In the drylands of Eastern Africa there are few climate change mitigation projects. The Kasigau Reducing emissions from deforestation and forest degradation (REDD+) project in Kenya protects over 500,000 acres of forest and brings the benefits of direct carbon financing as well as job opportunity to rural Kenyan communities while also securing the wildlife migration corridor between Tsavo East and West National Parks. The carbon credits are distributed equally over the company coordinating and administering the mitigation project (Wildlife Works), the owners of the land and the communities managing the land (see chapter 7.5 for further information).

Carbon credits have potential to create resilience because the stable income from carbon credits tends to buffer the income of the household, which otherwise would fluctuate because of the high volatility of income from livestock and other dryland products. Enhanced incomes, access to credit and more fuelwood, improved soil fertility are significant driving factors behind changes in land use practices in drylands for both male and female farmers. Whether men or women, both value non-cash benefits and developing an innovative land management system would provide space for men and women to come together and engage in decision-making and thus, open up opportunities for collaboration and cooperation [258].

Appropriate institutions are important to ensure proper implementation of mitigation measures. Legal entities representing land owners and service providers are required to formalize the transactions foreseen in a carbon payment scheme. This is easier to accomplish with privately-owned property where land owners have clear tenure arrangements than community owned lands [255]. In case of communally owned lands those providing the mitigation service need to have the certainty of receiving the rewards for the service they provide. Owned lands and a fair benefit sharing mechanism is required to avoid monopolization of the benefits. Parties involved also have to agree on how to verify, measure and monitor changes in carbon stocks. Eventually, building upon previous development work, engaging with pre-existing farmer groups, empowering farmers on the ground by strengthening the capacity of community-based organizations can ensure that benefits reach farmers and are distributed equitably, thus increasing project success. This can only be possible with a strong support of the institutional level [257].

6.4.5 The role of trees in regulating soil erosion

Wolde Mekuria, Kiros Meles Hadgu, Lulseged Tamene Desta

Soil erosion by water or wind affects agricultural production and the natural environment, and is one of the most widespread of today's environmental problems. It results in impacts both on-site (at the place where the soil is detached) and off-site (where the eroded soil is deposited). The consequences of soil erosion include decreased soil productivity, reduced agricultural production, declining quantity and quality of fresh water supplies, increased poverty and political instability [40, 259]. This section synthesizes the extent of soil erosion, the on-site and offsite effects of soil erosion, the role of trees in controlling soil erosion, and the factors that influence the effectiveness of trees in reducing soil erosion.

The Global Assessment of Human-induced Soil Degradation (GLASOD) is the commonly used global map of land degradation [260, 261]. GLASOD estimates a total land area subjected to human-induced soil degradation of about 2 Bha (Billion ha) with 1.1 Bha affected by water erosion and 0.55 Bha by wind erosion [262]. GLASOD further identified important soil erosion hotspots in South Asia, sub-Saharan Africa, Central America and the Caribbean, and the Andean region in South America [262] particularly in semi-arid and sub-humid climates at low and mid-latitudes.

The main on-site impacts of soil erosion include the reduction in soil fertility resulting from the loss of the nutrient-rich upper soil layers, and a reduction in water-holding capacity. In drylands, loss in plant-available soil water-holding capacity is probably the more serious impact of soil erosion because root-zone water-storage capacity can be changed substantially by erosion [263]. Erosion-induced loss in soil water holding capacity is more serious on shallow soils or soils having sub-soils with limited water holding capacity. Losses in available water-storage capacity can result in significant reductions in crop yields and negative effects of erosion on agricultural yields are widespread in the developing countries of Africa and Asia [264-266].

In addition to its on-site effects, detached and transported soil material can give rise to 'off-site problems' including the movement of sediment and agricultural pollutants into watercourses. This can lead to the silting of dams [267], disruption of lake ecosystems and contamination of drinking water [268]. Increased downstream flooding with devastating impact on people, their property and infrastructure may also occur due to the reduced water retention capacity of eroded soils [269].

Land management practices that maintain vegetation covering on the ground are effective in reducing soil loss and erosion. This is because run-off and soil loss are both inversely related to ground cover. Trees and non-woody vegetation increase surface roughness, reduce the energy of the impact of raindrops on the soil as well as the ability of running water to detach and transport sediment [270]. De-Ploey, [271] estimated that soil erosion rates on fields with bare soil are 100-1000 times higher than on fields with a permanent vegetation cover. Williamson et al., [272] also showed that riparian buffer strips and hill slope forestation reduced sediment export by 85%. The importance of soil cover to reduce soil erosion has also been shown in a study where soil loss decreased exponentially with increasing degree of vegetation cover [273-275]. Further, Descheemaeker et al., [276] and Mekuria et al., [277] demonstrated that vegetation re-growth in exclosures has become an important measure to combat land degradation. Runoff production in exclosures, measured using runoff plots [276], is significantly reduced when a degraded area is allowed to rehabilitate after closure. Though runoff is significantly correlated with event variables such as rain depth, rainfall intensity, storm duration and soil water content, total vegetation cover is the most important variable explaining about 80% of the variation in runoff. Runoff was found to be negligible when the vegetation cover exceeds 65% [276]. A study by Tamene and Vick [278] showed that the life span of some of the water harvesting reservoirs in northern Ethiopia could be extended by 50% through appropriate land management and surface cover with trees.

Trees can help reduce soil erosion by: (1) slowing wind and water flows, (2) providing protection from wind and water, (3) holding soil together, and (4) increasing infiltration

[279]. Rainfall interception is considerable in tree or shrub canopies. Mastachi-Loza et al., [280] illustrated that the canopy of native Prosopis and Acacia trees intercepted up to 20-30% of the rainfall. In addition, soil water infiltration rates are greater under canopies as a result of the soil protection from raindrop impact and compaction by the addition of organic matter from plants, improving soil crumb structure [281, 282]. Trees increase organic material levels through the decomposition of the litter they produce, and moderate soil temperatures and consequently improve soil moisture, resulting in a higher infiltration rate beneath the canopy cover [283, 284].

Dryland trees and shrubs also protect soils from wind erosion [285]. Scattered trees and shrubs reduce wind erosion in three ways: (1) it shelters the soil from the erosive force of the wind by covering a proportion of the surface; (2) it reduces the wind velocity by extracting momentum from the flow of the air; and (3) it traps sediment particles. Barriers placed in the path of prevailing winds reduce wind speed and thus reduce wind erosion. Hedgerows of trees and shrubs are particularly effective for this purpose. They should be planted with a range of species to obtain variation in height, densities and level of leaf/branch cover that remains relatively high throughout the year. Shelterbelts allow some airflow which eliminates the unwanted turbulence that occurs behind solid barriers. Although some yield reduction may occur to crops immediately adjacent to shelterbelts and windbreaks, research has shown that there is an actual overall increase in yield of crops that are grown in fields protected by shelterbelts [286].

How could we enhance the effectiveness of trees in controlling erosion? A perennial tree cover protects the soil better against erosion than do annual crops, as the latter leave soil bare and unprotected for part of the year. But trees and shrubs usually require several years to close their canopy, whereas most annual crops provide adequate cover within weeks after planting. During the immature phase of trees and shrubs, there may be insufficient soil cover [279]. Plantations are also vulnerable to erosion at harvesting where a single storm can cause severe soil erosion and degrade the landscape. It is therefore essential to plant trees in conjunction with deep-rooted and fast growing grasses which will also use water, increase infiltration and control flow [279]. If water is a limiting factor for the growth of vegetation, effectiveness of tree to controlling soil erosion can be enhanced by integrating planting of trees with terraces and water harvesting infrastructure and planting trees along the contours. Choosing trees, which allow grasses to grow under them so that water infiltration is increased and the soil is not left bare will protect the soil from erosive rain. Ground cover varies during the life of agroforestry crops. It is lowest at times of establishment, when bare land is highly vulnerable to erosion. Mulching or planting cover crops can help overcome bare soil at tree establishment.

The effectiveness of trees in reducing erosion is affected by differences in root biomass, rate of decomposition of the root system (i.e., the resistance to microbial decomposition), the growth rate, tree density, and species diversity of a stand. Decomposition rate of tree root systems will influence the amount and composition of soil organic matter, which consequently influence the hydrological properties and erodibility of soils. The planting of fast growing trees (i.e., species that quickly form a relatively closed canopy) with large root biomass could help enhance the effectiveness of trees in controlling soil erosion. Tree density is one of the important factors that determine the effectiveness of trees to control soil erosion, as it has a direct relationship with reducing wind speed. Supplementing tree planting with physical soil conservation measures can provide addition value – reduce runoff and erosion and sustain planted trees.

6.5 Cultural services

Maureen Kinyanjui, Mieke Bourne, Jan de Leeuw

The appreciation and adoration of trees has a strong psychological and social foundation in most cultures. Trees feature in all aspects of culture: language, history, art, religion, medicine, politics and even social structure. The variety of cultural values and symbolic functions ascribed to trees are as numerous and diverse as the communities and cultures. Below we describe four of the cultural services that trees provide in the drylands of Eastern Africa.

Religion and spirituality

Dryland tree species are important in religious and spiritual ceremonies and are conserved because of this cultural significance. In many African cultures, the tree such as the baobab (*Adansonia digitata*) features in many myths and tales and consistently reflects a few important symbolic images. The tree stands between heaven and earth and is associated with creation as well as the underworld. The tree is a maternal symbol: a protector and provider. The positive appreciation of trees is related to the numerous goods and services that they provide such as food, water, fuel and materials for shelter, clothing, fences and barriers. The baobab tree is particularly revered as it provides water and food during drought. Other species such as *Boscia* and various *Acacia* play important roles in the traditional oral histories and spirituality of dryland societies.

For the Kikuyu people of East Africa, cutting trees, breaking branches, gathering firewood, burning grass, and hunting animals are prohibited from groves that have the sacred *Mugumo* tree (*Olea africana*). Sacred groves have been protected because of cultural and religious reasons and they also provide certain species of trees which are used to perform rituals, provide medicinal values and support cultural functions such as areas where disputes are settled and functions like burials and weddings take place. These sacred places are revered and cared for by indigenous and traditional people and are often a fundamental part of their territories. Many ethnic groups in Kenya had special reverence for specific trees as meeting points where elders would discuss and provide council for the communities.

Community building

Very strong emotional ties exist between people and elements of natural settings such as trees. Trees often serve as property lines (boundaries) and define the location of a community. Trees and landscapes are shared symbols that become part of the identity and character of a place that foster peoples capacity to work together, become a source of pride and stimulate economic activities [287].