



RETENTION FOREST

FW3



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ADDRESSED HAZARDS



PROTECTED CRITICAL INFRASTRUCTURE



Primary functions and key services

(Gustafsson et al., 2012)

- **Sediment management:** retention forests reduce soil erosion and trap sediments before they reach rivers, **reservoirs, or hydro-power facilities**. This helps maintain water storage capacity, prevents clogging of **drainage systems**, and reduces dredging costs.
- **Water management and reduction of water quantity:** by enhancing infiltration and delaying runoff, retention forests lower peak flows during heavy rainfall, reducing flood risks. This protects **roads, railways, and urban drainage systems** from water damage and overflow events.
- **Diversion of debris flow material:** trees and root systems slow down and redirect debris flows, preventing uncontrolled sediment movement. This protects **roads, bridges, and settlements** from destructive impacts.
- **Bedload deposition into natural deposition areas:** retention forests encourage natural sediment deposition, preventing excessive buildup in river channels. This helps maintain **bridge piers, culverts, and embankments**, reducing the risk of structural failure due to sediment blockages.

Challenges this NbS addresses

- **Floods** – prevention/reduction: Retention forests improve water infiltration and slow surface runoff, reducing peak flows.
- **Debris flows** – reduction: roots stabilise slopes and prevent excessive erosion, reducing the likelihood of debris flow initiation.
- **Embankment and riverbed destabilisation** – prevention/reduction: Vegetation reinforces riverbanks and embankments through root binding.
- **Retention of sediment** – reduction/recovery: trap and retain sediments, preventing excessive downstream deposition.

Ecosystem services

(Nunery et al., 2010; Calder, 2007; Gustafsson et al., 2012)

- ▶ **Re-establishment of riparian forests and buffers**
- ▶ **Habitat creation:** provide critical habitats for wildlife, including birds, amphibians, and aquatic species
- ▶ **Biodiversity enhancement:** by maintaining natural vegetation cover, retention forests support diverse plant communities
- ▶ **Landscape connectivity:** can act as ecological corridors, linking fragmented habitats
- ▶ **Microclimate regulation:** tree cover reduces temperature extremes, mitigates the urban heat island effect, and prevents excessive soil drying
- ▶ **Carbon Sequestration and Climate Regulation:** forests absorb CO₂, contributing to climate change mitigation (Nunery et al., 2010)
- ▶ **Water Purification:** vegetation and soil filter out nutrients and contaminants from runoff
- ▶ **Recreation and Aesthetic Value:** provide spaces for outdoor activities like hiking and birdwatching

What is it?

Retention forests are natural or planted forests located in the middle reaches or alluvial fans of river systems that are capable of retaining large quantities of water and/or sediment. Retention forests increase the roughness of an area and thus reduce flow velocity, intended to cause a deposit of the suspended material load, bedload or debris flows.

(Gustafsson et al., 2012)



Retention forest retaining large amounts of sediment above an endangered CI object, Demo-Site Brunsee

Image Credit: [Rosemarie Stangl, BOKU], [2024]. Used with permission;



Retention forest after an event, Gaiserer Weißenbach in Bad Gaisern

Image Credit: [Johannes Hübl, BOKU], [2024]. Used with permission;

Environmental impacts (EU taxonomy)

- Climate change mitigation
- Climate change adaptation
- Sustainable use and protection of water and marine resources
- Transition to a circular economy
- Pollution prevention and control
- Protection and restoration of biodiversity and ecosystems.

Cost-benefit profile

Retention forests are cost-intensive but effective solutions for flood risk reduction, water retention, and biodiversity conservation. Establishment costs include land acquisition, site preparation, afforestation, and hydrological assessments, while annual maintenance expenses typically range between 2% and 4% of the initial investment, accumulating over 25–30 years (Fraser, 2019). According to Fraser, (2019) there are considerable additional costs involved in managing forests sustainably, compared with managing for maximum profit. The additional costs are not just one-off items for inventories and management plans, but must include the cost of additional human resources for implementing and monitoring all the necessary activities (such as training and capacity building).

The average opportunity cost arising from retention forestry practices amounted to 1795 EUR/ha by leaving a minimum deadwood volume of 35 m³ /ha and 2.5–5 habitat trees/ha (Augustynczyk et al., 2018). Additionally, conservation costs can emerge when establishing protected areas or ecological corridors to maintain biodiversity (Augustynczyk et al., 2018). Despite these costs, retention forests enhance water quality, reduce flood risks, and improve climate resilience, making them a long-term investment in sustainable land and water management. A comprehensive economic analysis is essential to balance implementation expenses with long-term ecological and societal benefits.



▼ Main components

- **Tree and vegetation composition:** deep-rooted, water-absorbing, and flood-tolerant species (e.g., willows, poplars, alders).
- **Forest floor and understory:** shrubs, grasses, and wetland plants enhancing water retention and soil stabilisation.
- **Soil and hydrology management:** organic-rich soils with high infiltration capacity to support groundwater recharge.
- **Buffer zones and riparian strips:** vegetated areas along rivers and slopes to slow water flow and reduce sediment transport.
- **Natural drainage and water storage:** ponds, swales, and depressions for temporary water retention.
- **Deadwood and organic material:** fallen logs and leaf litter to improve soil moisture and biodiversity.
- **Landscape connectivity:** links to adjacent forests, wetlands, and agricultural areas for ecosystem integration.

Example of installation

► Buffeldraai Landfill Site Community Reforestation Project

► **Location:** Durban, South Africa

► **Implemented by:** eThekweni Municipality in partnership with the Wildlands Conservation Trust

► **Description and results:** Initiated in November 2008, the Buffeldraai Landfill Site Community Reforestation Project aimed to offset a portion of the CO₂ emissions associated with Durban's hosting of the 2010 FIFA World Cup™. The project involved restoring natural forest ecosystems within the 757-hectare buffer zone of the Buffeldraai Regional Landfill Site. By engaging local communities as 'Treepreneurs', individuals cultivated indigenous tree seedlings at their homes, which were later transplanted to the reforestation site. This initiative not only enhanced carbon sequestration but also provided socio-economic benefits, including improved food security, education, and livelihoods for participating community members. As of June 2023, over 1,033,216 trees have been planted across 580 hectares, leading to a significant increase in biodiversity, with bird species richness rising from 91 in 2009 to 197 in 2023. (Douwes et al., 2015)

▼ Site suitability, scale and coverage

Retention forests are effective in middle reaches of river systems and alluvial fans, where they can intercept water and sediment. They are suitable for riparian zones, floodplains, and mountainous terrain prone to floods, erosion, and debris flows. Critical infrastructure such as roads, bridges, and hydro-power reservoirs benefits from their protective functions.

Retention forests can be implemented at small scales (buffer strips along riverbanks) or large-scale watershed management projects covering sediment catchments, floodplains, and riverbeds. Their effectiveness depends on tree species selection (e.g., poplar, willows, pines), terrain roughness, and integration with artificial barriers (e.g., check dams) to optimise water retention and sediment management.

- **Installation:** sediment or water can be redirected into existing forests or plantations through small modifications of the landscape (e.g. flood pits or troughs). Artificial barriers (e.g. check dams; other NbS) within a river system may also be used to divert flood events of a certain size into the retention forest without affecting the low water conditions.
- **Maintenance:** variations with flood pits and troughs might need to be emptied from large sediment clasts (e.g. boulders) if they cannot be washed out at normal water levels and affect the functionality of the NbS after a given event to maintain functionality of the system.
- **Material and Coverage:** riparian tree species (e.g. poplar, willows, oaks), species with high tolerance to fluctuating water availability (e.g. pines).



Schematic of a retention forest.
Image credit: [Freepik, AI generated], [n.d], Free to use.

References

- Augustynczyk, A. L. D., Yousefpour, R., Rodriguez, L. C. E., & Hanewinkel, M. (2018). Conservation costs of retention forestry and optimal habitat network selection in southwestern Germany. *Ecological Economics*, 148, 92-102.
- Calder, I. R., 2007, 'Forests and water—Ensuring forest benefits outweigh water costs', *Forest Ecology and Management* 251(1–2), pp. 110–120.
- Douwes, E., Rouget, M., Diederichs, N., O'Donoghue, S., Roy, K., & Roberts, D. (2015). Buffeldraai Landfill Site Community Reforestation Project. In XIV World Forestry Congress. Food and Agriculture Organisation of the United Nations.
- Fraser, A. (2019). Costs of Forest Management and Regeneration. In: *Achieving the Sustainable Management of Forests*. Sustainable Development Goals Series. Springer, Cham. https://doi.org/10.1007/978-3-030-15839-2_13.
- Gustafsson, L., Baker, S. C., Bauhus, J., Beese, W. J., Brodie, A., Kouki, J., ... & Franklin, J. F. (2012). Retention forestry to maintain multifunctional forests: a world perspective. *BioScience*, 62(7), 633-645.
- Hübl J, Loiskandl W, Feiersinger R, Gruber H, Holzinger G, Kraus D, Pichler A, Strauss-Sieberth A, Zott F. (2002): WLS Report 76 Hochwasserschutz durch die Reaktivierung von Überflutungsräumen: Evaluierung des Systemverhaltens im Verbaunungsprojekt "Pertisauer Wildbäche", Band 1: Modellaufbau und Methodik, Institut für Alpine Naturgefahren, Universität für Bodenkultur Wien (unpublished).
- Hübl J, Kuschel E (2024): Fact Sheet Pertisau (unpublished).
- Nunery, J. S., & Keeton, W. S. (2010). Forest carbon storage in the northeastern United States: net effects of harvesting frequency, post-harvest retention, and wood products. *Forest Ecology and management*, 259(8), 1363-1375.
- UNFCCC (n.d.) Buffeldraai Landfill Site Community Reforestation Project. Retrieved from: https://unfccc.int/sites/default/files/1_buffeldraai_reforestation.pdf (accessed 10.02.2025)