7. Environmental impacts

The use of biomass for energy production poses various potential threats to ecosystems and the services they provide. Harvesting that leads to the degradation or loss of native forests, will have other negative impacts on a number of parameters including, biodiversity, soil stability and water quality and quantity. Nevertheless, a sustainable forest management regime and the sustainable use of woodfuels can enhance and even improve the delivery of some ecosystem services – providing local emission control, increasing water availability, improving biodiversity and enhancing habitats and landscapes.

This chapter explores the potential impacts of woodfuel production and use and opportunities for sustainable use.

BIODIVERSITY

The unsustainable extraction of forest resources, such as for woodfuel, may lead to forest degradation and permanent loss of biodiversity. Globally, over one-half of the temperate broadleaf and mixed forest biome and nearly one-quarter of the tropical rainforest biome have been fragmented or removed by humans. Nevertheless, the establishment of dedicated woodfuel plantations and sustainable and community-based forest management can reduce the negative impacts of woodfuel production and even restore and enhance biodiversity.

A classic example of a positive outcome from woodfuel plantations is the Green Belt Movement in Kenya. This started in 1977 as a tree-planting programme to address deforestation caused by woodfuel gathering and the conversion of land for agriculture; today it is a movement for women-empowering, community-based reforestation and forest management to provide a sustainable woodfuel resource and enhance soil fertility for agriculture. To date, the Green Belt Movement has planted more than 40 million trees throughout Africa, contributing to the restoration of native vegetation, the development of biodiversity corridors and the protection of habitats.

Another good example of community-based management is in Madagascar, where the World Bank and the national government launched a five-year CBWP in 1992 for both forest production and the protection of the country's unique biodiversity. The approach involved the creation of contracts for the management and sustainable use of forest areas to community-based institutions. In 2000, over 500 contracts had been issued throughout Madagascar, involving about 500 000 hectares of forest and contributing to biodiversity conservation through the protection of corridors and key habitats. The project was successful in achieving biodiversity conservation goals; however, conservation interests were often imposed over the commercial interest of communities to distribute woodfuel –

without adequate compensation mechanisms for the environmental services the communities were providing. In 2008 the Government of Madagascar prohibited all forest exploitation in the country; however, there remains a high demand for woodfuel and a black market has developed, jeopardizing the work of the CBWP project (ESMAP, 2010).

Plantations can have both positive and negative impacts on biodiversity. Generally the biggest impact is due to the change in land use (ADAS, 2006). Biodiversity is likely to increase if the woodfuel crop is replacing introduced pasture or annual agricultural crops, and decrease if it is planted on land with high species diversity, such as unmanaged wetlands or native forests (Woods *et al.*, 2006). When woodfuel plantations are established, therefore, the initial land use is crucial in determining the impact on biodiversity. The choice of tree species can also have an effect: native species are likely to accommodate more of the native biodiversity. A buffer zone between a woodfuel plantation and established woodland or hedgerows can help to preserve edge habitat important for a diversity of species. Woodfuel plantations can also provide corridors between isolated natural habitats. Overall, careful planning and judicious siting of woodfuel plantations within a landscape can enhance biodiversity (Woods *et al.*, 2006).

Weed control is essential during the establishment of woodfuel plantations, but once the crop is mature the growth of a ground flora can have a range of beneficial effects on biodiversity. Ground cover encourages the presence of invertebrates, which in turn can lead to an increase in the presence of small mammals and birds (DEFRA, 2002). The timing of harvesting is another factor; in some climates, harvesting in early summer can affect breeding populations and in winter can remove shelter and food resource (ADAS, 2006).

AIR QUALITY: EMISSIONS AND CYCLES

Even where traditional biomass is harvested sustainably, woodfuel use may not be carbon neutral due to incomplete combustion – the idealized fuel cycle in which all carbon is converted to carbon dioxide is unrealistic. Instead, due to incomplete combustion, carbon is released in other forms, including methane, nitrous oxide, carbon monoxide and non-methane hydrocarbons. These compounds are referred to as products of incomplete combustion (PICs) and have much higher global-warming potential than carbon dioxide. According to the IPCC (2007), the 100-year global-warming potentials of methane and nitrous oxide are 25 and 298 times that of carbon, respectively. Because of the incomplete combustion of woodfuels, between 10 and 20 percent of the carbon released is in the form of PICs (Smith *et al.*, 2000b). The molar ratio of PIC emitted to total carbon emitted is defined by researchers as the k-factor of a fuel; it varies depending on the technology used to burn the fuel. Alternative cooking fuels typically have much lower k-factors than woodfuel (Table 38).

The potential to reduce carbon emissions in sub-Saharan Africa by shifting to clean cooking fuels is significant. Aside from their low k-factor, fossil fuels have several other advantages over woodfuels: a higher energy density, a higher nominal

TABLE 38
K-factors for various cooking fuels

Fuel	K-factor
Woodfuel	0.1–0.2
Kerosene (wick stove)	0.051
Kerosene (pressure stove)	0.022
LPG	0.0231
Biogas	0.00562

Source: Smith *et al.*, 2000b.

combustion efficiency, and a higher heat transfer efficiency. These factors offset their higher carbon density, as both LPG and kerosene produce less carbon per unit of useful energy than woodfuel. At the same time, because the k-factor is lower, even less of the carbon is released as PICs.

Given an unsustainable pattern of woodfuel extraction, in some cases a transition to petroleum-based fuels could reduce net carbon emissions. Emission scenarios based on this shift (to a combined use of kerosene and liquefied petroleum gas (LPG) to meet household cooking needs) project a decrease in cumulative emissions by 2050 of 1 to 10 percent (Bailis, Ezzati and Kammen, 2005). It is worth noting, however, that if woodfuels were produced sustainably and used with greater efficiency the associated carbon emissions would generally be less than those associated with petroleum-based fuels.

Notable potential impacts of woodfuel processing and energy production include emissions such as dust or fly ash that could affect sensitive plant species such as lichens, and the emission of dioxins and metals (depending on the combustibles used). Air-quality regulations could be used to control a range of such emissions (Scottish Natural Heritage, 2007). Biomass-based power plants could conceivably emit higher levels of nitrogen oxides, ammonia and particulate matter than some conventional power plants (e.g. oil and gas). Emissions of sulphur dioxide, on the other hand, tend to be lower. The disposal of waste products, such as ash, involves additional transport emissions and may create other environmental problems (Scottish Natural Heritage, 2007).

A heat-producing plant needs a local heat-distribution network to service its customers. This usually means the construction of the plant reasonably close to housing or commercial or industrial premises that can make use of the heat. The Royal Commission on Environmental Pollution (RCEP, 2004) recommended paying particular attention to emission control, for reasons of both public and environmental health and public acceptability. A modern wood-burning plant should be able to meet all air pollution control standards at a reasonable cost. In particular it is important that biomass plants are not located in areas where they would exacerbate existing poor air quality.

WATER: IMPACTS AND POLLUTANTS

Water availability

Poorly conducted, woodfuel harvesting can have significant effects on water quality and quantity, leading, for example, to increased soil erosion and run-off. On the other hand, forest plantations can require fewer fertilizers and pesticides than annual agricultural crops, thus reducing the risk of water pollution. In addition, forest root systems help to filter pollutants in surface water.

In some cases, forest plantations use less water than annual agricultural crops, but this is highly dependent on the species used and management regime imposed. Fast-growing, short-rotation forest plantations use more water than plantations composed of slower-growing species. Because of their large leaf area, willow and poplar, for example, intercept more rainfall than agricultural crops, reducing the amount of water reaching the soil and recharging aquifers or nearby surface water. In addition, they have high transpiration rates and deep root systems. As a result, willow and poplar short-rotation crops use more water than annual agricultural crops and can also tap into underground water in times of low rainfall (Woods *et al.*, 2006). The environmental impacts of such high water use are site-dependent: in areas of low rainfall or where there is high human consumption of water (e.g. the south east of England), for example, it could cause water shortages and lower the water table. On the other hand, it may be useful in reducing excess runoff and can help mitigate local flooding, even in low-rainfall areas. The effects of short-rotation forest plantations on hydrology should be evaluated through location-specific analysis that includes the species grown, soils, topography, and rainfall and management practices (RCEP, 2004; IEA, 2008).

The high water requirement of willow may constrain its use to areas where sufficient irrigation water is available (RCEP, 2004). Sewage or sewage sludge can be used to irrigate willow and will also provide additional nutrients (although the high heavy-metal content of sewage can potentially pollute the soil). Willow can be used to reduce soil contamination by absorbing heavy metals, but this, in turn, may affect the composition of the ash following the combustion of the wood.

Water quality

On good land, short-rotation forest plantations are likely to increase water quality compared with land used for agriculture because of its lower agro-chemical requirements. There is some evidence that, in particular locations, the application of fertilizers and sewage sludge can cause nitrate leaching. However, it has also been suggested that mixtures of trees and grasses used as bioenergy crops could be cultivated along waterways to act as buffers, limiting nutrient runoff from agricultural land (Woods *et al.*, 2006).

SOIL: NUTRIENTS, AGRONOMY, TOPOGRAPHY

Forest plantations for woodfuel remain in place for a number of years, establish good root systems, and develop leaf litter layers, all of which helps to conserve or promote soil fertility and prevent soil erosion. When harvesting forest residues for bioenergy, site-specific considerations should take into account the unique qualities of both the soil and the topography to avoid soil-related damage, especially on low-fertility sites (Mead, 2005). Large areas of open ground are exposed during the establishment of a forest plantation, leaving the site vulnerable to wind erosion (especially on light, sandy soils) and water erosion (especially on sloping sites during rain events).

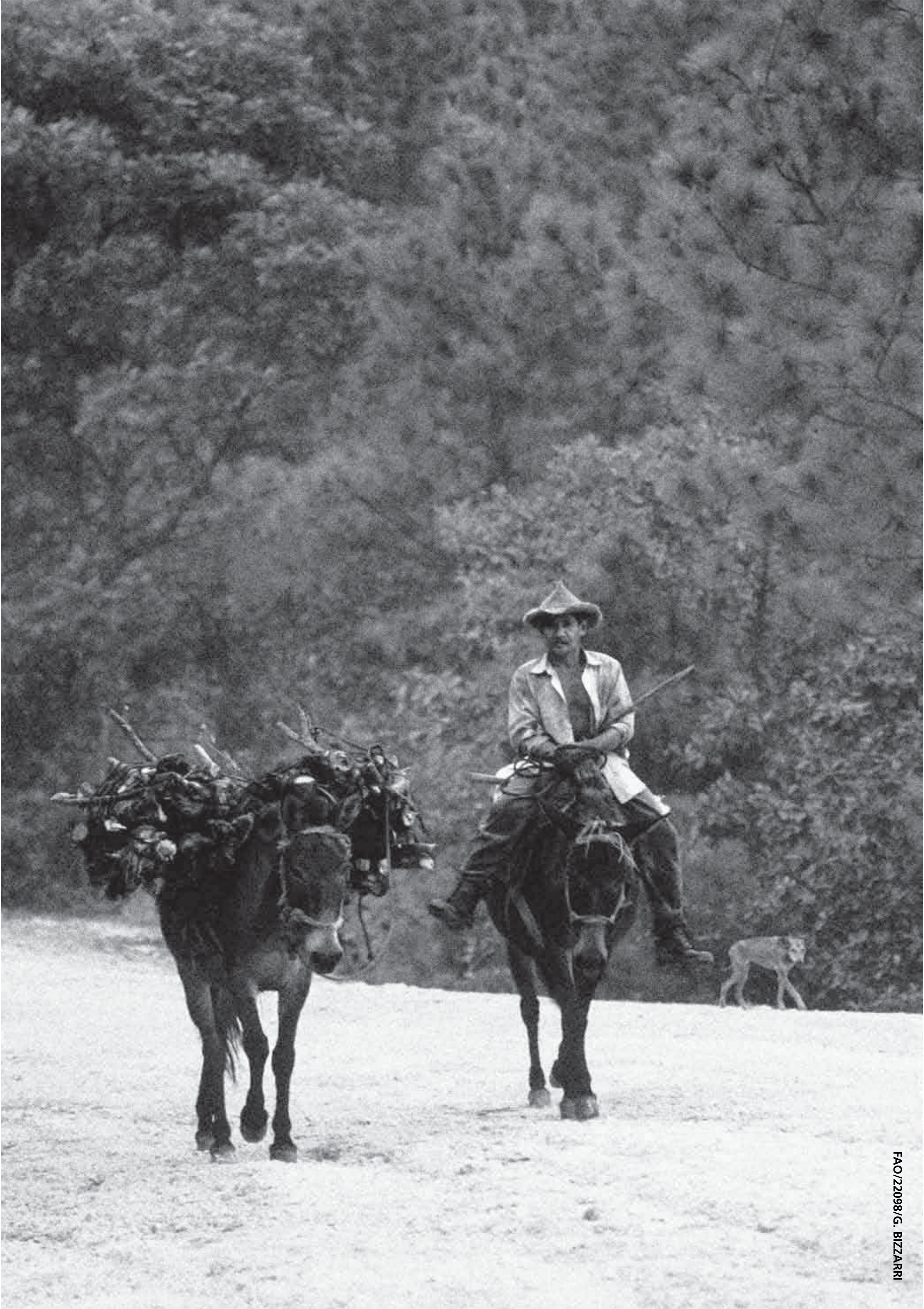
Harvesting should aim to minimize nutrient removal and physical damage to the soil. Ideally, most of the nutrient-rich foliage will be retained on the site. Minerals such as calcium, magnesium and, to a lesser extent, potassium and phosphorus, are contained in the bark of eucalypts and some other hardwoods. According to Santana, Barros and Comerford (2000), leaving the bark on site is a good nutrient conservation practice for eucalypt plantations in Brazil. Another common practice is to return the ash generated by combustion to the site to help compensate for the loss of nutrients caused by biomass removal. Nevertheless, this is not fully achieved and some sites need additional fertilizers (Mead, 2005). Harvesting machinery should be chosen carefully to minimize soil damage and avoid erosion.

A set of ten principles has been developed for nutrient management in woodfuel production with the aim of assisting foresters to strike a balance between production, ecological services and carbon management (IEA, 2008). The principles include the idea of a strong commitment to adaptive forest management, which requires continual monitoring and adjustment (Raison, 2002).

MARKET IMPACTS

The forest industry has the capacity to absorb some additional demand from the growing bioenergy sector, at least in the short to medium term (20 years). In particular, wood pellets, woodchips and other residues (the largest traded resources) originate mostly from by-products, residues and waste (including sawdust and other residues from the forest industry). In the last few years this resource has expanded in northern countries (e.g. Canada, the United States, Sweden and Norway) but it is still largely under-used in developing countries and thus there is considerable scope for expansion. Being largely a waste resource, such an expansion would require no additional land or other resources (such as water), and there may be positive economic outcomes for local forest industries. In some cases, however, an emerging woodfuel export industry may stress existing transport infrastructure.

Of concern is the potential impact in areas where there is little existing formal forest industry. In Mozambique and Tanzania, for example, there is no well-established forest industry from which residues could be obtained and woody biomass still supplies over 80 percent of domestic energy. The development of an international bioenergy market could have serious impacts on those domestic markets; the export of biomass from such countries requires careful assessment of its impacts.



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