Revegetation

INTERVENTION CATEGORY: RESTORATION

DESCRIPTION

Revegetation is the restoration of native habitat via either active planting or seeding, or passive measures which result in a suitable enabling environment for regeneration. Revegetation can involve restoration of natural forest, grassland or other habitat, and includes pastureland reforestation (active or passive forest restoration on grazing lands). Common activities involved in revegetation are site assessment and selection, site preparation (soil preparation and removal of unwanted vegetation/weeds), fencing and pest control if needed, direct seeding and planting, and various actions of maintenance and monitoring.[1]

With regards to water security, the main reasons for implementing revegetation include (i) an enhanced capacity to hold soil in place and reduce erosion, (ii)) natural filtering of pollutants from overland flow, and (iii) increase infiltration of runoff water into the soil, thus attenuating peak flows.[2]

This factsheet especially concerns revegetation of non-riparian and non-wetland areas, often located in upland parts of (mountainous) catchments. Other NbS involving revegetation, such as restoration of wetlands, riparian areas and floodplains, are described in the corresponding factsheets.

The Nature Conservancy
Protecting nature. Preserving life.
AFD
AGENCE FRANÇAISE DE DÉVELOPPEMENT

WATER SECURITY CHALLENGES (WSCs) ADDRESSED

TYPE		IMPACT	MAGNITUTE	DEPTH OF EVIDENCE BASE
Water availability	Groundwater recharge	Increased mean annual groundwater recharge	★★☆	★★☆
	Dry season flows	Maintained dry season flows	★★☆	★★☆
Disaster risk	Flood risk	Reduced peak discharge	★★★	★★★
Water quality	Erosion and sedimentation	Reduced on-site erosion and sediment yields	★★★	★★★
	Nutrients and pollutants	Reduced in-stream nutrient and pollutant concentrations	★★★	★★☆

Impacts of revegetation on water availability depend strongly on the temporal and spatial scales under consideration. For many geographical locations, forest types and climate conditions, annual water yields are reduced as a result of reforestation, due to enhanced access to soil water and transpiration of the vegetation.[3, 4] Especially in tropical climates, depending on tree species used, soil water content is effectively restored to natural conditions by reforestation and associated deep rooting systems.[5] It should be noted that increased landscape transpiration after revegetation also drives enhanced atmospheric moisture recycling, leading to increased precipitation either locally or elsewhere in the "precipitationshed".[6]

When looking at season time scales, peak discharges and associated flood risk are reduced due to the regulating effect of tree cover on hydrology, especially in mountainous watersheds.[7] In addition, dry season flows and groundwater recharge can be enhanced due to improved infiltration and percolation.8 A review of (re)forestation efforts in Andean watersheds showed an increase of soil infiltration rates by a factor of 8.[9]

With regards to water quality, strong relationships between stream salinity and reforestation can be found in areas prone to secondary salinity; a case in western Australia showed a 67% reduction of in-stream salinity after reforesting 14.5% of the watershed, allowing water to be classified as potable again.[10] Estimated water quality benefits of reforestation of marginal croplands in the Ohio River Basin (USA) include reductions of downstream nitrogen an phosphorus loads of 95–97% and 96–99%, respectively. In mountainous catchments in Latin America, around 20 years of forest cover presence was sufficient to restore erosion rates and sediment yields close to natural conditions.[9]

OTHER BENEFITS

WHAT?	HOW?
Provisional ecosystem services[11]	Provision of food, fiber, timber, medicinal resources, etc., including socio-economic benefits and food security.
Carbon sequestration[12]	Sequestration of carbon in newly planted/restored biomass.
Habitats / biodiversity[12]	Increased habitat and enhancement of biodiversity. Species richness/gene pool.
Recreation and (eco) tourism[13]	Increased aesthetic value and more pleasant environment.

Spiritual value[13]	Restoration of the natural situation that is often socially or culturally embedded in local communities
Reduced landslide risk[14]	Slope stability increases with deep rooting systems of trees
Improved air quality	Trees absorb these toxic chemicals through their stomata, effectively filtering these chemicals from the air.

LINKAGES TO CLIMATE CHANGE

Mitigation: Reforestation is regarded worldwide as an effective tool for sequestering carbon from the atmosphere and combating the greenhouse effect.[15]

Adaptation: Reforestation reduces temperature extremes by providing shade and using solar energy for transpiration of water. Attenuation of peak flows reduces risk of floods resulting from more extreme precipitation events, while enhanced groundwater recharge and baseflow increase resilience to prolonged episodes of drought.

DESIGN-ENABLING CONDITIONS AND TYPICAL CONSTRAINTS

- To increase chances of plant survival and healthy growth, in semi-arid conditions, timing of the outplanting window is determined mostly by soil moisture (water availability in general) and temperature.[16]
- Soil depth needs to be sufficient to minimize mortality of seedlings.[16]
- Steep slopes can be hard to manage and risky for labor. Upper slope limitations of equipment should be established to ensure safety and efficient operations.[16]
- Aspect can influence species selection and planting density and configuration. North-facing slopes usually have better soil and more shade, whereas South-facing slopes should be planted with lower densities and only with drought and light tolerant species.
- Species selection is influenced by site elevation and soil type. Usage of native species is most likely to be successful in establishing healthy plant communities and achieving the intended benefits.[16]
- Rockiness can be a constraint, as very rocky sites are hard to plant and manage. Heavy machinery may be required to break surface rocks to access underlying soil layers.
- Land use prescribed by governmental regulations needs to allow for reforestation.
- High levels of interest and engagement of the local community are key boundary conditions to ensure sustainable use and management of revegetated lanscapes.[16]
- Species selection is highly influenced by the site elevation and soil type.[16]
- Site accessibility can strongly influence project costs.[16]
- Grazing pressure can be relevant to consider, and fencing may be required.[16]
- Available project budget can impact the choice between active restoration and passive restoration, where the former is typically more expensive (but more appropriate in a reduced implementation window). Both strategies might be used in a complementary manner to compensate for high implementation costs, such as through the integrated " applied nucleation" approach.[17]
- Possible maintenance needs include[1]:
  - Post weed control
  - Maintenance of fences or other structures
  - Replacement of any plant losses
  - Thinning
  - Watering

RELATION TO GREY INFRASTRUCTURE

INFRASTRUCTURE?	SERVICE PROVIDED BY GREY SOLUTIONS	TYPE OF RELATION
Reservoirs/dams[27]	Water storage, flood mitigation, and/or power generation	Complementary
Retaining walls[27]	Decreased erosion, sedimentation, and land slide risk.	Complementary, Alternative

COMMON RISKS AND TRADE-OFFS

- Outcomes of natural seeding can be uncertain, e.g., depending on unfavorable weather and competing vegetation. This can result in a risk of potential over- or understocking or poor forest health. If deemed too risky, active planting can be seen as a more reliable option, despite higher costs.[18]
- Damage to seedlings by animals can be a risk for effective revegetation. Various control strategies may be employed, depending on the species and number of animals.[18]

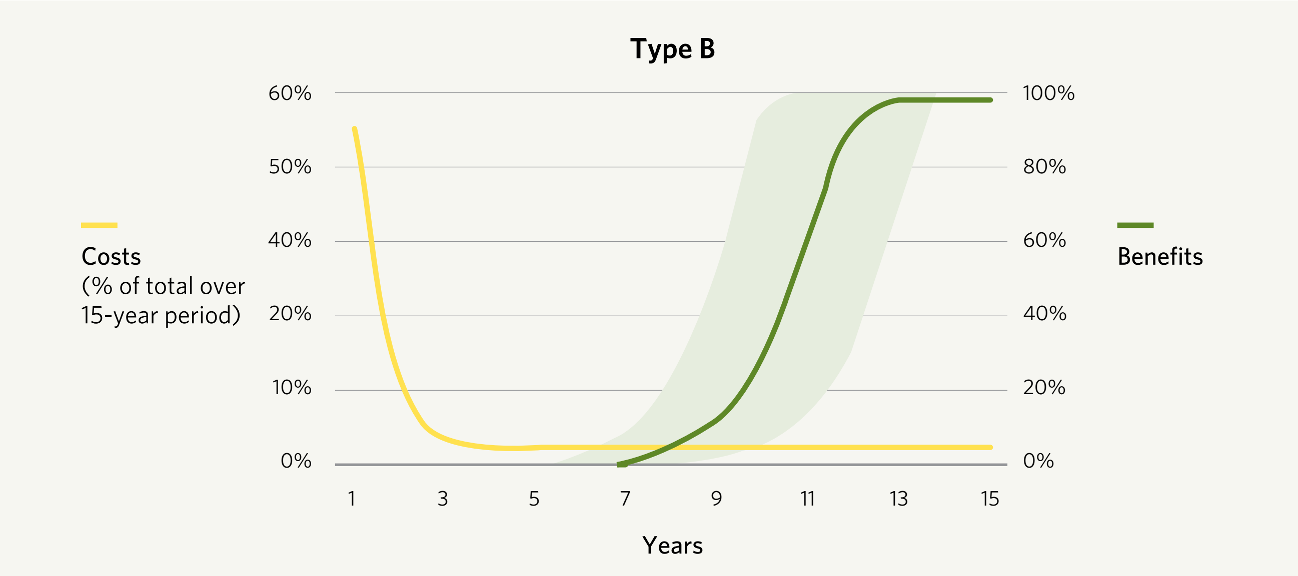
MONITORING OPPORTUNITIES

- Vegetation growth and regeneration can be monitored with satellite imagery, aerial photos and ground-truthing by field surveys.[19]
- Different in-field techniques exist for monitoring establishment and survival of different species.[1]
- Impacts on water quantity (dry season) can be monitored by measuring streamflow at downstream sites.
- Impacts on water quality can be monitored locally by measuring concentrations of relevant parameters (e.g, nutrients or sediments).

IMPLEMENTATION COSTS AND TIMING OF BENEFITS

Capital costs incurred in revegetation strongly depend on the method applied (natural regeneration, mechanical seeding, planting). Expenses include labor and equipment for site preparation and planting, costs of seedlings, material for fencing, In the U.S., estimated establishment cost. range roughly from $100 to $450 per acre (including labor).[20, 21] In a Chinese case study, depending on tree species, total reforestation costs are between $50 and $400 per hectare[22], mostly due to lower labor costs. **Recurring costs** of ongoing management and maintenance activities in the US are typically not more than USD 2–4 per acre. In the aforementioned examples, land acquisition costs were not applicable.

As with many NbS, revegetation involves costs incurred locally but benefits enjoyed on the watershed scale. Private economic **benefits** are strongly linked to timber prices, and depending on the specific context may or may not justify investment.[21, 22] Watershed services from revegetation are generally considerable and concern the various WSC-related benefits and others described in this factsheet.[12] The time needed for the benefits to materialize depends on the revegetation method applied, but generally is characterized by a slow onset (where seedlings develop and natural regeneration takes place) followed by a relatively rapid increase as the integrated vegetation-soil-water system develops.



Reforestation efforts in Extrema, Brazil (source: TNC)

EXAMPLES

Revegetation projects are being implemented worldwide, and documentation of empirical evidence and costs/ benefits is available from all continents.23 However, due to difficulties in monetizing many of the provided watershed services, particularly those related to WSCs ("non-use" values), cost and benefit analyses are often limited to private benefits and carbon credits.

Tennessee, United States[24]

Brief description: A cost-benefit analysis was performed for 15 target sites for implementing forest landscape restoration to protect the ridgelines and hillsides in the southern Appalachian region. Private and public benefits per dollar spent were estimated for each site, and implications for different payment schemes are discussed.

Lessons learnt:

- Much of the private benefit accrues to households living close to the reforestation site, while public benefits are mainly generated by indirect use values of stormwater control and improved air quality.
- Results for the 15 sites show that the magnitude of public benefits is between 5 and 50 times as high as the private economic benefits.
- Public return per dollar spent is over 1 USD for 13 out of 15 sites, whereas private returns only exceed 1 USD for one site.

South Gondar, Ethopia[25]

Brief description: A watershed rehabilitation program has been carried out that involves revegetation of hills and improved agricultural practices, as well as a supporting management plan. Plantings were designed with the multiple aims of providing soil and water conservation, fodder, construction and fuel material, and nutrient enrichment.

Lessons learnt:

- A strong business case for revegetation was identified. The results indicate that the benefits during the first 10 years after revegetation amounted to US$73,821 and US$374,008) for the smallest and largest of the rehabilitated watersheds, respectively, while the expenditure was US$17,701 and US$23,620. Benefits here are based on timber production and carbon sequestration; additional watershed services are excluded.

Sao Paolo, Brazil[26]

Brief description: This study evaluated how restoring forests as natural infrastructure can complement and safeguard the Cantareira Water Supply System, São Paulo's primary water source. In one of the analyses, the InVEST Sediment Yield Model was used to select 4,000 ha of land for restoration, an amount considered a reasonable target for the Cantareira region. Of the total revegetated area, 25% was assumed to be restored through passive restoration and 75% through active restoration (planting) techniques, over a period of 10 years.

Lessons learnt:

- The total cost of forest restoration was estimated to be $37 million. It was found that these efforts would avoid $106 million in sediment management costs over 30 years, in majority (+/- 90%) coming from water treatment costs savings as turbidity is reduced.
- Other cost savings are achieved through reduced needs for dredging (+/- 9%) and depreciation related to infrastructure and equipment (+/- 1%).

REFERENCES

1. Corr, K. *Revegetation Techniques. Greening Australia Victoria* (2003).
2. WWAP/UN-Water. *Nature-Based Solutions for Water. Unesco* (2018).
3. Duan, L. & Cai, T. Quantifying impacts of forest recovery on water yield in two large watersheds in the cold region of northeast China. *Forests* **9**, (2018).
4. Senent-Aparicio, J., Liu, S., Pérez-Sánchez, J., López-Ballesteros, A. & Jimeno-Sáez, P. Assessing impacts of climate variability and reforestation activities on water resources in the headwaters of the Segura River Basin (SE Spain). *Sustain.* **10**, (2018).
5. Liu, T. *et al.* A Method for Performing Reforestation to Effectively Recover Soil Water Content in Extremely Degraded Tropical Rain Forests. *Front. Ecol. Evol.* **9**, 1–10 (2021).
6. Keys, P. W., Barnes, E. A., Van Der Ent, R. J. & Gordon, L. J. Variability of moisture recycling using a precipitationshed framework. *Hydrol. Earth Syst. Sci.* **18**, 3937–3950 (2014).
7. Kabeja, C. *et al.* The impact of reforestation induced land cover change (1990-2017) on flood peak discharge using HEC-HMS hydrological model and satellite observations: A study in two mountain Basins, China. *Water* (*Switzerland*) **12**, (2020).
8. Buttle, J. M. Streamflow response to headwater reforestation in the Ganaraska River basin, southern Ontario, Canada. *Hydrol. Process.* **25**, 3030–3041 (2011).
9. Bonnesoeur, V. *et al.* Impacts of forests and forestation on hydrological services in the Andes: A systematic review. *For. Ecol. Manage.* **433**, 569–584 (2019).
10. Ruprecht, J., Sparks, T., Liu, N., Dell, B. & Harper, R. Using reforestation to reverse salinisation in a large watershed. *J. Hydrol.* **577**, 123976 (2019).
11. Bond, J., Millar, J. & Ramos, J. Livelihood benefits and challenges of community reforestation in Timor Leste: implications for smallholder carbon forestry schemes. *For. Trees Livelihoods* **29**, 187–204 (2020).
12. Di Sacco, A. et al. Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits. *Glob. Chang. Biol.* **27**, 1328–1348 (2021).
13. Altamirano, M. A., de Rijke, H., Basco Carrera, L. & Arellano Jaimerena, B. *Handbook for the Implementation of Nature-Based Solutions for Water Security. NAIAD project* (*European Union H2020*) (2021).
14. Marden, M. Effectiveness of reforestation in erosion mitigation and implications for future sediment yields, East Coast catchments, New Zealand: A review. *N. Z. Geog.* **68**, 24–35 (2012).
15. Silver, W. L., Ostertag, R. & Lugo, A. E. The potential for carbon sequestration through reforestationof abandoned tropical agricultural and pasture lands. *Restor. Ecol.* **8**, 394–407 (2000).
16. USAID. *Lebanon Reforestation Initiative a Guide To Reforestation*. (2014).
17. Díaz-García, J. M., López-Barrera, F., Pineda, E., Toledo-Aceves, T. & Andresen, E. Comparing the success of active and passive restoration in a tropical cloud forest landscape: A multi-taxa fauna approach. *PLoS One* **15**, (2020).
18. Rose, R. & Haase, D. *Guide to reforestation in Oregon*. http://www.starfirelumber.com/oldStarfire/SFI/LandownerInformationPackets/OR/Guide To Reforestation In Oregon.pdf (2006).
19. Gerlein-Safdi, C., Keppel-Aleks, G., Wang, F., Frolking, S. & Mauzerall, D. L. Satellite Monitoring of Natural Reforestation Efforts in China's Drylands. *One Earth* **2**, 98–108 (2020).
20. Fitzgerald, S. A. Successful Reforestation : An Overview. *Woodl. Workb.* 1–8 (2008).
21. Parajuli, R. *et al. Is Reforestation a Profitable Investment? An Economic Analysis. NC State Extension Publications* vol. 100 https://content.ces.ncsu.edu/is-reforestation-a-profitable-investment (2019).
22. Zhou, S. et al. The costs and benefits of reforestation in Liping County, Guizhou Province, China. *J. Environ. Manage.* **85**, 722–735 (2007).
23. Wainaina, P., Minang, P. A., Gituku, E. & Duguma, L. Cost-benefit analysis of landscape restoration: A stocktake. *Land* **9**, 1–25 (2020).
24. Chadourne, M. H., Cho, S. H. & Roberts, R. K. Identifying Priority Areas for Forest Landscape Restoration to Protect Ridgelines and Hillsides: A Cost-Benefit Analysis. *Can. J. Agric. Econ.* **60**, 275–294 (2012).
25. Yitbarek, T. W., Belliethathan, S. & Fetene, M. A Cost-Benefit Analysis of Watershed Rehabilitation : A Case Study in Farta Woreda, South Gondar, Ethiopia. *Ecol. Restor.* **28**, 46–55 (2010).
26. Ozment, S. *et al. Natural infrastructure in São Paulo's Water System. World Resources Institute* https://wribrasil.org.br/pt/publication/infraestrutura-natural-para-agua-no-sistema-cantareira-em-sao-paulo (2018).
27. IDB. Increasing infrastructure resilience with nature-based solutions (NbS). 52 (2020).