PART II – Chapter 27

Water-related ecosystem services of forests: Learning from regional cases

Convening lead author: Bart Muys

Lead authors: Jan Nyssen, Ben du Toit, and Enrico Vidale

Contributing authors: Irina Prokofieva, Robert Mavsar, and Marc Palahi

Abstract: Forests are widely recognised as recommended land cover for protection of water resources. It is commonly understood that forests control erosion, improve water quality and regulate water flows in catchments to some extent. Less-well understood are aspects of the so-called green water flow: biomass production in forests has a price locally in terms of evaporative water losses though it can provide rainfall elsewhere. In this chapter, we discuss the complex and sometimes contra-intuitive issues that emerge when trying to optimise forest management for water-related ecosystem services. We analyse three cases in very different geographical and socio-economic settings where the water-related ecosystem services of the forest have been a driver for forest management transition. In the first example from Ethiopia, forests are restored for soil and water conservation purposes related to green water, while in the second case in South Africa, plantation forests are removed with the intention of ecological restoration and increase in blue water availability. In the last case from Italy, we discover that schemes for payment for ecosystem services (PES) make a change with respect to water-related ecosystem services. The case studies show that such transitions can follow very different pathways, determined by the biophysical, socio-economic, and institutional contexts. But despite these differences, the case studies show patterns in common. The success or failure of management policies is highly scale-dependent (extension and intensity of the intervention). Changes aimed at improving an ecosystem service always show trade-offs with other ecosystem services. Often, measures in catchments are based on a correct interpretation of hydrological knowledge but fail to optimise for the range of upstream and downstream ecosystem services at stake. The main challenge for the future is to further foster the ongoing paradigm shift in the way water-related forest ecosystems services are considered, with a change from supply-side policies to demand-side policies and supply-demand linkages and from purely technical solutions to green infrastructure solutions.

Keywords: Blue water, green water, South Africa, Ethiopia, Italy, water tax, exclosure, payment for ecosystem services

27.1 Introduction to water-related ecosystem services

Fresh water is becoming a scarce global resource of strategic importance (Duda and El-Ashry 2000). In this context, the regulating role of forests has been recognised (de Groot et al. 2010), although the sponge model – the general belief that forests store water in the rainy season to slowly release it in the dry season (e.g. Hamilton 1985) – is not much supported by available data. Forests may increase low flows but in most cases they decrease them (Jackson et al. 2005, Birot et al. 2011). For a better understanding of the hydrological cycle, distinguishing between blue and green water (Falkenmark and Rockstrøm 2005, Birot et al. 2011) is very useful. Blue water resources are formed by the rainfall fraction that reaches rivers and lakes after percolation into the aquifers or directly as surface run-off. Humans strongly value the quantity and quality of blue water, as it forms the main source for drinking water,

Table II 27.1 Overview of the main water-related ecosystem services of a forest.

ECOSYSTEM SERVICES (ES)	MAIN WATER-RELATED ES OF A FOREST (**Green water services** in bold, *blue water services* in italic, green/blue water services underlined)
Supporting services (S)	**Canopy interception**, **Evapotranspiration**
Provisioning services (P)	*Irrigation water provision*, *drinking water provision, fish production,* **wood production**
Regulating services (R)	**Flood regulation**, **climate regulation**, erosion control, water purification
Cultural services (C)	Recreation, ecotourism

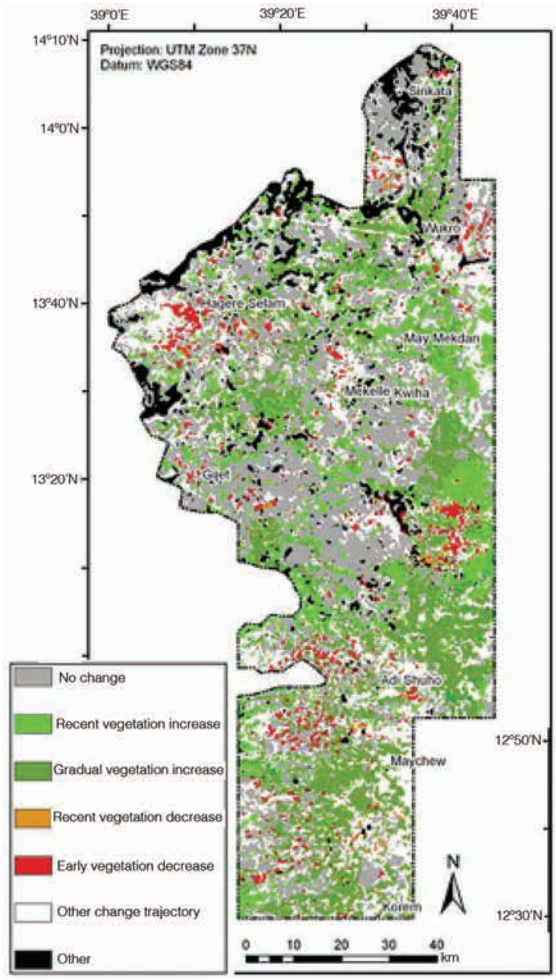
irrigation water, hydropower, and recreational activities. Green water resources are formed by the fraction of rainfall that does not leave the ecosystem through percolation or surface run-off. It may infiltrate into the soil and become available for uptake by plants. The green water flow is the evapotranspiration of this green water resource into the atmosphere. Precipitation water intercepted by vegetation canopies forms part of green water resources, and its evaporation is a green water flow. The green water flow includes the evapotranspiration from blue water resources as well, such as irrigation water used by crops and the so-called virtual water incorporated in imported and exported products like wood, food, and feed (Allan 1998).

Compared with other land uses, forests typically have larger green water and smaller blue water fractions, which means that afforestation generally decreases blue water quantities and deforestation increases them. Today there is a dominant blue water paradigm that considers green water flows and thus the very existence of forests as a water loss. But this paradigm largely ignores the important ecosystem services related to green water flows, including biomass production, erosion control, and nutrient retention (Birot and Vallejo 2011). Recent research has quantified the essential function of green water flows for precipitation recycling and relocation over continents (Keys et al. 2012).

Both blue and green water flows are essential for sustainable catchment management. There is a direct trade-off between green and blue water use, and development in either direction (blue water maximisation by, for example, impeding forest restoration, or green water maximisation by establishment of fast-growing exotic tree plantations) has tangible effects on the other. For this reason sustainable management of river catchments must take an integrated approach in which the ecosystem services of upstream (terrestrial) and downstream (aquatic) ecosystem services are considered together (Maes et al. 2009).

To consider trade-offs between green and blue water use, the ecosystem services framework proposed by the Millennium Ecosystem Assessment (MEA 2005) can serve as an excellent basis. MEA (2005) considers supporting, provisioning, regulating, and socio-cultural services. Table II 27.1 shows the water-related ecosystem services in each of these categories. Based on the aforementioned blue and green water definitions, we can now distinguish between blue water services of the forest (here defined as ecosystem services provided by the forest, related to the availability and quality of blue water resources), green water services (here defined as ecosystem services provided by the forest, related to the availability of green water resources or the existence of green water flows), and green/blue water services providing both (Table II 27.1). As a supporting ecosystem service, evapotranspiration is the driving process behind green water flows, but water interception by vegetation canopies is also an important process that will, for example, diminish the erosive power and influence the quality of precipitation water. Wood production is a provisioning service of the forest typically linked to green water flows, except when the water transpiration by the plant originates from irrigation water. Water purification is both a green- and blue-water regulating service, as both vegetative processes by canopies and roots and filtering processes in the lithosphere and surface waters can have a purifying effect.

In this chapter we discuss the complex and sometimes contra-intuitive issues that emerge when trying to optimise forest and land management for water-related ecosystem services. To do this, we analyse three cases in very different geographical and socio-economic settings where the water-related ecosystem services of the forest have been the driver for a transition in forest management or conservation. In the first example from Ethiopia, forests are restored for soil and water conservation purposes related to green water, while in the second case in South Af-



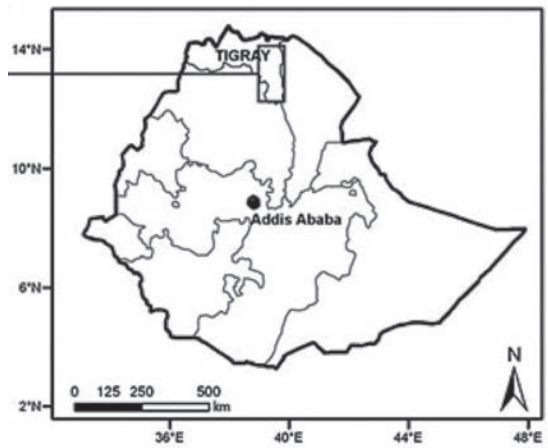


Figure II 27.1 Map of the study area in Tigray, Ethiopia showing the six major land-use and cover-change trajectories for 1972–2000, indicated by different colours (after de Mûelenaere et al. 2014. ©Reprinted with permission from John Wiley & Sons, Inc.

rica, plantation forests are removed with the intention of ecological restoration and increase of blue water availability. In the last case from Italy, payment for ecosystem services (PES) schemes make a change with respect to water-related ecosystem services.

27.2 Soil and water conservation: the case of exclosures in Tigray, Ethiopia

27.2.1 Biophysical setting and relevance

In the highlands of Tigray, exclosures (areas closed for animal grazing and biomass harvesting, see Aerts et al. 2009) have been established on former degraded lands (barren lands including communal grazing lands on steep slopes) with the aim of forest restoration and land conservation. Tigray lies in the north of Ethiopia between 11° and 14° N (Figure II 27.1), and much of the land has an elevation between 2000 and 2800 meters above sea level, which offers a more temperate climate than would normally be associated with the latitude. Average yearly rainfall ranges between 500 and 900 mm/year, with a uni-modal pattern. Time series analysis of annual precipitation shows that although the succession of dry years in the Ethiopian highlands between the late 1970s and late 1980s produced the driest decade in the previous century, there is no evidence for a long-term trend or change in the region's annual rain regime (Nyssen et al. 2005). The dominant land use is small-scale rain-fed subsistence agriculture, for which the main constraints are inadequate soil water and excessive soil erosion. Exclosures are forests under development but, at present, in terms of tree height and crown cover density, they may not all meet the requirements of the forest definition of the Marrakech Accords of the United Nations Framework Convention on Climate Change (UNFCCC) (Verchot et al. 2007). The current character of exclosures ranges between open savannah and bushland (Figure II 27.2), depending on the time since exclosure establishment and the vegetation status at establishment.

By 1980, forest resources had strongly decreased in the area, and only two large forests remained (Desa'a and Hugumburda) (Kassa 2013). At a re-

Figure II 27.2 Exclosures dominated by *Juniperus procera* (left) and eucalyptus plantation (right) at Amba Alage pass. ©Jan Nyssen

Figure II 27.3 Riverine trees have been allowed to grow and eucalypts planted in the upper Ilala gorge, between 1973 (left) ©Larry Workman **and 2008 (right)** ©Jan Nyssen**.**

gional scale, the supply of forest ecosystem services had come to a very low level, but the large-scale establishment of exclosures has given a decisive impulse to forest restoration. Interpretation of satellite imagery shows that between 1972 and 2000 there was an increase in vegetation cover in 16% of the area and a decrease in 7% of the area; the vegetation cover may, however, mainly be qualified as bushland (43% in 2000), compared to 2% forest and 4% eucalyptus plantations (de Mûelenaere et al. 2014). Not only in the formally established exclosures but even elsewhere, trees are now much better respected than before (Figure II 27.3), and it is generally considered socially unacceptable to cut a mature tree. Multipur-

Figure II 27.4 An exclosure located on earlier marginal farmland in Dogu'a Tembien (Tigray).
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pose trees outside forests have a major ecological and socio-economic role in northern Ethiopia. Some of the main functions they have are erosion control, provision of wood and non-wood products, and a seed source for forest rehabilitation (Reubens et al. 2011).

In terms of water relationships, exclosures significantly decrease surface run-off and increase water infiltration in the soil. Reports from villagers and observations also suggest re-emergence of springs, offering opportunities for irrigated vegetable gardens and improved drinking water supply, which would suggest increased percolation and improved baseflow. Translated into water-related ecosystem services, exclosures mainly support forest biomass growth, drinking and irrigation water, and improved erosion control.

27.2.2 Socio-economic setting

The extreme degradation of the Ethiopian environment, including soil erosion, is the consequence of drought, war, and famine (Stahl 1990). The establishment of exclosures is one of the major initiatives of post-war relief and rural reconstruction. A land tenure regime introduced in the 1980s has led to an approximate equalisation in size of landholdings among households (Hendrie 1999). The establishment of exclosures was made possible by this important land-tenure change in which large feudal agricultural lands in the valley bottoms and other lower-level areas were shared among local farmers. It decreased the pressure on hillslopes, where exclosures could then be established (Lanckriet et al. 2014) (Figure II 27.4). Activities related to the management of exclosures (guarding, forest management in rare cases, and economic activities such as beekeeping, cut and carry of grass, etc.) generate income for community members. Equity is considered when the villages establish rules on sharing harvested grass from these areas – in some cases, all the grass is harvested collectively and shared; in others, every household may send one person to harvest or the livestock owners may do so.

27.2.3 Institutional setting

After the terrible episodes of war and hunger in the 1980s, the northern Ethiopian highlands were left more degraded and deforested than ever. The regional government then compelled local communities to set aside degraded grazing lands for restoration purposes. It should be noted that international policies and institutions have been of minor importance in the development of exclosures and their management. The essence of exclosures is the implementation of new local laws (*serit* in the local Tigrinya language) over a piece of land that makes its free use illegal. Guards paid by the community, or sometimes by NGOs, enforce these local laws, fining trespassers or sending them to local courts. In order to decrease pressure on these newly available wood resources, there is a ban on wood transport between districts,

Figure II 27.5 Partial view of the Mesebo escarpment in 1973 (left) ©Larry Workman **and in 2008 (right)** ©Jan Nyssen**.**

though there is pressure from urban politicians to soften such restrictions. Forest products such as firewood cannot be collected; permission to collect dry wood tends to be abandoned since this led to intense illegal debarking of trees. Trapping of wildfowl is illegal but is sometimes carried out. Collection of wild edible fruits or medicinal plants is generally discouraged since it can easily be used as a pretext for illegal cutting of grass. The major non-timber use is the installation of beehives, either by cooperatives, individuals, or private companies in or at the edge of the exclosures.

Ethiopian national and regional governments invested large amounts of money in land rehabilitation, mainly through building of erosion-control structures called stonebunds, inside the exclosure areas. Most of the work is done by farmers through food-for-work programmes. The effectiveness of these investments has been proven (Descheemaeker et al. 2006a, 2006b). Further, through the Bureau of Agriculture and the Relief Society of Tigray (REST), a relief organisation supported by regional politicians, there is quite an impressive structure of extension workers, training initiatives, and such. The main topics addressed in these initiatives are both technical and managerial. Main policy lines have been food security, poverty reduction, soil and water conservation, and land management. At the regional level, the policies concerning exclosures for soil and water conservation and the idea of commercial forestry in exclosures are not well-matched and are not consistent. Community exclosures are initiated by the Bureau of Agriculture and commercial forestry is an initiative of REST. Also, the policies for exclosures and those for management and conservation of national forests, such as the Desa'a remnant forest on the Rift Valley escarpment, are not really coordinated, since protection of exclosures seems to cause increased pressure for woodfuel harvesting in the national forest.

27.2.4 Changes to landscapes and livelihoods

An evaluation of environmental changes using repeat landscape photographs taken in the dry seasons of 1975 and 2006 concluded that the overall situation has improved with respect to vegetation cover on non-arable land, as well as grass and shrubs between cultivated farm plots. Whereas the population of Ethiopia has increased from 35 to 87 million between 1975 and 2012 (FAOSTAT 2013), overall vegetation cover (Figure II 27.5) has improved in the study area. These changes are not climate-driven but instead are the result of human intervention (Nyssen et al. 2009).

The interventions leading to these changes incorporate an implicit landscape-level approach, but there is little conceptual background available or published. A few studies (e.g. Balana et al. 2010) tried to optimise exclosures and other land use at the landscape level, but there is so far little implementation of such land-use optimisation exercises. Socio-economic studies using large randomised questionnaires over all social layers of communities revealed that grazing lands and exclosures play a significant role in the rural livelihoods of northern Ethiopia (Balana et al. 2008). Exclosures support the survival of traditional uses by avoiding local extinction of tree and shrub species. Environmental benefits exist in terms of soil and water conservation, in particular gully erosion control and downstream protection from flooding, which has been quantified by Nyssen et al. (2008) and Balana et al. (2012).

The improved marketing of non-wood forest products from exclosures, such as honey or frankincense, has been promoted and supported by governmental and non-governmental initiatives. Other values, such as the soil and water conservation value, have been scientifically quantified (Descheemaeker et al. 2006a, 2006b, 2006c, 2009; Balana 2012) but remain unconsidered externalities. This should change since the government and the electric company have a huge vested interest in decreased siltation of reservoirs used for hydropower production. Exclosures are a very cost-effective measure for erosion control and soil fertility restoration.

So far, most exclosures are closed for wood harvesting and as such have not faced the challenge to develop wood markets. Illegal harvesting from exclosures has a certain impact on the firewood and charcoal market, but this is difficult to quantify. About 2000, there were attempts from the regional government to link exclosure activity to commercial forestry development. Enrichment planting and even monocropping with commercial (mostly eucalyptus) trees in exclosures was initiated with food-for-work programmes. The long-term goal was to produce industrial roundwood for construction poles and a local chipwood factory and hence contribute to industrialisation. This project created, among other results, uncertainty among commoners concerning the ownership of the trees and the land tenure. Today these trees are being harvested for the first time, and the wood is transported to a chipwood factory in Maychew (see Figure 27.1). Trees were taken without payment to local communities, which only benefited from labour opportunities and from the opportunity to buy branches at a cheap price.

27.2.5 Monitoring and research

There is no formal monitoring of exclosures by the Ethiopian government. A monitoring programme combining remote-sensing approaches with ground inventory would be very relevant. Limited remote-sensing exercises have shown the feasibility and relevance of this approach. Participatory monitoring on the ground has not been implemented so far but is an interesting option for engaging and empowering locals in the restoration and sustainable use of their resources. Though there was not an official scientific follow-up of the exclosure programme, many scientific studies, largely involving the Forestry Department of Mekelle University and often in the framework of international academic cooperation programmes, have been produced. Some focused on the vegetation dynamics and the role of silvicultural intervention (Aerts et al. 2007, 2008a, 2008b; Aynekulu et al. 2009, Reubens et al. 2011). Others focused on the improved erosion control and water infiltration (Descheemaeker et al. 2006a, 2006b, 2006c, 2009) and still others on the socio-economic impact of exclosures on livelihoods and related governance issues (Balana et al. 2008, Lanckriet et al. 2014).

27.2.6 Lessons learned and recommendations

Although centrally imposed, the establishment and implementation of exclosures is rather bottom-up. Participation is enhanced by the implementation of remunerated soil and water conservation (SWC) and plantation works. Location, area, local laws related to restrictions and management, and instalment and payment of guards are most often decided by the local village (*kushet*) authorities, who follow guidelines set by the local Bureau of Agriculture. Such land management decisions are then included in local laws. Overall, villagers are convincingly participating in reforestation and other conservation activities (Kumasi and Asenso-Okyere 2011).

Pressure on the land remains high. Exclosures occupy only part of the communal land, and there is generally no competition with cropland because sites are marginal, but competition with grazing land remains. There is also illegal wood harvesting. This is the reason why there is interest in and pressure to identify new types of income from exclosures such as cut and carry, haymaking for stall feeding, grass for thatching roofs, beekeeping, restricted wood harvesting, or even payment for ecosystem services such as reduced sediment flow to dams or carbon sequestration (not operational so far). Another option would be a rotational system where new parts of the communal land sequentially go through this phase of ecosystem restoration, to be released later for regulated sustainable use. The potential (legal or illegal) harvest levels and the dimensions of harvestable wood increase as exclosures mature. If managed well, they can provide sustainable wood harvest in combination with extensive levels of grazing or cut and carry of grass.

Local communities invested long term in this large-scale restoration project. Restoration effects become visible, and communities' expectations are rising as they see some benefits returning to the community. Local authorities now face the challenge of moving from strictly closed areas to areas with certain use rights, remaining within the limits of sustainable use. In the current phase there is tension between stakeholder expectation and authorities' fear of a new tragedy of the commons. At this stage, developments are too recent to establish whether the Tigray highlands are undergoing a forest transition, meaning that changes in population density are no longer inversely coupled to changes in tree cover. The shift from deforestation to reforestation is still patchy in nature, but several elements inducing the forest transition are present in the study area: increasing population, increasing food production, forest scarcity, zoning of forestry land (exclosures), and expansion of forest (eucalyptus) plantations (Nyssen et al. in prep.). In any case, this future depends on the type of management rules and management plans that result from ongoing discussions between government and local communities. The challenge is to find the balance between sustainable use and protection. Experiments of self-organisation with bottom-up participatory management plans should be welcomed.

27.3 Trade-offs between blue and green water ecosystem services: the case of forest plantations in the Western Cape, South Africa

27.3.1 Introduction and relevance

South Africa is a dry country sparsely endowed with forests. It has a hydrological regime that is extremely variable among seasons and years, and the annual run-off coefficient varies between 0.1% and 11.4% for the major catchments, with a country-wide average of 8.6%. It is clear, then, that South Africa is a country where blue water resources are under pressure. As a consequence, water use has become strongly regulated, particularly with regard to industrial afforestation activities. Large parts of the Western Cape Province have a Mediterranean climate, where the rainfall seasonality provides additional challenges with regard to water supply for urban use and for irrigated agriculture. The climate and associated fire regimes also place limits on the size, extent, and growth rate of forests. The south-eastern section of the province enjoys more abundant rainfall in all seasons and this is where the largest concentration of natural forest patches and planted forests occur, in a mosaic pattern in the landscape.

The population in the Western Cape Province is approximately 5.3 million people (Statistics SA 2011) and is still growing. The steady increase in the population and in the economy is a concern with respect to available water in the area. Unemployment in South Africa is high compared to developed countries, with official estimates of about 25±1% for the past two years (Statistics SA 2011). Agriculture is a very important land use and employment provider in the Western Cape. The main agricultural products (in decreasing order of value earned) are fruit, winter grains, white meat, viticulture, and vegetables. The province contains 12.4% of South Africa's agricultural land and it produces 23% of the country's agricultural gross domestic product (GDP) (WCDA 2005), despite challenges posed by drought, rainfall seasonality, and irrigation water supply. In the four major river systems of the province, irrigated agriculture consumes approximately 87%, 42%, 68%, and 61% of the total water supply, respectively (DEA and DP n.d.).

In terms of water relationships of the Cape forest resources, there is scientific evidence that forests reduce stream flow in this semi-arid environment. The stream flow reduction resulting from the historical pine afforestation of about 80 000 ha of some of the wetter scrubland (known as fynbos) areas in the province was calculated to be 1.96% of the total run-off in the province's catchments (Scott et al. 1998). Calculations based on the work of Gush et al. (2002) estimate the stream flow reduction as 1.06% of the annual total before afforestation. This number would fall to a value of between 0.8 and 1.3% of the total run-off following deforestation of approximately 30 000 ha of plantation forest (based on work by Scott et al. 1998 and Gush et al. 2002) – i.e. if the Cape conversion process is partially reversed, thus allowing some 50 000 ha of plantations to remain. So in terms of water-related ecosystem services, plantation forests provide wood production as a major green water service, with stream water reduction as a relevant but regionally limited blue water disservice.

27.3.2 The extent and condition of forest resources and their contribution to livelihoods

Only a small portion of South Africa (approximately 0.5 million ha, or 0.4%) is covered by closed canopy forests, in addition to the 29.3 million ha of woodland in the northern and eastern parts (24% of the country). The plantation forest industry covers 1.26 million ha and is responsible for the bulk of the country's commercial roundwood production (19 million m^3/year), mainly from stands of exotic *Pinus* and *Eucalyptus* species (FSA 2010). There are three large categories of tree and forest cover in the Western Cape Province: indigenous forests, exotic tree plantations, and invasive thickets of introduced trees. Their main features and their contribution to livelihoods follow.

The indigenous Western Cape Afro-temperate forest type is confined to very small pockets along river valleys and on south-east facing slopes with relatively high precipitation, surrounded by scrubland (fynbos) vegetation. The Southern Cape Afro-temperate forest (south-eastern part of the province, extending into the adjacent Eastern Cape Province) is made up of a mosaic of fairly large blocks of forests, roughly situated in a strip between the ocean and the mountain ranges. The extent of the Western and

Southern Cape Afro-temperate forests is 4700 ha and 68 600 ha, respectively (DAFF 2011). In addition, the Western Cape has about 2500 ha of coastal milkwood forests (DAFF 2011). Natural forests thus occupy a mere 0.4% of the land area in the Western Cape Province. All indigenous forests in the province have very low growth rates (less than 1 m^3/ha/year) and are managed primarily for conservation and biodiversity purposes. The forests are also extensively used for recreation and the provision of non-timber forest products – such as ferns, medicinal bulbs, tubers, bark, etc. – to local communities (Vermeulen 2009).

Industrial plantation forests in South Africa have decreased from 1.4 million ha to 1.26 million ha during the past decade (DAFF 2011). Plantations (mostly pines) in the Western Cape covered more than 79 000 ha during the 1990s, diminishing to fewer than 50 000 ha in 2013 due to government policies (the Cape Conversion Process, see section 27.3.3). The current industrial plantation cover in the province constitutes less than 0.4% of the land area, and the mean annual increment of individual plantations averages from 10 to 15 m^3/ha/year, depending on the sub-region. The industrial forest sector is responsible for more than 95% of the timber volume purchased by the wood processing industry in the country and is therefore an irreplaceable component in the local wood value chain. One of the major benefits of the industry is job creation in rural areas. Forestry in the Western Cape Province supplies approximately 2600 direct jobs and 16 300 indirect jobs and is tied to the livelihoods of 56 000 people. Small-scale tree planting of mostly exotic species on farms (for pole production, windbreaks, fodder, firewood, general utility timber, shade provision, and honey bee forage) is common in all but the driest parts of the province. Products from these forests are seldom sold commercially but rather used locally. For example, woodlots with specific eucalyptus species are essential providers of honey bee forage in the Western Cape Province (de Lange et al. 2013). The small fragments occupied by woodlots are not included in the industrial forestry area estimates previously cited. Trees also play an important role in recreational areas of cities and peri-urban areas.

Australian *Acacia* species originally introduced to stabilise coastal sands have become invasive in several parts of the province. In particular, large concentrations of *Acacia* thickets can be found on the West Coast plain and the Agulhas plains, with dense thickets spread over an area of more than 26 500 ha (van Laar and Theron 2004a, 2004b). Several zones of less dense infestation (< 10% crown cover) also occur. These invasive tree thickets have been and are currently being used extensively for fuelwood in the urban and peri-urban areas around Cape Town (du Toit et al. 2010). In addition, biological control of these plants by introduced insects is well-established and teams of people have been employed in the government's Working for Water (WFW) programme to systematically eradicate these invasive plants from riparian zones and other areas of infestation. A combination of very effective biological control, intensive utilisation, and efforts of the WFW programme mean that this wood resource will be strongly reduced over the next two decades.

In summary, the Western Cape's natural forests are fairly well protected, but commercially used timber resources are shrinking rapidly – the current landscape setting of forests in the Western Cape is illustrated in the aerial photo in Figure II 27.6. The most productive forests (pine plantations) have been greatly diminished and this will lead to large structural timber shortages in the area from 2018 onward. It will also strongly affect the economy of scale and the processing sector that relies on these forests. A fuelwood shortage is also forecast if concerted efforts are not made to establish woodlots for fuelwood production.

27.3.3 Forest policies and governance

During the past two decades, several changes in forest land-tenure regimes have taken place as a result of new government policies and legislation. However, evolution has also come about through voluntary management decisions at a strategic level in commercial timber companies. Key examples of both types are briefly discussed below.

The Afforestation License System (National Water Act, Act No. 36 of 1998) replaced the afforestation permit system that was in place since 1972. No afforestation may be done without a license, and water use and ecological impact studies are needed to obtain a license. In addition, licensed forest growers must pay for stream flow reduction caused by commercial afforestation. This process began in 1999 and the current payment cost is relatively low, on average ZAR 0.42/m^3 (EUR 0.04/m^3), compensating for the water loss caused by converting indigenous vegetation to plantation forestland. Although industrial forestry is the only land use that has been classified officially as a stream flow reduction activity, the forest industry has absorbed this cost and has largely maintained business as usual (in areas where it was not limited by other policies).

The Restitution of Land Rights Act (Act No. 22 of 1994) entitles a person or community dispossessed of property after June 19, 1913, as a result of past racially discriminatory laws or practices, either to restitution of that property or to equitable redress. A complication is that current owners of forest estates often own land that has been legally and legitimately

Figure II 27.6 Aerial photograph showing land-use patterns near the town of Grabouw, Western Cape Province (34°9'5 S, 19°0'54 E). Note the productive plantation forests planted outside of the riparian zone (bottom left), irrigated fruit orchards (bottom right), mountain land with indigenous fynbos vegetation that had been recently burned (top right), and formerly productive plantation forest currently clear-felled and not replanted because of the Cape Conversion Process (top left). ©Anton Kunneke

bought (willing buyer and seller) between 1913 and the present day on which such land claims are now being made. To date, the land redistribution process has progressed slowly because many landowners are not willing to sell. This has moved the government to consider other possible avenues such as expropriation of the land, although this has not been implemented.

The Cape Conversion Process, which calls for the partial cessation of commercial forestry activities in the Western Cape Province on state-owned land, was approved by the cabinet of the South African government in 2001; it applies to some 45 000 ha of plantations in the province. After implementation, reforestation following clear-cutting was thus prohibited in these commercial plantations, which led to large-scale deforestation in the Western Cape. The main driver in this conversion process was the relatively low productivity of these forests (approximately 10 m^3/ha/year), compared to other plantations in the high rainfall zones of the country and the notion that these forests may not be commercially viable in the future. A report (VECON 2006) has subsequently shown that the original assumptions were inaccurate and that many of these plantations are in fact economically viable. In 2006, on the strength of this report, the cabinet made a decision to partially reverse the Cape Conversion Process decision and to allow renewed planting of approximately 22 500 ha of the original 45 000 ha earmarked for conversion. The bulk of this land is largely unsuitable for other intensive land-use activities such as fruit or wine production. However, no reforestation has been done in these areas to date because no decision has been made on who should be allowed to do the reforestation.

During the past two decades, many forestry companies have embarked on a voluntary process to obtain third-party forest certification and to demarcate wetlands on their landholdings by permanently removing all plantation trees that had been established in such areas. These wetlands are thus converted back to indigenous vegetation to ensure minimum impact on the county's water resources – it has been established that trees in riparian zones and wetlands use disproportionately large amounts of water.

The Conservation of Agricultural Resources Act (Act No. 43 of 1983) targeted invasive plants. It allowed for the categorisation of exotic plants in terms of their invasiveness, among its other regulations. This paved the way for large-scale clearing of thickets of invasive plants through the Working for Water programme since 1995. In South Africa as a whole, more than a million ha of invasive plants have been cleared to date, providing jobs to 20 000 people (WFW 2012). Approximately one-tenth of this effort was focused on the Western Cape. This has produced more stream flow from rivers and supplied harvested biomass during the clearing operation. Strict follow-up measures are in place to prevent invasive plants from re-colonising the cleared areas.

27.3.4 Antagonistic consequences from changes in policy and governance

Processes that led to business uncertainty or undue delays in decision-making have caused the commercial forest industry to stagnate or even shrink slightly during the past two decades, with negative consequences on the livelihoods of people in the forestry and forest products value chain.

The first example is the Cape Conversion Process. More than 20 000 ha of plantation land that had been clear-felled since 2001 is currently still unplanted, despite the fact that the cabinet approved partial reversal of the process and that the international investment company that bought the major shares in the local lease holding for this land offered investment money and a partnership with the government for the reforestation. This process is currently leading to unemployment in the Western Cape rural areas (De Beer 2012) and it has created a gap in the normal forest age class distribution of at least 12 years – up to 20 years in some areas. This means that the next leaseholder of the land will effectively have to start a "green fields" afforestation programme from scratch if forestry is allowed to continue to be practised on this land.

The second example is the afforestation license system (on a national level). It is recognised that afforestation cannot be allowed to increase in catchments that are already threatened by severe water shortages. However, in catchments where significant volumes of unused water is available, afforestation licenses could be granted, as assessments showed that more than 100 000 ha of land is suitable for afforestation in the Eastern Cape Province alone. However, during the past decade, there has been no significant growth in new afforestation in South Africa. In fact, the industry has shrunk in size due to a lack of new afforestation coupled to the conversion of some areas out of timber for environmental reasons (DAFF 2011). Poorly prepared applications as well as some administrative bottlenecks delayed the processing of afforestation licenses.

The third example is the Restitution of Land Rights Act, which aims to redress inequalities from past regimes but which has potentially disastrous long-term consequences for forestry, agriculture, and the country at large if not managed well. There are many southern African examples showing that few beneficiaries of land claims on agricultural land have to date managed to continue with economically sustainable farming or forestry practices (Dardagan 2012). Many forced land transfers have led to subsistence agriculture, which is much less productive than the commercial farming or forestry that it replaced. As such, the Land Restitution Act is perceived by the commercial forest processing industry as a threat because it could strongly compromise the long-term security of raw material supply in the forestry value chain. The privately owned forest industry has therefore embarked on a voluntary land redistribution scheme, which is structured as follows: land ownership is voluntarily transferred to local communities but leased back to the industrial forestry grower-processor for two crop rotations, along with strong technological support and extension services made available to new landowners. In return, 1) industrial forestry is allowed to continue on the land for at least two rotations, and 2) the industrial partner has the first option to buy both the first and second rotation of timber produced from plantations on such estates (at market-related prices). The owner can sell the timber on the open market if the industrial company that transferred the land does not exercise its right to buy the timber. Pilot-scale land transfers under this scheme have already taken place (SA Forestry 2010) and it appears to be a more workable solution than forced land redistribution. This land-transfer process, coupled to the out-grower schemes that are already in place (i.e. technical assistance and support for previously disadvantaged tree growers – see Cairns 2000) is starting to make an impact on redressing inequalities from past discriminatory laws.

27.3.5 Positive consequences from policy and strategic management decisions

The consequences described in this section stem from a mixture of government policies and strategic decisions by industrial forestry growers-processors including voluntary forest certification, the government's support to the WFW programme, and the creation of ecological corridors in the landscape.

The strategic (voluntary) decision by many private forest growers to certify plantation forests as being managed under sustainability criteria has led to a more conciliatory management style that is more in harmony with nature, while at the same time opening up new potential markets. Examples of positive management outcomes are strong restrictions on the use of intensive fires during slash burning, voluntary conversion of land out of timber where trees were planted in places that encroached on wetlands or riparian zones, improvements in the working conditions and safety of employees, and strong restrictions on the type and use of chemicals in plantation forests.

The WFW programme, where unemployed people are trained to assist with clearing of invasive thickets, has been a successful policy. It has created many temporary jobs and provided training for people while also leading to improved stream flow in cleared areas. The clearing of invasive thickets has a much greater effect on stream flow than limiting industrial plantations. This is because plantations are not allowed (by law) to be planted within 20 m of any perennial stream, whereas invasive thickets often occur in riparian zones, wetlands, and the upper reaches of non-perennial streams. The Conservation of Agricultural Resources Act has had mostly positive consequences, but there have been some notable exceptions. The legislation categorises introduced plants as category 1 (declared weeds), category 2 (invasive plants with economic potential that can be grown in demarcated areas), and category 3 plants (invader plants that can be left to grow where they exist). The spirit of the legislation was to place non-invasive exotics in category 3, therefore the labelling of these plants as invaders rather than introduced plants or exotics is unfortunate. Secondly, category 2 plants cover a very wide spectrum, from aggressively invasive (but with economic potential) to effectively non-invasive (but still exotic) with economic potential. Virtually all introduced commercial plantation species have been lumped together in this category. A reclassification of several species is needed and more specifically, a classification of the hybrids of these species (which appear to be mostly non-invasive) needs to be done.

The creation of ecological corridors in the landscape ensures that indigenous plants and wildlife continue to prosper. Ecological corridors are large networks of natural vegetation that are linked with each other like a web in order to maintain biodiversity and ecological processes. They are usually constructed around water courses, where legislation dictates that no commercial afforestation may take place closer than 20 m from rivers courses. However, in many cases these riparian zones are widened over and above what the law stipulates (especially around wetlands), and these areas are also linked to additional patches of natural vegetation for biodiversity conservation, gene flow, and maintenance of ecosystem services. These networks are also important for livelihoods and spiritual well-being and water quality (Samways et al. 2010). Approximately 30% of South African plantation forestry estates consist of natural vegetation in the form of ecological networks.

27.3.6 Synthesis and recommendations

South Africa is a water-scarce country that has limited areas of natural forests with generally very low growth rates. These forests are well-protected, so that the country is very reliant on industrial plantation forests (and to a lesser degree on agroforestry and woodlots) to provide sufficient fibre and timber for the country's commercial needs. If the industrial forestry sector is disadvantaged, it thus has immediate and serious implications for the economy (in particular the wood processing sector), employment, and foreign revenue earnings. During the first decade of the newly elected democratic government, 1994–2004, industrial forestry interests have not been well-nurtured by the (then) Department of Water Affairs and Forestry, causing the industry to stagnate or shrink in certain regions. From the examples given, it appears that many of these negative consequences are reversible if the government allows private industry to work in partnership with them. The movement of the entire forestry portfolio to the newly formed Department of Agriculture, Forestry, and Fisheries (DAFF) has brought some hope of a better dispensation, but much still remains to be done to ensure growth and prosperity in the forestry sector, particularly in industrial forestry. The following issues should be addressed through strong partnership between government and private industrial forestry companies:

- Land restitution should proceed in a way that ensures a continued supply of timber from plantation land. Alienation of the industrial forestry sector in this process by relying on forced land redistribution could have severe socio-economic drawbacks.
- Government agencies would need to become more sensitised to the fact that industrial forestry provides sustainable livelihoods and economic stimulation in rural areas and does this while having a relatively small impact on stream flow reduction. For example, removing all industrial forests would hardly contribute to the run-off in the Western Cape's streams but would have major consequences for employment, timber processing, and wood supply in the province. It would also impact negatively on carbon sequestration and soil conservation. The water gains from clearing of invasive thickets and the regulation of wasteful water use in some irrigation and urban usage areas is potentially much larger than water gains from phasing out plantation forestry in the Western Cape Province.
- Further improvements in speed and efficiency of the afforestation license procedure are essential to create a favourable investment climate for forestry. It is striking that several licenses allowing large-scale surface coal mining and exploratory fracking of sedimentary layers for shale gas have been issued in South Africa during the past five years (both unsustainable enterprises with heavy carbon footprints), while afforestation licenses (a green investment) have been stagnating partly due to administrative bottlenecks.
- A more relaxed view on tree planting on farms is necessary. Allowing the establishment of small-scale woodlots for fuelwood, bioenergy, poles, honey bee forage, and all-purpose timber, by using land with low potential for agriculture, holds a lot of promise for relieving the looming shortage of timber, fibre, insect pollinator, and energy. To do this, the licensing system for afforesting small areas (e.g. less than 10 ha) has already been made simpler, and this initiative has been very positively received. Such afforestation could be done using fast-growing species that use water efficiently and that do not pose an invasive threat.
- Reforestation of economically viable industrial plantation land is strongly recommended to avoid large-scale timber shortages in the future, unless there are other compelling reasons not to do so.

27.4 Drinking water provision from the forest: a case from northern Italy

27.4.1 The institutional setting

Water quality and quantity have been a core issue in European environmental policies of the past few decades. Although policy-makers have considered tap-water use as a priority with regard to other uses, it has not been clearly addressed in the legal system implemented among the European countries. Nevertheless, efforts coordinated by the European Commission have posed a kind of hierarchy on water uses, in which water for human consumption has been considered essential, together with the environment, in the water catchment (Aubin and Varone 2004). This has been formalised in the European Water Framework (WFD) 2000/60/EC, as the final result of a long conceptual process related to water use. Since then, several European countries have started to adapt their legislative systems based on the main principles of the directive. The planning of water service costs and the principle of full recovery of the cost of water service have been two major economic changes pushing policy-makers to consider the cost of environmental conservation in the catchment areas. Despite the traditional top-down approach, where a set of legal constraints were implemented, the aim of the WFD was the active promotion of market-based mechanisms to enhance the provision of high water quality though particular land management practices. Basically, the need to move from command-and-control approaches to market-based mechanisms has been the formal recognition of the concept of equality along the tap-water supply chain. This has brought the landowner into the picture as the first, though weakest, actor in the chain.

In Italy, the concept of environmental cost along the tap-water supply chain was introduced by Galli's Act (Law 36/94). Instead of implementing new legal constraints based on a command-and-control approach, policy-makers anticipated some of the WFD principles, introducing the concept of environmental cost compensation, as a positive economic tool aimed to stimulate the improvement of the water cycle between the spring and the river mouth. Galli's Act suggests the adoption of an extra payment on the water bill (from 3% to 8% of the water bill) to compensate directly for maintenance of the upstream area (mainly forest land). But due to the high fragmentation of private land and the historical incapability to coordinate or associate landowners, the law highlighted the potential role of public authorities as the only players able to manage a sufficient land surface to stimulate forest environmental services like water filtering, hydraulic regulation, or soil conserva-

Table II 27.2 Soil erosion and forest management practices.

	year 1	year 2	year 3	year 4	Average
Silvicultural practice	Erosion (kg/ha)	Erosion (kg/ha)	Erosion (kg/ha)	Erosion (kg/ha)	Erosion (kg/ha)
Coppice with clear-cut	92.2	80.5	1.1	5.6	44.8
Coppice conversion to even-aged forest	62.7	24.1	0.8	4.4	23.0
Natural evolution	5.2	2.9	1.0	1.5	2.6

Source: Bagnaresi et al. 1999.

tion. In fact, the application of some particular forest management practices at the scale of a cadastral land unit (generally a few thousand square meters) would not allow this approach to achieve tangible results. These can only be achieved if the targeted forest management is extended over a whole water catchment area. Despite the law's intentions, market-based mechanisms have only been introduced formally in two Italian regions – Piedmont and Veneto – where an extra charge on tap-water bills has been implemented (Pettenella et al. 2012). Both regions have used the fund, approximately 3% of the extra charge on water bills, to compensate mountain areas in terms of projects or infrastructure aimed to improve local forest management practices, but so far the relatively small investments upstream have been insufficient to result in a significant change in water quality or quantity.

27.4.2 Romagna Acque, a success story on payment for drinking water services

Apart from these large-scale regional schemes, Galli's Act has not had a wide implementation on the Italian peninsula, but it inspired Romagna Acque S.p.A., a multi-utility company in the central Apennines. It became a success story – a historical case in which a specific forest service was stimulated through a set of annual payments to cover the cost of specific forest management practices undertaken by landowners. Begun as a consortium of municipalities to reduce the cost of the supply of drinking water in 1966, it was able to cover the distribution of water to the entire Romagna area in 1989; only a few years later, in 1994, Romagna Acque S.p.A. was founded, becoming owner of the water resources in 2004. The principal mission of the company has been to provide high-quality water in sufficient quantity to cover the demand of the Romagna in a context of ecological sustainability and financial optimisation. While this last aspect has been achieved through planning of a water tariff to meet the WFD requirements of the full-cost recovery of the water service, the ecological aspects were thoroughly studied before deciding on the strategy to be implemented in the field.

The most important company water source is a dam basin located in the central Apennines (Ridracoli area – municipality of Bagno di Romagna), which covers 50% of the entire Romagna tap-water demand (108 million m^3/year). Especially during the summer season, the basin is fundamental to the supply of high-quality water to the coast, densely populated by tourists. Since its construction, the biggest problems have been dam sedimentation and maintenance of high-quality water. In 1993, the company invested in research to understand the link between different forest management practices and soil erosion as well as water quality stabilisation. In terms of water-related forest ecosystem services, four years of research have demonstrated the clear impact of forest management systems such as coppice with clear-cut and forest conversion from coppice to high forest on soil erosion, while minimising silvicultural treatments or natural stand evolution markedly reduced the degree of soil erosion (see Table II 27.2).

In Table II 27.2 the large variability between years can be attributed to inter-annual variability in rainfall patterns but management effects are consistent over the years, except in a year with few torrential rainfall (year 3), where erosion is near zero for all management types. Moreover, conversion to high forest and natural stand evolution have proved to have a positive influence on nitrogen reduction and pH stability. The translation of these effects into a price for water was done by calculating the difference between the annual traded water and the cumulated changes of water level in the dam. Based on this evidence, an extra payment, 1% to 3% of the water-bill has been used to compensate landowners who convert their coppice forest in even-aged stands within the catchment areas, helping them to cover the cost of changes

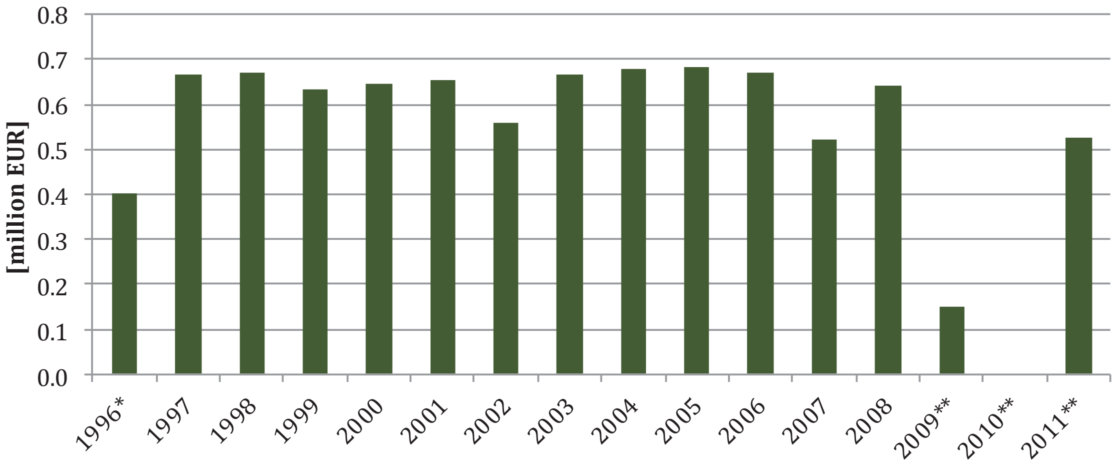

Figure II 27.7 Environmental cost to limit soil erosion and enhance water quality: A single-starred year, 1% of extra payment; double-starred years, years after water-tariff reform. Source: Romagna Acque S.p.A

in management practices and land opportunity cost (relatively low due to the scarce access). In general, more than EUR 0.6 million (see Figure 27.7) have been delivered in the water catchment area (37 km^2), where all but a few landowners decided voluntarily to be part of the payment scheme. However, in the year 2009 a new water tariff mechanism stopped the company's environmental investment due to an erroneous interpretation of the accounting law – it was re-established in 2011. So far, the average payment to forest owners has varied from EUR 108/ha in the first year, to about EUR 170/ha in 2008.

The positive impact of the payment scheme was a general decrease of the initial soil erosion in the catchment of 20% (originally 42 000 m^3/year versus 33 600 m^3/year today) and a consistent reduction in nitrogen as well as pH stabilisation. In terms of performance, both Romagna Acque S.p.A. and the landowners have increased their benefits: on the one hand, the company has reduced its water purification costs and increased the life expectancy of the dam (due to the lower soil erosion); while on the other, landowners have maintained or even increased their annual forest revenue. Though other options were considered, such as mud and sand removal with hydro dredging, the limited access to the dam basin and the technical difficulties of dredging in deep water led the company to opt for forest investment. Due to the complex bureaucratic process, the company decided to acquire the land wherever possible. Moreover, part of the water tariff has been invested in programmes to inform water users on the tap-water use as well on the effects of the positive management practices adopted in the catchment area.

27.4.3 Lessons learned

Romagna Acque is a positive example of the environmental services trade. The case study has highlighted both the powerful effect of the market-based mechanism and the fragility of the mechanism due to the unclear or fast-changing legal systems in force. The results, though they may seem relatively small, represent an innovation in the forest sector, traditionally managed for wood production. In this case, the object of the contract was simply the adoption of a new management practice in a water catchment area, ensured financially by a monopsony market – a market similar to a monopoly, where a large buyer instead of a large seller controls the market.

27.5 Conclusions

In this chapter we focused on the water-related ecosystem services of forests. In general, these ecosystem services are considered very important, but misunderstandings persist about the role of forests in their delivery. With a selection of revealing cases, we have shown how initiatives are taken to improve water-related ecosystems services through a transition in the management of forests, such as combatting water erosion by installing exclosures free of grazing, decreasing the forest cover to increase the availability of blue water for irrigation agriculture, or improving tap water quality by continuous-cover silviculture.

The case studies show that such transitions can follow very different pathways, determined by the natural, socio-economic, and institutional context. In Ethiopia, a rather top-down approach had the advantage of being widespread and having measurable impact at a regional scale but the next challenge is to motivate the commoners for the longer term. In South Africa, a complex mixture of top-down and bottom-up storylines is resulting in rather confusing policies and lock-ins between actors. In Italy, a voluntary market-driven process has led to an interesting win-win situation.

But behind these differences in process, the case studies also show some patterns in common – for example, that success or failure is very dependent on scale (how much intervention and where in the catchment). They also clearly show that provoked changes always have effects on other ecosystem services (see Muys et al. 2011).

Also, changes of paradigm can be recognised in the way water-related ecosystems services are considered, with a shift from supply-side policies to demand-side policies and to supply-demand links, and from purely technical solutions (for example, building stonebunds or dredging of dams) to green infrastructure solutions.

The role of science has been quite distinct in the cases. In the Ethiopian case, science did not play a major role in the top-down restoration decisions taken after the civil war but researchers entered in a later stage, first as independent observers, now participating in efforts to improve the schemes (e.g. Muys et al. 2006). In the South African case, science has been one actor in a complex set of drivers leading to the phasing out of the forestry sector in the Western Cape and it has been a decisive driver in the creation of a water tax on forest plantations and the eradication of exotic bush vegetation. One could say that these measures have been based on a correct interpretation of hydrological knowledge, but failed to add other ecosystem services such as wood provisioning and long-term employment into the balance. In the Italian case, scientific understanding has been the main driver of the installed payment scheme, but even in this case, trade-offs with other ecosystem services, for example the long-term effects of the measures on catchment biodiversity have yet to be considered.

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