-making and optimise rotation planning).
CAPEX	1,000 - 20,000 €. Main type of costs: Equipment and materials (seeds and planting materials, machinery and fertilisation); Labour (land preparation and other tasks).
OPEX	200 - 350 €/ha y. Main type of costs: Labour (seeding, fertilisation, soil management, harvesting and weed control).
By-product(s):	Organic biomass from trimming, pruning, clippings, straw and fallen leaves (for mulching, soil amendments, composting, organic fertilisers, energy production and biofuel). Forage and fodder (for livestock or other animals).

LAND MANAGEMENT TECHNIQUES

CARDIMED	TERRACING
<i>Picture not available.</i> Synonyms: Terraces; Crescent terraces. Description: Terracing involves constructing a series of horizontal platforms or steps on sloping or hilly terrain (such as crescent terraces). These platforms, often created with retaining walls or embankments, provide flat surfaces at different elevations. Terracing is primarily used in agriculture to reduce soil erosion by slowing down the flow of water down slopes. It creates level planting areas for crops, making it easier to manage irrigation, prevent soil loss, and enhance crop productivity, soil erosion and improve water retention.	
Main challenges targeted	Rainwater management & flood protection, Biodiversity & renaturalization, Societal benefits

Regulation and Maintenance Services	Reduce flood risk, Reduce sediment flow into drainage systems, Reduce combined sewer overflows, Reduce landslides, Reduce urban runoff, Stormwater source control, Permeability restoration, Create or restore habitat, Support pollination, Forest creation and/or restoration, Connect green spaces, Develop resilience of green spaces, Support free movement of species, Stabilize soil / substrate, Improve soil fertility / biodiversity, Enhance and stabilize water retention, Improve carbon sequestration, Provide thermal regulation / cooling
Cultural Services	Health and Well-Being improvement, Increase recreational and socialisation value, Increase aesthetic and patrimonial or cultural value, Ensure accessibility to green spaces, Facilitate education, Reduce undesired behaviours, activities and vandalism, Support environmental awareness, Increase stakeholder engagement, Increase physical health, Promote mental health, Reconnect people with nature
Provisioning Services	Promote natural aquifer recharge / preserve groundwater supply, Material reuse
Other Services	Contribute to local employment, Increase land/property monetary value, Reduced costs in comparison with other solutions, Favour green economy (reuse of local by-products)
Replicability	★ ★ ★
Design & planning	When constructing terraces, several factors must be considered. The slope , typically less than 50%, though it's feasible to manage steeper slopes up to 100%, requires gradual and consistent construction. Careful balance between soil cut and fill is crucial. The size of the terrace depends on drainage needs and agricultural methods employed. Similarly, terrace length varies based on the lot's size and shape. The width of non mechanised crops, terrace ranges from 2.5 to 5 m, while mechanised crops require wider terraces, typically spanning 3.5 to 8 m.
Operation and maintenance	Monitoring and maintenance are essential, especially after severe storms and harvests, particularly during the initial two to three years following construction. It's important to conduct inspections and promptly repair any damage to the structure. Others: Training to staff and volunteers responsible for the operation and maintenance. Regular documentation of maintenance activities, operational issues, and measurements. Safety protocols and training (to prevent accidents and ensure compliance with safety regulations). Track legal and regulatory compliance. Be prepared to adapt your operation and maintenance practices over time in response to changing environmental conditions, market dynamics, and other factor
Combinations with other NBS	Cover crop , Crop rotation , Compost application , Mulching application , Urban micro forest and Agroforestry (for improving soil quality, reduction of erosion, water and moisture retention, and suppressing weeds). Porous asphalt (to enhance erosion control, water management, and water quality improvement).

Supportive units & smart tech	GPS and GIS (for identifying erosion hotspots, for mapping terraced landscapes and guiding earth-moving equipment).
CAPEX	<i>not available</i> . Main type of costs: Equipment and materials (irrigation systems, planting materials, plants, stones, tractor, wire and staking poles); Labour (land levelling, ploughing/harrowing, destoning, terrace wall construction, irrigation system installation, planting and staking/wiring).
OPEX	<i>not available</i> . Main type of costs: Labour (ploughing/harrowing, fertilisation, plant protection, weed control, irrigation, pruning, topping/thinning and harvesting).
By-product(s):	Surplus soil, rocks, or other materials excavated from the site (for landscaping, construction projects, or filling in other areas prone to erosion)