Surviving pastoral decline: pastoral sedentarisation, natural resource management and livelihood diversification in Marsabit District, Northern Kenya Deel: *Vol. I*

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Forest cover and water-yield linkages: an economic approach to indirect functions of Marsabit Forest Reserve

"Situated as it is, and standing out as a well-preserved forest island in the midst of low-lying arid country, fast turning to nothing short of desert, its principal function is climatic. It is high enough to catch the mists, large enough to attract the rain, and forested enough to conserve water to support the Boma population plus a considerable number of agriculturalist immigrants who can only practice agriculture. Thanks to its presence." (Working Plan Report, Marsabit Forest Reserve, 1945: 7).

It is widely accepted that forests fulfil a variety of functions and generate forest benefits like water conservation through the protection of catchment areas (i.e. the hydrological functions), the prevention of soil erosion, climate regulation and the provision of a habitat for a variety of wildlife species. At the level of human resource use, forests provide wood fuel and building materials for the rural population in addition to a wide variety of food products, medicines, fodder and fibres. In Kenya, the importance of these functions is reflected in forestry development policy and forestry development packages relating to gazetted forests like the Marsabit Forest Reserve. Local afforestation schemes and rural afforestation extension are some of the primary development objectives of the Forest Department (MDDP 1979; MDAR 1996). That said, forestland faces competition from other land uses like agriculture, whose pay-offs are often realised in short or medium terms, unlike most of the indirect forest benefits. For similar reasons, most of the forest functions and other forest effects on the climate are not quite quantifiable in monetary values (Barbier et al. 1995; Perrings 2000). The argument put forward in this chapter contributes to the forest conservation debate in relation to several points of view that have been articulated (Dasgupta et al. 1994; Barbier & Rauscher 1994; Dasgupta & Mäler 1995; Dasgupta 1996; Folke et al. 1996; Putz et al. 2000; Perrings 2000). In general terms one can state that:

- forest ecosystems support a wide range of ecological functions, including watershed protection; and
- related to the first point, the forest cover essentially sustains a number of climatic functions. For example, forests positively influence rainfall and thus rainfall is partly a function of forest cover.

The flow of the ecological services provided by the forest ecosystem supports a wide range of economic activities. Yet the links between ecological parameters of forested areas and their
support of economic production are difficult to determine. Equally difficult to assess are the so-called hydrological benefits or services that forests generate. In this regard, it can be argued that even if benefits from forests are positive at the margin, it is impossible to get a grip on their distributional pattern or magnitude. These challenges place a greater emphasis on the indirect forest ecosystem's functions, which have got several characteristics of a public good, more than the direct use value of the forests.

In contrast to Chapter 13 which considered direct use values of the forest and the role of forests and woodlands in the rural economy and people's livelihoods, this chapter considers the indirect functions of Marsabit Forest Reserve (MFR in short), particularly the forest ecosystem's watershed function or hydrological service. Arable farming, water sources and the mountain's micro-climate are, for example, related to the watershed functions of the forest ecosystem. Contrary to the direct use values, which are revealed by current consumption patterns of the forest-adjacent population, the benefits of indirect forest functions are, characteristically, hidden in the short term and generally accruable to the local communities only in the long term. This chapter aims to improve our understanding of medium and long-term forest benefits through consideration of the importance of indirect forest functions related to the forest's watershed function, with a view to exploring the 'added-value' in forest conservation. To address this concern we examine the forest's indirect support of irrigated agriculture and water production for the urban population.

In the following section, we will first review the outcome of analyses presented earlier in this book and which are relevant for the discussion of the forest's watershed and related indirect functions. Issues addressed in this respect relate to arable farming (Chapter 12), the importance of the conservation of the forest ecosystem (Chapter 9) and household use of forest and vegetation resources (Chapter 13). The review focuses on trends in human population, rainfall and expansion of arable farmland on the mountain that have been pointed out in the previous chapters. This review is intended to clarify the link between hydrological functions and the supporting role of the forest in farming activities. Next, we provide an overview of the watershed function of the montane forest, paying attention to water discharge and regulation of the water quantity, the provision of irrigation water and urban water supply. We then pay more specific attention to the provision of irrigation water as an indirect forest function. We analyse economic returns and factors limiting the expansion of irrigation activities. Next, we address the role of the forest in urban water supply, with an emphasis on the volume of water produced, the economic aspects and costs of urban water production from within the forest reserve and the performance of the public provision of piped water supply. In the last but one section we model the likely effects of rainfall trends and changes in forested areas on urban water production. More explicitly, this section examines the effect of human economic activities related to the expansion of arable land on the forest cover and on forest-based water production. The section questions the outcome of woody vegetation cover removal by humans for the indirect ecological services of the legally protected forest ecosystem areas on the mountain. The focus here is on the link between the forest ecosystem's indirect watershed function and crop cover changes over time. We explore this link using an economic approach which integrates and investigates the possible synergies between changes in vegetation cover in the forested area (habitat size), the expansion of
cultivated land on the mountain, annual rainfall and urban water production generated from within the forested area. In this section, we pay ample attention to the policy implications of the model outcomes.

The method employed in the chapter is inspired by the ecosystem approach which primarily aims to improve our understanding of the importance of conservation policies and protected forest areas. In this regard, we empirically verify the economic and ecological underpinning of forest conservation policies as explicitly reflected in the opening quotation to this chapter. The last section deals with the ecosystem approach to forest ecosystem, focusing explicitly on the role of local communities and the need to include them in forest resource management.

Findings from previous chapters

*Human population on the mountain*

In Chapters 4 and 5 we noted that the mountain area experiences a much more rapid population growth compared to the rest of the district. In Chapter 9 we dealt with human pressure on forest and wildlife and gave an overview of the population distribution on the mountain. This overview revealed the imbalances in the population distribution at micro level and a dense pocket of human habitations on the eastern side of the mountain.

Three observations are worth pointing out and need to be borne in mind. First, human populations are more densely concentrated in Marsabit Town than in the other two areas and the eastern side of the mountain is more densely populated than the south-western side. With regard to the distribution of ethnic groups, the Boran, Gabra, Burji and Turkana occupy the north-eastern side of the mountain, while the Rendille, Samburu/Ariaal inhabit the south-western sides of the mountain. Marsabit town accommodates all groups. Secondly, the areas on the mountain with human populations not only differ in terms of their concentrations (population numbers and number of households) but also demonstrate varying growth trends in the course of time. For example, the eastern side of the mountain had a higher density than Marsabit town by 1979 and this relative population concentration reverses in the subsequent decades. In recent decades, Marsabit town had a population density that was almost twice as high as that on the eastern side and six (in 1989) and five (in 1999) times more than the density in the south-western areas. Faced with uneven population distribution we would rationally expect that individuals and families re-allocate across the mountain zones, moving towards a less densely populated locality. Such movement is, however, hindered by differences in the ethnic composition of the population on the eastern and south-western sides of the mountain and this perpetuates the population imbalances.

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1 The 'eastern' and 'south-western' sides refer to the east-to-northern and southeast-to-south-western sides of the mountain respectively. The Samburu/Rendille (and Ariaal) are the main ethnic groups settled on the latter side, while the Gabra, Boran and Burji are some of the main ethnic groups on the eastern side. These terms are only used for simplicity.
Variations in rainfall
With reference to the Marsabit Mountain, the combination of relatively high altitude amidst low-lying plains, relatively high amounts of rainfall and its moderate variability and good soil types, primarily enable and support diverse human economic activities on the mountain, especially rain-fed agriculture. For this reason, rainfall is the most instrumental factor influencing production in the study area and it has an indirect effect on production possibilities. In addition, rainfall, both in amount and temporal variation, significantly influences the multiple watersheds functions of the forested area.

Earlier, we analysed rainfall data for Marsabit Mountain over the last 80 years and compared the rainfall trends of the mountain with five other locations in northern Kenya. The observed changes in the rainfall pattern within a wider regional perspective and the decline in rainfall amounts on the mountain need to be borne in mind. The effect of the decline in rainfall on the mountain, and by extension in the region, seems to be mixed in terms of specific resources.

Trends in farm land expansion on Marsabit Mountain
Livestock keeping and rain-fed arable farming are the main human economic activities on the slopes of Mt. Marsabit. Chapter 7 showed that a household on the mountain on average owns about 8 TLU in absolute terms, while also owning 6 acres of arable land in 1998. The history of settlement, farming practices and related crop production activities on the mountain are mainly addressed in Chapters 5 and 6.

Chapter 6 described changes in cultivated land (i.e. crop cover) for the main crops grown on the mountain since the early 1970s. Directly or indirectly, arable farming on the mountain primarily depends on amounts of rainfall and this in turn is an indirect function of the forest ecosystem. The land suitable for rain-fed agriculture presently makes up between only 3 and 5 per cent of the total district’s area (approximately 269,000 ha). The process of clearing and converting the vegetation cover to crop land reduces the originally protected habitat on the mountain. That is, the cultivated areas also give a measure of the rate of fragmentation of the habitat. In this chapter we consider what the effect of this process is on water yield.

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2 In a formal sense of protected areas, ‘forests’ are restricted to legally protected areas. Note that our use of ‘forested area’ goes beyond legally defined areas and encompasses vegetation cover on the mountain which serves as a buffer zone and supplements the role of the protected forest in protecting the mountain catchments areas.

3 Maize, beans, teff and wheat are the main crops grown on the mountain, with maize and beans being the main food crops (cereals). Although accurate estimates of total land area solely devoted to these crops are generally limited, crops are often intercropped on a field, especially maize and beans. However, based on crop cover estimates for several years by the Ministry of Agriculture, between 90 per cent and 99 per cent of the total cropland is planted with one of the four main crops.

4 There is very little data on the cultivated land on the mountain in earlier years. However, the earliest initial occupation on the mountain dates back to 1909 (Brown 1989) and the first serious farming activities started in the 1920s. That was when the colonial administration sent certain Konso and Burji families to Marsabit to settle and farm on the mountain (MDAR 1922; Marsabit Handing Over Report 1922). The primary aim then was to increase agricultural production on the mountain. Around 1919/20, only 3.63 ha of land was being cultivated and planted mainly with Hickory King maize. Farm productivity was about 9,20.4 kg per ha, which works out at about 10 bags per ha, using the commonly used measure of a 90 kg bag. By the end of the 1920s, the total land under cultivation had increased to about 11 ha.

5 Of this, 80 per cent is either forest, game reserve or grazing land (Lusigi 1983; MDAR 2001).
Following on from Chapter 6, a total of 4,247 ha was under cultivation on the mountain as a whole by 1973. The area used for the main crops increased at a constant annual rate of about 2 per cent for cultivated land over a 20 year period (4,200 ha in 1977 and 6,115 ha in 1998). The land cultivated with the main crops amounted to 9,331 ha in 1987, 11,196 ha in 1989 and 7,718 ha in 1999 (MDARs various years). The land actually planted with crops reached high levels in the late 1980s and plunged to a lower land area in the 1990s. The land area actually cultivated in the second half of the 1990s was, on average, what it used to be in the mid-1980s; that is approximately 8,000 ha. Over the decades, the total area actually cultivated with crops increased from about 4,000 ha in the 1970s to 8,000 ha in the 1980s and to about 9,000 ha in the 1990s, but decreased again to 8,000 ha during the last few years. These last ‘reductions’ might also be a result of the lower quality of reporting by the Ministry of Agriculture in the 1990s.

The population growth on the mountain is also reflected in the number of farming units. In recent years, the total number of farmers (i.e. farm units) on the mountain registered with the Marsabit County Council (MCC) increased from about 1,150 farms in 1994, to about 1,400 farms in 1997 and reached about 1,693 farms in 19997 (MCC 2000: land file accessed by the authors). Thus, the number of farms increased by roughly 47 per cent and 21 per cent over the 5 year and 2 year period respectively. Trends in cultivated land (cropland) and the growing number of farm units, both jointly and separately, indicate increasing settlement and the growing importance of arable farming on the mountain.

Likely effects of farmland expansion
The farming activities on the mountain are closely linked to indirect forest functions. Forest-linked rainfall on the mountain enables rain-fed agriculture, which benefits the wider society. This section assesses the effect of farmland expansion on the forested area and on water production in the area. The changes in cultivated land demonstrate a rising removal of vegetation cover, as more land is brought under crop cultivation. Population growth and sedentarisation are two main factors that necessitated the expansion of farmland on the mountain. There are two dimensions to the population increase on the mountain: (i) increased settlement, which is accompanied by more land being brought under cultivation and (ii) expansion of the town which means that farm parcels close to the town are inevitably given up as farms and allocated to settlements. These farms are subdivided into small units as residential plots and are only used as home gardens. Both the increases in the number of households and the population of the mountain suggest possible expansion of farmland into the ecologically marginal frontier beyond the currently settled areas and the simultaneous subdivision of farmlands into smaller sized residential plots. The fact that the current land area cultivated is about the same size as in the mid 1980s implies that the cropland estimates do not show the total mountain area cleared of vegetation cover and settled by humans. In

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6 Land tenure of the settled areas is basically freehold and land control is vested in Marsabit County Council. Registration of land with the council would mean payment of annual land rent. Owing to a lack of proper land holdings in the form of title deeds and in order to evade payment of the annual rent, many farmers would presumably opt not to register their land parcel. Therefore these figures are again at the lower limits of the land holdings on the mountain.

7 Today, the average household farm sizes are between 5 and 6 ha for the mountain as a whole.
other words, these areas give an underestimation of the size of the habitat fragmentation of the mountain area.

The expansion of agricultural land or increase in human population on the mountain matters for three important reasons:
1. Increasing human settlement is likely to intensify human-wildlife conflicts.
2. The amount of crop production of the settled families may affect the way forest resources are used locally.
3. An increase in cultivated land (and land-cover changes) as a result of clearing vegetation cover (see Chapter 6) reduces the size of the forested areas on the mountain.

That is to say that removal of the vegetation cover on the mountain, including the vegetation cover outside the legally defined forested areas, may affect the buffer capacity of the forest ecosystem. The rate of change in cultivated land, moreover, represents a fragmentation of the protected areas habitat on the mountain. The area of the cultivated land is also similar to the extent of habitat loss, especially with regard to the originally designated total area of Marsabit National Reserve in 1948 which embraces the entire mountain area. By then, the protection of the entire mountain area was a result of the fear expressed by the colonial government of the livestock use threat to the forest and subsequent government proclamation of the mountain and its resources:

"By Government Notice No. 936 of 24th September 1948, all the Game Reserve in the District was proclaimed a National Reserve ..." The (new) boundaries of the reserve were extended to include the whole of Marsabit Mountain ... this has the effect preserving all the Greater Kudu who never wander much further than half way down it" (MDAR 1948: 21).

Since then there have not been any major changes in the status of the protected areas on the mountain, apart from the reductions indicated earlier in Chapter 9. Extended removal of bushy vegetation for use as farmland has the direct effect of diminishing the habitat size and may have negative feedback effects on the watershed capacity of the forested area ecosystem. This problem is addressed here with reference to commercial water production in the forested areas.

*Effect of removal of vegetation cover on soils*

Soils on the mountain are generally deep to shallow, well-drained, red volcanic soils with a high infiltration capacity of surface soil (Schwartz et al. 1991). The soils are rich in organic matter content and, other things being equal, they are suitable for crop production and enable all manner of farming activities to be carried out. Farming takes place mostly in the highland foothills on low, rolling or undulating slopes at inclines of between 5 and 16 degrees and 0 and 12 degrees in the case of Songa ridges.

Vegetation cover generally influences the microclimate and reduces the eroding power of rainfall intensity. The plant biomass on the mountain would, as a whole, slow down soil erosion through the secondary function of reduced surface run-off. The downside of the expansion of arable agriculture on the mountain is that the process of using more land for cultivation potentially exposes soils to the risks of erosion. The long dry seasons and commonly observed dust bowl in Marsabit town are indicators of wind erosion.
Although water and soil erosion are stated as being moderate to low (GoK 1997), the clearing of land and the removal of vegetation cover exposes the soil to erosion hazard and thus aggravates soil sensitivity to erosion in the case of cereal cultivation as carried out on the mountain. Soil types also affect the ecological sensitivity of the forest. There are several seasonal gullies and ravines that originate from the mountain and run downwards. In instances where such gullies are on farms adjacent to gully-slopes, which are relatively steep, the risk of erosion is high. Gully erosion processes\(^8\) are apparent on these steep slopes, but they are not yet critical (Schwartz et al. 1991; Umuro, Soil Conservation Officer, pers.comm. 2002).

Examples of watershed functions of forested areas on Mt. Marsabit

Around Marsabit mountain there are a number of water sources\(^9\) whose sources are in the forest reserve. Some of these water sources have been developed and utilised for: (i) irrigated agriculture and (ii) improved access to piped water for the urban population of Marsabit township. The use of water from the forest for irrigation activities and urban water production are illustrations of indirect functions of the forest on the mountain related to the forest's watershed function. Susswein et al. (2001: 7) note that the forest's watershed function comprises (i) maintenance of high quality water (e.g. for drinking water, irrigation, fishing etc.); (ii) regulation of water quantity (maintaining a reliable water yield, flood avoidance); and (iii) maintaining the water sediment balance in watersheds (low sediment load, few landslides/mudflows). The following section specifically looks into the prospects of irrigated agriculture on the mountain, using welfare measures of production and relative price changes (i.e. arc-elasticity). After that, we deal with the economics of urban water production and with issues of public provision of water utilities. Thereafter, we will examine the effect of arable land expansion on the mountain and the accompanying reduction of forest habitat size on the water yield. But first, we will shed some light on the discharge flow rates and the distributional aspects of forest-related water supply.

*Forests and their watershed protection function*

The montane forest area indirectly supports arable farming on the mountain. The relatively high altitude and the catchment area of the forest primarily influence the rainfall on the mountain. Rainfall is the sole means of recharging water sources and of replenishing underground aquifers on the mountain as well as in the adjacent lowlands.\(^{10}\) The forested area therefore has a critical watershed function.

There is no adequate data on capacity, discharge flow rates and users of water sources in the region. There is only a limited amount of data on a few springs. This information is

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\(^8\) Farming methods used by farmers on the mountain bear immediate consequences for arable production, and may also affect nature and extent of soil erosion (see Chapter 12 on farming).

\(^9\) Institutional water management; access right and related use rights issues have been discussed in Chapter 8 of this book.

\(^{10}\) The fact that boreholes like Kalacha (177 m³/hr) in the lowland, with low rainfall, have a higher discharge flow than boreholes on the mountain can largely be attributed to the recharge function of the rainfall on high altitude areas, and ecological linkages between these zones.
utilised here to examine the benefits of Marsabit forest to the local communities. Particular emphasis is placed on the micro-level distribution of water sources, their potential yields and their use for irrigated agriculture and urban water production. Unequal resource endowment at the micro-level typically differentiates access to, and the use of, water resources and options coupled with water availability.

**Water discharge rate flow for selected water sources on the mountain**

There are several permanent springs and a few shallow wells on the mountain that are forest-dependable sources\(^\text{11}\) of water. The various water sources have been described in detail in Chapter 8. In this section we focus on the distributional and discharge pattern of water sources on the mountain. Table 15.1 shows the distribution and discharge flow rates (yields) for the main water sources on the mountain, which are mainly springs.\(^\text{12}\) Some of the springs are situated on the edge while others are inside the forest reserve. Some of these springs are used in their natural state as pools\(^\text{13}\) and are of immense importance for livestock watering and domestic use by the rural households (WRAP 1997).

The water discharge flow rates in Table 15.1 were measured during the wet and dry seasons in 1995 and 1996 respectively. The total annual rainfall during these years was 512.7 mm and 466.7 mm respectively. In both years, the annual rainfall for the mountain was below the average of about 800 mm.

Bakuli, Badassa, Songa and Karare springs are all located in the interior of the Forest Reserve.\(^\text{14}\) Water from the Bakuli (I and II) springs serve residents of Marsabit town.\(^\text{15}\) These springs are clearly the most productive sources. Bakuli II has a noticeably higher yield and is thus a principal source of the urban water supply. These sources still produce an inadequate amount of water to meet demand from the town, especially during dry seasons (WRAP 1997). The problem of water shortages is persistently one of the main concerns on the mountain\(^\text{16}\) (see below as well).

Badassa, Songa and Karare springs have been developed and water is fed into reservoir tanks through a piped system by gravity flow. The \(\text{f}^{-}\)ne and receptor tank facilities were developed in the 1950s by the British colonial government in response to livestock grazing

\(\text{11}\) Water availability is localised, especially during the dry seasons. Detailed information on the locations of these sources in the district can be obtained from various reports (Schwartz et al. 1991; Odero 1993; WRAP 1997).

\(\text{12}\) There are four main boreholes within the vicinity of the mountain: Jaldessa (with a discharge rate of 4.8 \(\text{m}^3/\text{hr}\)), Gudas (8.2 \(\text{m}^3/\text{hr}\)), Sagante (8.1 \(\text{m}^3/\text{hr}\)) and Dirb Gombo (8.1 \(\text{m}^3/\text{hr}\)) (WRAP 1997). All the boreholes are located in the eastern lowland region of the mountain. Importantly, these boreholes are recharged by the precipitation on the mountain. The average depth of the boreholes during the dry season is high compared to some boreholes in the lowlands (Odero 1993).

\(\text{13}\) The local communities and their livestock herds are the main users of the shallow wells and boreholes found around the mountain. Information on the number of users of these sources is generally not available.

\(\text{14}\) Lake Paradise and Marsabit Lodge are the other important sources in the reserve and they are used exclusively by wildlife.

\(\text{15}\) Aite (protected spring with a storage tank) and El-Willy well (protected shallow well equipped with a hand pump) also serve Marsabit urban township. Aite has a yield of 60 litres/min. in the wet season and 40 l/min. in the dry season, while the yields at El-Willy are 2.0 litres and 5.8 litres respectively.

\(\text{16}\) As long ago as in 1939, the water table of the main township supply dropped considerably and caused severe water scarcity. As a result, water was rationed and for most of the year the town residents were compelled to draw their water from L. Paradise (MDAR 1939:30), about 8 km away.
and the water-demand pressure on the protected forest observed at the time (MDARs 1945, 1954, 1956). These facilities are also used in the current micro-irrigation schemes set up to grow horticultural crops on the mountain. The spatial distribution of water sources translates directly into the availability of water. Table 15.1 shows that the south-western side of the mountain at the margin has more water sources than the north and north-eastern sides. The distributional imbalances in water sources cause a differentiation in development potentials. Owing to these uneven distributions and potentials in water sources, the rural households on the eastern region are served by piped water which improved their access to water sources.

Table 15.1
Discharge flow rate for selected water sources on the mountain

<table>
<thead>
<tr>
<th>Source</th>
<th>Pop.</th>
<th>Livestock served</th>
<th>(m³/day)</th>
<th>Discharge rate (L/sec)</th>
<th>Mean² (m³/day)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1. Marsabit Town</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Marsabit lodge</td>
<td>1,000</td>
<td>1,000</td>
<td>1979</td>
<td>1979</td>
<td>8,716</td>
<td>Spring</td>
</tr>
<tr>
<td>Bakuli I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>Bakuli II</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1979</td>
<td>Spring</td>
</tr>
<tr>
<td>2. Eastern side</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>Badassa</td>
<td>1,000</td>
<td>1,000</td>
<td></td>
<td></td>
<td>1979</td>
<td>Spring</td>
</tr>
<tr>
<td>3. South-western side</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>Karare</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,881</td>
<td>Spring</td>
</tr>
<tr>
<td>Songa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>606</td>
<td>Spring</td>
</tr>
<tr>
<td>Hula Hula</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>500</td>
<td>Spring</td>
</tr>
<tr>
<td>Songa Dambella</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>500</td>
<td>Pipelines</td>
</tr>
<tr>
<td>Balessa Bongole</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>500</td>
<td>Pipelines</td>
</tr>
<tr>
<td>Gof Bongole</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>500</td>
<td>Pipelines</td>
</tr>
<tr>
<td>(Ilchuta)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>500</td>
<td>Pipelines</td>
</tr>
</tbody>
</table>

Notes:

a. In the table p = production, and c = capacity, specially for water tanks, and double ‘--’ or blank’ means no data.

b. The ‘dry and wet’ refer to season of the year when water discharge rates were recorded.

c. Population served refers to human use of urban water supplies or water from reservoir tanks. The water used for livestock and rural households’ domestic requirements comes from other sources.

d. The mean estimates (m³/day) are authors’ estimates based on 10 hours of production per day and on dry and wet season discharge rates.

Sources: Marsabit District Development Plan, 1979-83; District Water Office, 2000 (July).

17 Over the course of time, these facilities have been reinstated and maintained by various organisations including MoWD, using funding from the District Development Committee (DDC), the National Christian Churches of Kenya (NCCK) and the Marsabit County Council (MCC) (Marsabit District Development Plan 1979).

18 These do not include the series of shallow wells found on periphery of the Forest Reserve (see footnote 13).
The provision of irrigation water as an indirect forest function

Rain-fed arable farming is very limited in the district and is confined to relatively high-altitude, high-productivity niche areas like Marsabit Mountain. Of the 3,512 ha of cultivated land in the total district as reported in 2001 – which might perhaps be used for one-season crops alone – only about 693 ha have irrigation potential (MDAR 2001). In turn, of the 693 ha, only 53 ha of the district and 50 ha on the mountain are already under irrigation (Table 15.2 below). Irrigation is facilitated by the availability of water outside the normal rainy seasons.

Water has always been a chronically scarce resource on the mountain, as reports dating back to the 1930s have shown. Water shortages were compensated by rationing, the implementation of livestock grazing controls in the forest and by piping water from within the forest. The colonial government attributed the water problem to the limited size of the protected forest area (129 km² as gazetted in 1927) and the deteriorating conditions of the forest and decided to extend the protected area to 153 km² (officially gazetted in 1932). It was in response to this problem that the colonial administration developed a few springs in the forest reserve and piped water out of the forest into the open area (MDAR 1954: 34). Receptor water tanks were constructed downstream at Songa, Gof Bongolle and Badassa on the forest fringe. Water is piped from each spring and fed by gravity flow into a reservoir tank from which it is piped to the consumption units. It was then that the present irrigation facilities were constructed. The current irrigation opportunity emerged as an unintended outcome of conservation endeavour, and a direct attempt to tackle the water problem (MDAR 1942).

### Table 15.2

<table>
<thead>
<tr>
<th>Areas</th>
<th>under irrigation and existing irrigation potential in the region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>1996 and '97</td>
<td></td>
</tr>
<tr>
<td>Area in use (ha)</td>
<td>48.2</td>
</tr>
<tr>
<td>1998 and '99</td>
<td></td>
</tr>
<tr>
<td>a. Area in use</td>
<td>53</td>
</tr>
<tr>
<td>b. Estimated potential</td>
<td>141.5</td>
</tr>
<tr>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>a. Area in use</td>
<td>54</td>
</tr>
<tr>
<td>b. Estimated potential</td>
<td>143</td>
</tr>
<tr>
<td>c. No. of farm households</td>
<td>627</td>
</tr>
</tbody>
</table>

Note: a. Songa, Kituruni and Karare are in the southern part of the mountain and Badassa is in the eastern part. Kalacha is in the lowlands.

Source: MDARs, various years

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19 At the time of construction, 1954-56, each tank had a capacity of 75,700 litres (MDARs 1954, 1956).
20 These figures in the reports vary slightly because the actual irrigation profile in the district is yet to be fully assessed. Here we use the average of the estimated irrigation potential area.
Even today, these facilities still support micro-scale irrigation schemes on the mountain (MDAR 2001; see Table 15.2), benefiting some 590 farmers (7.1% per cent of the households) on the mountain, mostly on the south-western side. Over time, the initial structure and design of the system has not been expanded to accommodate a larger irrigation effort. The irrigation activities were, however, intensified in Songa and Badassa in the early 1990s, on the basis of the original design of the facilities (MDAR 1991).

Table 15.2 shows that some 7 per cent of the 693 ha, which could be irrigated, are under effective irrigation on the mountain and yet the irrigation potential in the region is estimated at 19 per cent of the total arable land. The area under irrigation remained at nearly 50 ha over the 5-year period. The mountain evidently accounts for a nontrivial share of the district’s irrigation potential.

There is also an imbalance between mountain areas which are suitable for irrigated agriculture, both with regard to the area under irrigation and the irrigation potential. Of the irrigated area (50 ha) and the irrigation potential (135 ha), about 80 and 78 per cent respectively are on the south-western side of the mountain. The rest, of which 20 per cent is in use and 22 per cent could potentially be used, are found on the eastern side (MDAR 2001). This suggests that the south-western side is an area of considerable irrigation activity and also offers opportunities for future improvement.

The natural position of the forest affects the distribution and availability of forest-linked resources such as the potential for arable land, water and vegetation resources. The forest extends further down the south-eastern side (windward) of the mountain as shown by the 900 m altitudinal limit of vegetation cover (Synott 1979; Bake 1984). Moreover, the forest cover is denser on this side compared to other sides of the mountain (Synott 1979). Apparently the better water endowment and natural forest cover on the south-western side seem to correlate. This essentially confirms the fact that the forest has a watershed function. Thus, denser forest cover and a better endowment of water sources on the south-western flanks of the mountain lead to an increase in the irrigated area and enhance the possibilities for future expansion of irrigated areas on the south-western side.

The irregularity of resource availability clearly mirrors heterogeneities in farming and water endowments between the various ethnic groups that inhabit these zones. The water endowment gap across the areas of the mountain and the technological investment to facilitate access to improved piped water sources inadvertently prompt a regional inequality as regards access to resources. This imbalance is also demonstrated by the distributional disparity in water sources at local level and the improvement of water sources for irrigation and crop production using irrigation technology. However, the social benefits from present irrigation activities on the mountain and the future development of existing potential to the local consumers are likely to prevail over the observed disparity of the water resource endowment across the mountain zones. Thus, the farming activities supported by the forest confer wider benefits on the local economy as a whole, in addition to generating private income which benefits the individual farmers with irrigated plots.
Land cover and yields of main crops under irrigated agriculture

In recent years there has been increased recognition of the importance of irrigation on the mountain. Kale (sukuma wiki in Swahili), tomatoes and onions are the main horticultural crops grown under drip irrigation around Songa, Badassa and Kituruni. Irrigated agriculture is used to produce vegetables for the local market almost all year round (MDAR, 1997). This option therefore generates reliable opportunities for farming and is a source of rural income. In this subsection we use 6 years of data on land area (ha), production (output in tons/ha) (Table 15.3) and the yield value of the crops (Figure 15.1) under irrigated agriculture on the mountain to throw some light on irrigated farming. The data constitutes aggregates at market level.

Table 15.3
Land area and production of main vegetables grown under irrigation

<table>
<thead>
<tr>
<th>Year</th>
<th>Land area (ha)</th>
<th>Production (tons/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kale</td>
<td>1.8 44 48 60 70 60</td>
<td>2 20 20 20 10 6</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>12 10.2 6 12 16 11</td>
<td>2 2 2 12 18 14</td>
</tr>
<tr>
<td>Onions</td>
<td>8 6.5 6 7 9 6</td>
<td>5 4 3 9 12 10</td>
</tr>
<tr>
<td>Mean*</td>
<td>3</td>
<td>8.7 8.3 10.3 13.3 10</td>
</tr>
</tbody>
</table>

Note: a. * The mean values are averages of production for the three crops.
Source: Marsabit District Annual Reports, various years

As this table illustrates, the main horticultural crops registered a mean increase in acreage and yields of almost three times over the 6-year period. However, the area coverage and yields of the individual crop vary over the years.

- Kale

Between 1996 and 2000, the land area used for kale increased moderately. The expansion of the area used for kale led to kale production increasing significantly from 2 tons/ha in 1995 to

21 In 1978, for example, 20 settled families in Songa grew chillies and earned Ksh. 12,000 using the irrigation system (piped water).
22 Some fruits (e.g. oranges, avocados, passion fruit and paw paws) and crops like capsicum, spinach, coriander and brinjals are also grown but these crops are grown on a relatively small scale and are produced in limited quantities.
23 Long-term data that would allow an investigation into household level welfare changes of the irrigated agriculture is rarely available. No data is available for other years, although the records do sometimes contain remarks about these crops without giving data.
24 Other vegetables grown using irrigation are carrots, cabbage and crops like pepper (chillies). Some irrigation is carried out at Kalacha, on the fringe of Chalbi Desert, using oasis springs (Table 15.2). Kalacha is over 100 km North-west of Marsabit Town and we assume that crops produced there are not sold at the Marsabit Market.
25 Arable production and production activities in general require a wide range of factor inputs, in varying proportions. These may, for example, also include qualities of other natural factors such as soil types, physical capital and labour factor inputs. We have adopted these factors as given.
26 The local strain of kale grown on the mountain is Bondo (sukuma wiki, which literally means 'push the week' in Swahili)
20 tons/ha in 1996-98. However, production dropped from 10 tons/ha in 1999 to 6 tons/ha in 2000. The fall in kale output in 1999 was due to the after-effects of El Niño rains (1997/98), which caused crop destruction, damage to piping systems, water logging and a high incidence of pests (especially Diamond black moth) and diseases (MDAR 1998: 19). Similarly, an outbreak of leaf-eating caterpillars in the early part of 2000 adversely affected overall kale production by 40 per cent per ha.

- Tomatoes
The total area planted with tomatoes is roughly 11 ha. Tomato production remained low during the first three years and rose nearly five times during the latter three years. In 1999, the production of tomatoes increased. However, its yields, both in the irrigation areas and around home gardens, would have been higher was it not for diseases such as mildews and blights that severely constrained its production (MDAR 1999). In 1999, farmers from the irrigation scheme produced sufficient amounts of tomatoes (about 288 tons) to meet the local demand in Marsabit town (ibid.).

- Onions
The area planted with onions remained low at less than 10 ha throughout the period. Onion production is concentrated around the irrigated areas only (MDAR 1998). In 1998, farmers expanded their production of onions substantially from 18 tons to 63 tons, but over 80 per cent of the crop consumed was imported from Meru District (MDAR 1999).

**Figure 15.1**
Trends of marketed-value of the main crops under irrigated agriculture

Water shortages and diseases are the main factors hampering the production of horticultural crops. Specifically, poor rainfall causes lower water levels in the irrigated areas. In 2000, for example, the rainfall on the mountain fell to only half of the normal mean of about 800 mm. Water shortages attributed to this partial rainfall failure resulted in a drop in
tomato and onion production and in rain-fed kale production as well by about 30 per cent (MDAR 2000). Moreover, while onion production decreased because of thrips infestation, tomato production faced the problem of excessive dampness in the nursery around the irrigated area (ibid). This problem reduced tomato seedling production by at least 20 per cent.

**Marketed value of the main crops under irrigation**

Figure 15.1 depicts the marketed value (Ksh/tons) of the main horticultural crops under irrigated agriculture.

As this figure shows, the mean market value of the crops declined significantly. The increase in yields and fall in prices (overall market value) of the crops follow the law of demand. As production increases, the price per unit of an output falls and this forces the aggregate marketed value of the output to fall as well. Inherent in the declining trend in price levels is the general welfare gains to the local consumer resulting from a fall in prices.

Compensated variation (CV) is the standard practice for measuring welfare changes based on the demand function; either net loss due to increase or gain caused by a fall in prices (Hicks 1941; Freeman 1993). The approach would measure money income that accrues to a local consumer following a fall in the price of horticultural crops, which are largely produced under micro-irrigation. This unfortunately cannot be ascertained from these data at the household level. From production and price levels it is possible to derive an arc-elasticity of supply estimate for each crop at the aggregate (market) level (Bittermann 1934; Allen and Lerner 1934; Vaughan 1988; Slesnick 1998). The notion of arc-elasticity ($\eta_s$) between the quantity and price is:

$$\eta_s = \frac{dx}{x} / \frac{dy}{y},$$

which approximates the supply elasticity with changes in price and the quantity of output.27

The arc-elasticity of supply using the output-price data of the irrigated crops is 0.21 for kale (inelastic supply - concave upwards), 1.23 for tomatoes (elastic supply - concave downward) and 0.10 for onions (inelastic supply - concave upward). When the supply is elastic, *ceteris paribus*, a unit increase in price is associated with a more proportionate increase in the output and a reduction in total expenditure. Similarly, when the supply is inelastic, a percentage change in quantity of output is less than the percentage change in price and a rise in expenditure. Also, a simple output function over time indicates that a marginally higher relative increase in production per ha is on average associated with a lower relative decrease in price.28 Put another way, a slight improvement in the local production of the crops will cause a considerable fall in the local market prices at the margin. From a consumer’s point of view, there is therefore strong evidence to support the promotion of the agricultural yields

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27 Bittermann (1934) explains the distinction between slope (gradient - relative change) of the supply curve and the elasticity of supply. The two measures are similar when dealing with linear relations and arc-elasticity measure is more reliable than the ordinary coefficient of elasticity (ibid: 429). In theory, where the concern is to know how much production will change as a result of a given price change it is more significant to know the proportionate or relative changes.

28 Alternatively, for specific crops a relatively high fall in price is associated with an increase in kale production relative to the other two. This result is obtained from fitted slope of averages production and marketed value of the crops (see Table 15.3 and Figure 15.1). This estimation ignores various other intervening disturbances such as diseases and change in consumer choice and there is no way of telling the nature of production costs from the derived elasticity measures.
from irrigated fields and improve the welfare of the local consumers. This provides a convincing connection between forest services and human welfare.

However, the net social gain from irrigated agriculture ultimately depends partly on the gap between the levels of change in output, the increase in price and marginal price rise of variable farm inputs\(^{29}\) such as pesticides, and partly on the effect of that gap on output. The measure of arc-elasticity, although inconclusive for all the three crops, points to an important public policy concern insofar as the expected welfare changes from irrigation efforts ultimately affect agricultural policy of food security and the well-being of the local population.

Relationship between irrigated crops prices and rainfall

Arable cultivation on the mountain depends mostly on rainfall levels. In light of the influence of forest-rainfall interactions, sufficient rainfall would be expected, on average, to improve crop yields of rain-fed agriculture and, in turn, lower output prices. Hence the question arises: How do market prices of the irrigated crops relate to the amount of rainfall? Based on the bi-modal rainfall pattern on the mountain, Figure 15.2 depicts bi-modal rainfall and prices of horticultural crops. The yearly post-scripts represent whether a given rainfall or a crop price is during the long (-1) or short (-2) rain period. The prices are measured on the primary \(y\)-axis (left) and the rainfall on the secondary \(y\)-axis (right).

Figure 15.2
Bi-annual prices of horticultural crops and rainfall pattern compared

<table>
<thead>
<tr>
<th>Year</th>
<th>93</th>
<th>96-1</th>
<th>96-2</th>
<th>97-1</th>
<th>97-2</th>
<th>98-1</th>
<th>98-2</th>
<th>99-1</th>
<th>99-2</th>
<th>00-1</th>
<th>00-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price (Ksh.)</td>
<td>0</td>
<td>200</td>
<td>400</td>
<td>600</td>
<td>800</td>
<td>1000</td>
<td>1200</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


There is a clear systematic and lagged negative correspondence between commodity prices and the bi-annual amount of rainfall, especially for onions and tomatoes. The figure also reveals evidence of seasonality in prices, as in the rainfall. Tomato and onion prices show wide fluctuations in the course of time and their prices seem to follow lagged rainfall amounts. Tomato and onion prices were high during 1998 because of the heavy El Niño rains

\(^{29}\) For example, seed input prices were Ksh. 4,800 for onions and Ksh. 7,000 for tomatoes per kg, while pesticides used for kale cost Ksh. 400 for 200 ml of Karate (a type of pesticide).
and during 2000 because of low local production due to disease. In both cases, the crops were imported from districts like Meru and Isiolo to supplement local demand and prices were inflated due to transport charges. The prices were forced down again once the local production picked up. Kale prices mostly do not follow rainfall trends and are subject to minor dips and peaks, except in 1996 when there was a short rainy season and in 2001 when the rainy season was much too short for sufficient crop production, as a result of which yields were low and prices increased. Kale is mainly produced locally applying irrigation, particularly at Songa, Kiturni and Badassa.

The market prices of the crops are determined daily by the interplay of forces of demand and supply. Tomato and onion prices are much higher, between 5 to 10 times that of kale. In general, local kale production accounts for about 5 per cent of the total volume of vegetables at the local market (MDAR 1998). The fact that they are mainly produced locally keeps kale prices fairly stable on the local market during most seasons. The relatively high prices of kale in 1996 (about Ksh. 30) and in the first-half of 2000 (Ksh. 20) correspond to their low acreage in those seasons. Owing to the heavy El Niño rains at the beginning of 1998, kale was scarce on the local market and that pushed prices up, although the price stabilised in the second quarter of the year. At the local market kale is normally sold at an affordable price of between Ksh. 10 and 20 per bunch (5 to 8 leaves). The low kale price favours the low purchasing power due to low income of the rural household and kale can also be served with a variety of dishes, whereas onions and tomatoes are basically additional vegetables. The marketing of kale involves many small-scale producers and middlemen. The marketing chain creates beneficial trade effects for rural farmers and traders. An increase in local production of irrigated agriculture improves the welfare of rural farmers as well as of local consumers.

Local economic gains from irrigated agriculture

The irrigation activities contribute to, and stabilise, the income of the individual farmers and evidently improve the welfare of the local consumers through the lowering of the consumer prices of horticultural crops grown on the mountain under irrigation compared to a situation in which there is no irrigation. Irrigation agriculture involves high labour input but little effect on the mountain ecology in terms of reducing the vegetation cover. Promoting irrigation on the mountain can therefore be a good idea. The local demand for horticultural crops notably outstrips the supply of local produce (MDAR 1998) and when production is low on the mountain high local demand ensures high prices for traders. In response, grocery traders normally bridge the needs of a demanding local market through imports brought in from other districts. A low local horticultural production creates a demand-supply shortfall and also necessitates importations from outside the district to supplement local demand. This move potentially lowers and stabilises prices, but maintains prices at a relatively high level to cater for the transport costs reflected in the local prices (MDAR 1996: 14; MDAR 1998). Evidence

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30 One important indicator of the ecological stress and the health of the water catchment areas are temporal changes in water levels in the waterholes. The colonial government used water bailiffs to measure water levels on major water sources and adjusted measures on water controls correspondingly. These measures were done away with after independence, but today there is greater need for such measures in the light of the increasing population on the mountain.
already indicates that increases in local irrigation initiatives reduce the volume of imports and also lower local market prices thanks to cuts in transport costs:

1. In 1998, the increased production of tomatoes by the local farmers reduced imports of tomatoes from outside the district by up to 60 per cent and forced down the relative prices considerably (from Ksh. 100 to only Ksh. 30) at the local market (MDAR 1998: 19).

2. In 2001, the volume of tomatoes imported dropped by 50 per cent, and no kale was imported because it was available on the market from local sources (MDAR 2001). The increase in kale production led to a 50 per cent drop in the volume of imported cabbages, which are a substitute for kale. Additionally, although onions were largely imported, the volume of imports decreased by 25 per cent owing to increased local production (ibid.).

The level of imports and fluctuations in local prices are partly a consequence of poorly irrigated agricultural production. The positive effects of irrigated agricultural production are spread between stable income to the rural farmers and benefits to local consumers as improved local production forced market prices down. This suggests that there are significant economic benefits and substantial welfare improvements to be gained from the future expansion of irrigated agriculture on the mountain. Moreover, the irrigation water also supplies other activities and offers broad benefits to the rural households and the local economy. Irrigation enables the development of agroforestry tree seedlings\footnote{31}, the propagation of fruit trees\footnote{32} and more recently the planting of miraa (khat) trees as a cash crop (see Chapter 12). Successful adoptions of agroforestry trees might provide woodlots that may ease the demand for natural forest products.

An increase in irrigated agriculture and associated yields generates micro-level economic gains to the income of rural farmers, who gain whenever output is increased. Irrigation directly supports at least 570 farm households on the mountain (MDAR 2000: 22), comprising 120 farm households in Badassa and Kituruni each, 290 in Songa and 40 in Karare (see Table 15.2). These villages enjoy production privileges outside the normally expected crop seasons which benefit subsistence as well as cash crop production. The irrigation opportunity shields households against frequent risks of crop failure induced by inadequate rains and poor rainfall distribution. By way of an illustration, the production of horticultural crops with irrigation water was less seriously affected during the severe drought of 1984 compared to other crops (MDAR 1984: 9). Again, in 1996 and 1997 when the production of the main food crops totally failed, the irrigated produce still realised some output (Table 15.3). Irrigated agriculture and related farming proceeds stabilise production shocks produced by variations in rainfall. The capacity of irrigated farming to reduce (prevalent) production risks and lessen income variability is a priority concern for the rural household. Improving the agricultural capacity of the mountain will certainly reduce the

\footnote{31}{The most effective tree nursery is at Songa where fruit tree seedlings are sold at a price of between Ksh. 10 and 40/piece (MDAR 2000).}

\footnote{32}{Fruit trees such as mangoes, bananas, pawpaw and citrus are grown on the mountain, both through irrigation and also outside irrigated farming (see MDARs 1978, 1997 & 1999). Fruit production is seasonal and during peak production periods prices often plummet considerably (ibid). This production is not necessarily linked to irrigation, but may be directly linked to the rainfall.}
widespread absolute poverty that currently affects over 80 per cent of the district’s residents (MDAR 2001).

Factors limiting the expansion of and proceeds from irrigated agriculture
Several factors, in combination, influence local market prices (or marketed value) of crops and hamper the realisation of potential crop yields under irrigation. First, the variability of production conditions related to rainfall variability and outbreak of diseases are likely to impact on yields (and prices), as was the case in 1997. On the one hand, while shortage of water especially in the areas outside the irrigated fields caused a reduction in the local production of horticultural crops on the mountain, the high costs of pesticides continue to be a major constraint to the production of horticultural crops. Secondly, damage to irrigation pipes by wildlife is a constant cause for concern with regard to the production of horticultural crops (MDAR 2000) and water losses. This renders the system non-functional. Thirdly, in the event that the produce is imported, infrastructure conditions affect relative prices due to changes in transport charges. The relatively lower value of the crops in 1999 compared to 1998 is a case in point since it was then that the roads were in poor condition due to heavy El Niño rains (MDAR 1999).

The farmers on upland forest slopes have better water supplies than those downstream. These water supplies were constructed for irrigated agriculture (MDAR 2001) and by no means favour farmers downstream. This represents a typical unidirectional externality problem as regards the allocation of irrigation waters (Dasgupta & Mäler 1996) and has explicit implications for the equitable distribution of irrigation water.

The improvement of irrigation potential primarily entails the expansion of the capacity of the water sources. Concerted efforts to make more effective use of the existing irrigation potential are hindered by: (i) limited permanent water supply and (ii) lack of investment funds (MDAR 1997: 27). At village level, water is allocated and managed by the water users’ association of farmers. In this regard, leadership wrangles have been seen to affect effective operation of the schemes, particularly in Songa (ibid.). This scheme covers a larger area and a greater potential for irrigation compared to other schemes and interest in resources may be more contested.

Concluding remarks on forest-supported irrigated agriculture
The forest-related rainfall facilitates the arable potential of the mountain, contributes to economic production and sustains human welfare. The drip irrigation-based horticultural production (yields) is relatively reliable compared to the rain-fed one and also supports the local rural economy. However, Marsabit continues to be an importer of most of the horticultural crops, except for fruits (MDAR 1997). The present horticultural production trends indicate scope and promise a bright future for the expansion of irrigation activities. This indicates that the mountain may produce sufficient vegetables to meet the local demand. Perhaps targets to achieve best yields from irrigation would encourage sound land-use practices and alternatively push out production frontiers and engage more families in irrigation. To do so puts pressure on the promotion and expansion of at least the present irrigation potentials through financial commitment, which conforms to the recently proposed
Community Development Trust Fund, the CDTF (MDAR, 2000). Recognising that diseases, on occasions, adversely affect crop production, an urgent call has been made to institute precautionary measures targeted at minimising incidences and tightening measures to control diseases through, for example, integrated pest management strategies.

Water scarcity is repeatedly cited as a restraint to the expansion of irrigation activities. Yet there is no proof that water endowment impedes the expansion of irrigation potentials. Moreover, the current levels of crop production are attained with intensification efforts, based on the initial design of the irrigation facilities as they were developed in the 1950s. These facilities were then developed to reduce the pressure exerted by livestock herders and farmers on forest-based resources. These facilities were designed for domestic uses but not for the current irrigation purposes. A lack of investment funds is most likely a major obstacle to the expansion and increase of irrigated productions rather than the unavailability of water per se. The expansion of the irrigation potential would be dictated by an option to revamp and improve the yields of the system, which again requires financial commitment through public expenditure or even a public-private mix.

The discharge flow (production) of the springs and gravity flow of water used by the irrigation system are determined by environmental constraints. This flow crucially sets the maximum amount of water produced. The question of whether or not the environmental constraints could be relaxed remains the most important issue to be addressed. In addition, frequent droughts and poor access to water in the area emphasise the need for the efficient allocation and distribution of the available water. Moreover, ahead of the future expansion of irrigation agriculture, the perishable nature of the crops needs to borne in mind. This precaution may serve as a disincentive for expansion beyond local levels of consumption.

The drip irrigation productions indirectly depend on the forest ecosystem services, which underscores the indirect ecological-economic links in the forest ecosystem. The irrigation activities depend on the exploitation of springs in the interior of the forest reserve and the flow of the springs largely depends on forest ecosystem functions. The forest's watershed function therefore indirectly supports rural livelihoods, enabling irrigation activities and related production, thus contributing to human welfare particularly via comparatively stable crop yields. The links between hydrological functions of the forest and drip irrigation provide a powerful justification for forest conservation.

The forest’s indirect support of urban water supply

Water demand estimation, consumption and uses by type

The different users utilise water sources on the mountain in different ways. The various uses include livestock watering, uses by wildlife and domestic use by rural households and the urban population. There is hardly any data available on water production and the number of

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33 The Songa irrigation scheme is an example of such a CDTF project. The project was estimated to cost Ksh. 15,682,863 with the local community contributing 10.5% (i.e. Ksh. 1,649,500) of the total project budget (MDAR 1999).
users\(^{34}\) for most of the sources on the mountain. An exception is formed by the Bakuli (I and II) springs, which were specifically developed to satisfy the urban demand for water. These springs are located in the heart of the Marsabit Forest Reserve and are the main sources of water for Marsabit Town.

The Bakuli springs are operated and managed by the Ministry of Water Development (MoWD). This ministry has the mandate to develop water sources\(^{35}\) and provides public water utilities for Kenya as a whole. The springs are harnessed at the source with water being piped to reservoir tanks and then piped to serve the urban population. Water from the springs is produced, allocated and supplied by the ministry to various consumers (Table 15.4).

The table shows the demand for urban water of Marsabit Township (Central Division), operated by the MoWD and based on the Bakuli springs only. Total domestic water demand was estimated at 1,160 \(m^3\) of water per day based on the projected mountain population of 27,483 people in 1995 (55 per cent urban dwellers and 45 per cent rural-based). The rural villages on the mountain and their livestock herds use water sources (e.g. pools and shallow wells) other than the springs that supply the urban residents.

<table>
<thead>
<tr>
<th>Table 15.4</th>
<th>Water supply and water demand (in (m^3/day))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unit demand</td>
</tr>
<tr>
<td>Domestic demand</td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>--</td>
</tr>
<tr>
<td>High housing</td>
<td>0.20</td>
</tr>
<tr>
<td>Medium housing</td>
<td>0.10</td>
</tr>
<tr>
<td>Low housing</td>
<td>0.03</td>
</tr>
<tr>
<td>Rural</td>
<td>--</td>
</tr>
<tr>
<td>Kiosk</td>
<td>0.03</td>
</tr>
<tr>
<td>Intermediate</td>
<td>0.05</td>
</tr>
<tr>
<td>Other demand</td>
<td></td>
</tr>
<tr>
<td>Institutions</td>
<td></td>
</tr>
<tr>
<td>Schools</td>
<td>0.02</td>
</tr>
<tr>
<td>Public</td>
<td>4.40</td>
</tr>
<tr>
<td>Business enterprise</td>
<td>0.14</td>
</tr>
<tr>
<td>Livestock</td>
<td>0.02</td>
</tr>
<tr>
<td>Administration (offices)</td>
<td>0.08</td>
</tr>
<tr>
<td>Total demand</td>
<td></td>
</tr>
</tbody>
</table>


Whilst water availability is generally poor in many rural settings, water is also disproportionately allocated amongst urban users. The domestic water demand takes up the greatest share (about 71 per cent) of total water needs. The urban housing sector accounts for

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34 By 1997 there were eleven institutional water supplies in Central and Sagante Divisions (MoWR 1997: 8). The institutional water supplies are also fed by the same springs as Marsabit town and were examined in more detail in Chapter 8.

35 Prior to October 1973, this ministry existed as a department of water development under the Ministry of Environment and Natural Resources (MDAR 1974). In addition, almost twenty non-governmental agencies have developed water facilities and improved the availability of water resources in the district (Odero 1993: 22-3).
half of the overall water demand and over 70 per cent of the domestic water demand. The urban housing sector also accounts for slightly more than twice the water demand of the rural sector. Additionally, the springs serve 9,180 livestock representing a water demand of 199 m$^3$ per day, which accounts for about 41 per cent of the other water demand (12 per cent of the total water demand). The livestock population served by the urban water supply alone is roughly the 10,000 livestock limit prescribed by the colonial government in the 1950s as the maximum sustainable population that the forest ecosystem could ably support through grazing concessions during the dry season. Public institutions such as schools, prisons etc. have a total water demand of about 190 m$^3$ per day and business enterprises and government offices together have a demand of 91 m$^3$ of water per day.

*Water produced and production costs for Marsabit town*

The problem of water scarcity, either structural or temporal, has existed for a long time. As early as in the 1930s and 1940s, water rationing was used when the water supply to Marsabit Town dropped$^{36}$ and until the water situation returned to normal (MDAR 1959). At the time, the town had only about 2,000 inhabitants. The limited availability and scarcity of water on the mountain posed particular problems at all levels of demand: for livestock, domestic consumption, arable farming, public utility or enterprises such as hotels, butcheries, hospitals and schools.

We obtained data on the volume of water produced, the revenue earned and the costs of water generated from the MoWD from 1970 to 2001. Figure 15.3 displays the annual water production from the Bakuli (I & II) springs$^{37}$ compared with the trend line of the annual rainfall for Marsabit Meteorological station. Water is taken from the springs, pumped out of the forest for 10 and 12 hours during dry and wet seasons respectively (MDAR 1995). The volume of water produced increased by an annual rate of about 6 per cent between 1977 and 1989. The annual water produced dropped considerably from 15,571 m$^3$ in 1991 to 8,318 m$^3$ in 1996. The daily water demand by the population served by the urban water supply was estimated at about 2,500 m$^3$/day by 1997, whereas the daily water production stood at only 300 m$^3$/day (Ministry of Water Resources 1997), thereby accounting for only 12 per cent of the total daily water demand. As these figures show, there is a clear contrast between increased water production from within the forest reserve during the later years and a declining trend in the annual rainfall on the mountain. The annual rainfall accounts for only 3.6 per cent, 5.9 per cent and 6.0 per cent of the water produced on a year-to-year basis, a period of one-year lag and periods of up to two year-lags respectively (t-values of (-) 0.921, (+) 1.169 and (-) 1.15). These t-values are not statistically significant. A close inspection of the trends shows opposing relationships between water production and annual rainfall and this is an important indicator of the capacity of the forested area to ‘reserve’ rainwater for future abstraction and uses.

$^{36}$ The supply of water to the township dropped to only 2,198 litres daily from approximately 4,396 litres per day (MDAR 1958: 42).

$^{37}$ Bakuli I was established in 1970, located at about 7 km south-west of Marsabit Town, about 3 km north-east of L. Paradise, at an elevation of 1,330 a.s.l. (GoK 1995).
Marsabit town is from time to time faced with chronic water shortages. This problem partly persists because of the rapid population growth\textsuperscript{38} of the town and partly because of the weak provisional ability of the public sector to improve access to water (see the assessment below). This in turn is partly due to the fact that water is produced using the facilities developed in the 1970s which were designed for a much smaller population (MDAR 1991). As a result, water rationing is commonly used to allocate the amount of water produced. The rationing system uses zoning, whereby the water distribution lines are clustered into zones.

\textsuperscript{38} The Central Division of the mountain had a total of 6,945 households in 1989 (30,685 people) and 8,344 households by 1999 (37,445 people). The mountain had a continuous annual growth rate of about 6 per cent between 1969 (6,635 people) and 1999.
and thereafter one or more zones are scheduled to receive water on certain days. Essentially each zone receives water twice a week and the system is out of service most of the time. The rationing scheme rarely works effectively. Priority distribution lines such as hospital and prison may request water outside their rationing schedule and thereby upset the planned rationing system. In addition to the weaknesses in water provision, the variable costs of water abstraction and production are normally high. The high cost of water production is partly due to an increase in the price of diesel used to generate water (MDAR 1991).

The high cost of water production has been a nationwide concern. In this regard, the government proposed measures, in the economic reform paper of 1996, for implementing a water policy which involved charging urban consumers water tariffs sufficient to cover capital repayments and operation and maintenance costs as stated in the water-sector policy reform (GoK/IMF 1996: 29-30). In addition, the government regarded the low water cost recovery as a primary factor that contributed to the inadequate maintenance of the country's water supply schemes (many of which were in poor condition) (GoK/IMF 1996: 29). The low cost recovery also gave rise to financially weak water agencies, including the line ministry. Having realised this, the government made investments in the rehabilitation of the main sources of urban water supply. More specifically, this entailed electrification (i.e. electric motor-powered pumping) of the supply intakes (Bakuli I and II) and the construction of rising mains (6" pipe) from the source to treatment works. In addition, a 600 m$^3$/day composite filtration unit and a 225 m$^3$ storage tank were revamped in 1993 to improve urban water supply (MDAR 1991: 53). Much of the increase in the volume of water produced after 1997 corresponds to the installation of electric power to generate water supply during 1991/96 period, following the government's capital investment (Figure 15.3). The recent increase in water production, owing to technological innovation, contrasts sharply with the earlier view of the colonial government which had also warned that dwindling water supplies would cause local tribesmen to start using forest resources at an alarming rate. The small town of Marsabit then hardly had 4,000 inhabitants while today the town is home to well over 17,000 people. Moreover, the mean daily urban water production prior to 1997 (mean production of about 40 m$^3$/day) and after 1997 (mean of about 217 m$^3$/day) (Figure 15.3) were both still well below the potential yield estimates based on discharge flow rates (see Table 15.1, Bakuli I and II) – the pooled mean of 1,780 m$^3$ of water per day. The improved water production in the face of variable annual rainfall and a downward trend in the amount of annual rainfall demonstrate, in particular, the reserve capacity of the forest ecosystem. This may also indicate that past limited provision of water supply on the mountain has been largely due to a lack of capital investment.

In particular, water produced between the periods increased by almost 30 per cent. According to the 1989 and 1999 Census reports, the mountain supported about 33 and 31 per

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39 To encourage the economic consumption of electricity, the policy paper anticipated an increase in tariffs to cover long-run marginal costs (LRMC). As a short-term measure, tariffs would be increased to cover 75 per cent of the LRMC by 1996 (GoK/IMF 1996: 31)

40 This project was financed in Marsabit District at a cost of Ksh. 187,800 through the MoWD between 1991 and 1993 (MDAR 1991). This expenditure represented about 46 per cent of the total district's allocation for the fiscal years 1991/92 (GoK 1991: 29).
cent respectively of the total districts' populations. According to the same censuses, Marsabit Township accounted for 49.5 and 47.4 per cent of the mountain population in 1989 and 1999 respectively (GoK 1994a,b, 2001). Again using the shares in town population, the township population is equivalent to about 11,223.2 and 13,784.9 Adult Equivalent Units (AEUs) respectively. Furthermore, according to WHO/UNICEF (2000), an individual requires about 20 litres of water per day (or equivalently 0.02 m$^3$/day or 7,300 litres of water annually). Thus, during the census years, the town population had a total water demand of 81,929.4 and 100,629.8 m$^3$ litres of water per annum in AEU (see Table 15.5), which by far surpasses the average annual volume of water produced for urban water supplies. On this note, the differences between the water needs and production on the mountain are an indication of the lack of water, defined as a condition in which annual water availability is 1,000 m$^3$ or less per person (Hinrichsen & Tacio 2002: 5-8). On the basis of our conservative estimates of the water production-population nexus, there is plenty of water unaccounted for which is neither available for the generation of revenue nor for human consumption. Thus, the main problem concerns incentive policies that will encourage a better use of water and we advocate a more efficient use of available water resources. In this regard, there is an urgent need for further investigation in order to pinpoint sources of inherent inefficiencies in the urban water production and appropriation in the light of chronic water scarcity on the mountain.

The production economics for urban water supply

During the economic policy reform of 1996, the Kenyan Government stated that it would make water services economically efficient and also pay for the costs of capital investment. This decision in part revoked the electrification of urban water supply. The main contextual argument with regard to water service is that improving the fiscal position of water agencies brings increased efficiency through capital investments in accordance with the economic profitability of water services. In this regard, water charges per unit of consumption increased progressively over the last decade. Considering the essential nature of water resources, any

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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit consumption charge per month* (in Ksh.)</td>
<td>21.5</td>
<td>35.5</td>
<td>60</td>
<td>65.5</td>
<td>90</td>
<td>120</td>
<td>160</td>
<td>200</td>
</tr>
<tr>
<td>Constant rate of change in unit water charges/ month (%)</td>
<td>4.18</td>
<td>2.19</td>
<td>0.73</td>
<td>3.16</td>
<td>1.50</td>
<td>2.40</td>
<td>0.93</td>
<td></td>
</tr>
</tbody>
</table>

Note: * Water charges are based on water sold through individual metered connections. Water consumption that does not exceed 10 m$^3$ was charged above these rates each month. For additional amounts other water tariffs apply (see Kenya Gazette)

Source: Kenya Gazette Supplements, various years.
increase in the costs of water produced and tariffs by concerned institutions inevitably leads to higher water bills while production costs are passed on to the consumers.

Table 15.5 shows the average annual figures of the main variables in the production of water for Marsabit Town (see also Table 15.3). The table also compares the volume of water produced, revenue earned and the costs of the water production *ex ante* and *ex post* the government economic reform.

These values relate, either directly or indirectly, to the economic production of the urban water supply. The annual rainfall is not directly 'coupled with' the water produced (on a year-to-year basis) but does affect it in the long run. The negative change in the annual rainfall reveals little in terms of the fluctuations in water produced, but we alluded to a similar decline in the rainfall earlier.

This table shows that there are relative increases in the water produced, the potential revenue earned and all the costs associated with the production of urban water supplies between the two periods. Comparatively, the volume of water produced and sundry cost show a moderate rise following the economic policy reform measures. The most striking rise in the *ex post* rehabilitation investment is evident in the cost of fuel (electricity) consumption (over 300 per cent) and an even higher rise in the revenue of water generated ~ well over 400 per cent. The cost of chemicals used, such as chloride for water treatment, rose almost twice as much as the increase in the water produced in the *ex post* rehabilitation period. This increase might reflect the improved treatment of water, although this is inconclusive since the amount of chemicals used for treating water produced is uncertain.

**Table 15.5**

Average parameter value of urban water production, 1977 - 2001

<table>
<thead>
<tr>
<th>Name of the variable</th>
<th>1977 - 1992 Average</th>
<th>1993 - 2001 Average</th>
<th>Relative change (%)</th>
<th>Share of total cost (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual rainfall[a]</td>
<td>780.38</td>
<td>684.68</td>
<td>(-) 12.3</td>
<td>--</td>
</tr>
<tr>
<td>Vol. of water produced[b]</td>
<td>7,247.20</td>
<td>9,276.47</td>
<td>(+) 28.0</td>
<td>--</td>
</tr>
<tr>
<td>Water revenue generated[c]</td>
<td>14,824.30</td>
<td>84,556.56</td>
<td>(+) 470.4</td>
<td>--</td>
</tr>
<tr>
<td>Cost of fuel consumption[c]</td>
<td>20,928.31</td>
<td>84,876.96</td>
<td>(+) 305.6</td>
<td>48.6</td>
</tr>
<tr>
<td>Labour cost (salaries)[d]</td>
<td>9,136.80</td>
<td>26,232.80</td>
<td>(+) 187.1</td>
<td>21.2</td>
</tr>
<tr>
<td>Sundry cost[c]</td>
<td>10,676.13</td>
<td>12,441.71</td>
<td>(+) 16.5</td>
<td>24.8</td>
</tr>
<tr>
<td>Cost of chemicals used[c]</td>
<td>2,364.84</td>
<td>3,636.09</td>
<td>(+) 53.8</td>
<td>5.5</td>
</tr>
<tr>
<td>Total cost</td>
<td>43,106.08</td>
<td>124,422.70</td>
<td>(+) 188.6</td>
<td>--</td>
</tr>
<tr>
<td>Unit production cost</td>
<td>5.95</td>
<td>13.41</td>
<td>(+) 125.4</td>
<td>--</td>
</tr>
<tr>
<td>Unit price of water</td>
<td>2.05</td>
<td>9.12</td>
<td>(+) 344.9</td>
<td>--</td>
</tr>
</tbody>
</table>

Notes:

a. Mean annual rainfall measured in mm.

b. Water produced in cubic metres (m³) per month.

c. Water revenue, labour-cost and sundry (or miscellaneous) cost in Kenya shillings (Ksh. for brevity) per month.


As shown in the table, much of the accrued water revenues are realised by a relatively low rise in costs of chemicals and other miscellaneous (sundry) costs (compare columns 5 and 6), although the returns are hampered to some extent by a disproportionate rise of the electricity bill on the cost side of water production. The main costs of water production include chlorine,
soda ash, aluminium, lubricant and diesel (or electricity) consumption and high overhead costs such as administration costs and the costs of transportation to the water sources site in the forest. Furthermore, it is apparent that the observed revenue gains can mainly be explained by the substantial increase in the unit price of water rather than by relative changes in the total and unit production costs. This demonstrates in explicit terms the soaring charges per unit of water used, independent of the costs of water production. However, in Chapter 10 we saw that the Kenyan shilling depreciated at an annual rate of 3.5 per cent against the strong foreign currencies (in particular the US dollar) during the last three decades. This would also indicate the effect of the Kenyan economic decline on the fate of water production cost and the decline in consumer purchasing power. Despite the drop in value of the Kenyan shilling, we still find a more proportionate rise per unit price of water, production costs and water revenue. Thus, the gain in water revenue is due to the rise in water charges (the demonstrated change in the unit price of water) and possibly the cost recovery through improved revenue collection, although not — it would seem — through the original intention based on the economic efficiency argument which was to cut down on operation and fuel costs. In other words, the increase in water revenue did not occur due to improved delivery of water services and more efficient operations of water abstraction. As Table 15.5 shows, the cost of fuel consumed in the water production is higher in the first and almost equal in the second period compared to the revenue generated. Instead, the rise in water revenue (i.e. water profits) is due to price increases. Moreover, despite the original idea being to downsize diesel-related production costs, the Marsabit Power Plant, which is the sole provider of electricity for use in water production, is diesel-driven. As a consequence, the electricity-related cost of fuel used in water production is still subject to diesel price increases through electricity charges, which in turn depend on the unit cost of diesel and the cost of crude oil on the world market. The high costs of water production prevent economically efficient gains as anticipated in the policy reform and stretch the payback period of the capital investment. The recent progressive changes in rural water tariffs also put the burden on the consumers as their purchasing power declines with the downward inflationary spiral of the shilling, as well as the economic downturn of the Kenyan economy.

The performance of the public provision of piped water supply

The provision of and access to water are among the global commitments to improve the quality of human life (UNCED 1992). Several indicators are used to measure provision performance of services such as water (see WHO/UNICEF 2000: 39). Limited data did not allow an in-depth investigation and we only attempted to make an assessment of the public provision of urban water supply for Marsabit town. The average raw water production in the urban water supply based on 1993 (Aug.-Dec.) was estimated at 5,521 m$^3$ per month and at 7,797.5 m$^3$ for February 1994 (GoK 1995). Although the latter figure shows an increase in the water produced, the latter level of water production only met about 14 per cent of the total water demand by the targeted urban population (ibid.).

Generally, water is either piped to metered individual connections$^{45}$ or through communal water kiosks. More specifically, water is delivered through three main outlets: (i) metered individual connections (private); (ii) public institutions (e.g. schools, hospital, prison etc); and

$^{45}$ The metered individual connections refer to the number of households connected to a piped water source.
(iii) communal water points or water kiosks, which are usually metered. The communal water kiosks are located around the town and water is sold directly to the consumers on a spot payment basis. In the case of (i) and (ii), payments for water consumed would normally be settled on a monthly basis. Institutional consumption units such as schools and service industries (e.g. hotels) cater for many water users. These units show a different demand schedule compared to the metered individual connections. The differentiated characteristics of water consumption units undermine an effective evaluation of progress in the public provision of water in relation to the town population. Presumably, provision or an improvement in access to water services may non-linearly relate to the number of households.

In the literature, improved access to water sources is represented as a percentage of total population with access. According to the WHO/UNICEF (2000: 4):

“access to an improved water source is defined as the percentage of the population with reasonable access to an adequate amount of water from an improved source46, such as a household’s connection, public stand-pipe, borehole, protected well or spring, and rainwater collection. Additionally, reasonable access is defined as the availability of at least 20 litres a person a day from a source within one kilometre of the dwelling.”

In this respect, the urban water supply of Marsabit Town served 150 individual metered connections and three communal public kiosks47 in 1974 (MDAR 1974). Between 1974 and 1979 the town population increased from 7,591 to 9,000 people (MDAR 1979). In 1988, the urban water supply served a total of 25,000 people, including institutions (MDAR 1988). The water supply grows at a much slower rate than the rapid growth in demand over the years (MDAR 1991). Due to limited water supplies, particularly during prolonged dry seasons, consumption units are divided into zones and they are supposed to receive water twice a week. This suggests that the water supply is out of service for most days of the week. In 1997, the urban water supply served an estimated population of 28,000 people. This population was served through 800 metered connections, 37 flat rate connections and communal water kiosks (usually metered). Compared to the population numbers in 1979, the town population increased by more than three times in 1997 (MDAR 1997) since, which gives a constant annual population growth rate of about 6 per cent during the last two decades. The metered individual connections grew annually by 7 per cent. In 2000, about 12 per cent of the households were served by individual metered public connections, despite irregular water supplies. The metered individual connections increased at 8 per cent annually between 1997 and 2001, signifying an improved provision of water services in recent years.

**Inefficiency factors in water production and deliverance services**

The poor economic performance as regards water utility deliveries has to do with the low cost recovery. This problem is often indicated by an apparent mismatch between revenue earned and revenue collected from the water produced. To illustrate this, only 51 per cent of the revenue earned was collected per month in 1997 (MDAR 1997), indicating that water

46 Unimproved sources include vendors, tanker trucks and unprotected wells and springs (WHO/UNICEF, 2000).

47 By then, 2 kiosks were temporarily not operational and 14 individual meters were disconnected (MDAR 1974)
unaccounted for amounts to almost half of the potential economic returns on water produced. There is, overall, a moderately significant correlation (coeff. of 0.59, p<0.01) between revenue earned and revenue collected from the water generated. Such discrepancies arise due to individual consumers failing to submit water bills on time. The water meters are old and pipes are defective (42 per cent) and water is also lost through leakages caused by pipe bursts or damage by wildlife. Nevertheless, residents of Marsabit town suffer frequent water shortages. The discrepancy between revenue earned and revenue collected may arise owing to one of the following or combinations thereof:

1. Most of the individuals on metered connections are charged on the basis of average assessment. This system charges a low rate per unit of water used (MoWR 1997), which is comparable to the charges of individuals on the flat-rate metered connections;

2. Blockages in the water distribution network, meaning that water fails to reach the consumption units through the meters and

3. The disconnection of meters due to non-payment of charges for water used (MDAR 1974).

The problem of water shortages may partially be abated through rainwater-harvesting technologies and by making efficient use of the available water. We will come back to this at the end of this section.

A critique on the centrally-determined tariffs system

Water is typically a scarce resource on the mountain and access to water is severely limited, as is the case also in many other rural settings in sub-Saharan Africa (WHO/UNICEF 2000; Turton & Warner 2002). To put things in perspective, local people traditionally respond to water shortages by digging additional water holes (hand-dug wells) to cater for growth in water needs. In this regard, the numbers of borehole and hand-dug wells for livestock and rural household has increased tremendously in recent times, especially around the legally protected forest area, in order to make water available for growing human and livestock populations on the mountain. The creation of extra water holes is an option well placed within the traditional institution of expanding access rights to water resources.

At household level, travel time to the source and the labour effort (often regarded as free) are additional costs associated with water in many rural settings. The water-related concerns that many rural households have go beyond increases in water charges that are meant to improve economic viability and water quality. Often, women and girls cover great distances when hauling and delivering water to their homes. In the case of Marsabit Mountain, people spend an average of between five hours per week and one-hour each day searching and delivering water to their homes (Adano 1999). This labour input undoubtedly places a heavy burden of demand on female energy expenditure. Rural water usage is not priced using the conventional cash market method - by which prices are negotiated and determined through demand-supply relationship. Despite the constant water crisis, the regulation of water access rights by the local institutions lack mechanisms that allow users to appropriately adjust their access to water or their consumption behaviour in a way that is commensurate to the availability of water for various uses.

Onjala (2002: 6) also reports similar collection inefficiency for Eldoret and the National Water Conservation and Pipeline Cooperation.
These days, the water tariffs in Kenya are determined centrally at the organisation's headquarters; that is at national level. This way of determining tariffs assumes homogeneity in the characteristics of rural households, wealth levels and ability to pay. By determining charges the central authority also presupposes the existence of a uniform water demand and supply nation-wide. In other words, the nation-wide determination of resource charges assumes the existence of a large chunk of resource-user behaviour, which is undifferentiated as regards the demand for, and equally constrained in the supply of, resources. A similar process is also used to fix charges for forest products in Kenya. Yet, in practice, no uniform society exists upon which such resource fee decisions can be based.

In particular, the centrally-determined rural water tariffs have a tendency to price water and other environmental resources without taking any regard of the demand-supply relationship. Generally, such systems of determining charges are inflexible, involve lengthy procedures to alter and have prices that are not regularly adjusted to reflect the level of resource availability. One of the main setbacks as regards the centrally-determined resource fee is the distortions in market prices. Failing to reflect demand and supply conditions, they do not offer resource users the desired incentives to respond to market price signals and adjust their resource consumption to the resource availability. Even though the centrally fixed resource fees are determined with all the good intentions, in terms of demand and supply the centrally regulated system of resource charges does not correspond to the realities on the ground. Hence, the central system of fixing resource prices largely remains an inappropriate mechanism for setting resource prices and allocating resources.

A note on water access outside Marsabit Town and the potential of water-harvesting techniques

According to the 1989 and 1999 censuses, only about 13 per cent of the households in the district were served by piped water (GoK 1994c, 2001). According to the 1989 census, less than 1 per cent (0.8 per cent) of the rural households in Marsabit District, compared to about 59 per cent of the urban households, had a piped source of water (GoK 1994c: 46). The majority of rural households or consumption units on the mountain are not connected to the piped water system but depend on other water sources. By 2002, barely 3 per cent of the households on the mountain were connected to piped water system (MoWD, raw data), which is about 25 per cent of the urban households. However outside town there are some households (perhaps 570 households with irrigation in Badassa, Songa, Kituruni and Karare) that are connected to the piped water system (see Table 15.2). Besides households in these villages, some other households on the mountain in Sagante and Dirib are within a one km walk from a water source.

The average water consumption of a household on the mountain is estimated at 20-40 litres of water per day for an average family of six people (Adano 1999, see also Chapter 8). According to the WHO/UNICEF (2000), these levels of consumption are below general standards. Furthermore, water availability and use vary according to distance to water sources. For example, human water use in the district has been noted earlier as being 2-3 litres

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49 This level of water supply coverage is comparable to Kenya as whole, as well as many rural African countries but well below the mean coverage for Africa (see UNICEF/WHO 2000: 33 and 41-43 for details)
if the distance to the source is 15 km, between 3-6 litres in the case of 1 km and between 10-20 litres for a distance of a few meters from the water source per day (Lusigi 1983: 94). Thus, water consumption varies inversely to the distance to a water source. This also shows that water consumption among the rural households on the mountain is low but is still much higher compared to the rural household water consumption elsewhere or in the district as a whole.

The fact that the various consumption units, such as households, access water for domestic uses suggests the existence of inefficiencies and weaknesses in the distribution system of the water supply. The very limited water supply poses severe constraints at all levels of production. As we have seen in Chapter 8, the available water is used for watering livestock, irrigation, household consumption and other domestic needs, including the development of agroforestry trees. In our view, the main water problems are linked to allocation issues and thus the current water shortages on the mountain raise concerns about how best water resources can be distributed and allocated to the various consumption units.

An option at household level, would be to invest in water-harvesting structures such as roof catchments, rock catchments or water pans. However, the high initial capital investment, the prohibitive cost of inputs and the high maintenance costs – which are, at times, much higher than the costs of investing in a new source – seem to make this option unfeasible for the majority of low-income households (GoK/GTZ 1991). By 1999, a water tank with capacity of about 30,000 litres cost Ksh. 150,000 (own field notes). The total cost of a unit Ferro-cement water tank of 10,000 litres capacity (8 ft diameter) increased from about Ksh. 25,000 in the 1989/90 financial year to about Ksh. 32,000 in 1994/95 and about Ksh. 34,000 in the 1998/99 fiscal year (Marsabit Public Health Office 2000: raw data). The construction of such a tank requires specialised technical know-how and entails over 20 costing items, whose prices or charges increased to varying degrees over these periods. The lump sum money requirements for such water reservoirs are beyond the means of many urban and rural households that dearly need improved access to water. Moreover, constructing such a tank requires an iron-roofed, tile-roofed or a concrete house. Only one-fifth of the main dwelling units for the entire district comply with these requirements (GoK 2001b: 4-4). For the majority of the rural households with grass-thatched houses (48 per cent) and other lower-quality houses (42 per cent) (GoK 1994b) such a capital investment is a fortune and the application of the existing water-harvesting techniques is therefore not feasible. Furthermore, the potential of water harvesting approaches as a means to improve water supply is limited by climatic and other conditions such as unreliable rainfall, high evaporation rates and long dry periods that regularly develop into prolonged dry spells. In sum, the harnessing of water-harvesting technologies currently seems to be viable particularly in high altitude areas (like Mt Marsabit and Kulal) in the district and on locations on the mountain where irrigation is not possible and water-harvesting technologies have remained under-exploited. This option is a priority for the future development of water resources in relatively high rainfall areas.
Linking land-use change and water yield: a model and its policy implications

This section returns to the links between rainfall and land-use change with which the chapter started. It also relates rainfall and the land-use pattern to the support that the forest offers to the urban water production through its watershed function.

The conservation literature recognises that the conversion of forest to farmland is a significant factor driving tropical deforestation (Mahar 1989; Hyde et al. 1991; Barbier & Rauscher 1994; Geist & Lambin 2002). The concern about deforestation is based on the fact that the removal of vegetation cover encourages degradation and promotes loss of environmental values such as the watershed function (but also biodiversity conservation, climate regulation and soil protection, to name but a few).

The question raised in this section is whether a relationship exists between vegetation cover and the forest’s watershed functions. The question is whether there are links between water production to meet urban water demand and conservation of the mountain’s forest area. To address this question brings to the fore the link between water availability and forest-cover change. The main hypotheses and also the representation of arguments in this subsection are as follows:

1. The amount and variability of rainfall is the most critical factor input sustaining ecological services of the montane forest. This also holds for rangelands in the surrounding lowlands.
2. The extent of forested area and vegetation cover to some extent influences the amount of rainfall.
3. Water production (or availability) for both agricultural potential and agricultural production is a direct function of the rainfall and an indirect function of woody vegetation and forest cover on the mountain.

In relating these variables, this section seeks to address how human economic activity that is directly dependent on the cultivation of the land and thus the expansion of potentially arable land into ecologically fragile frontiers influences water production, which is indirectly supported by the watershed function of the forest ecosystem.

In spite of general acceptance of the different forest functions in government circles and despite agreements to conserve forests, Kenya’s indigenous forests have come under a serious threat of excision in recent years. The government forest excise decisions are not only contrary to one of the Forest Department’s objectives to identify potential forests for reservation and/or gazettement (but not de-gazettement) but also to national legislation. The government plan of excises is meeting with resistance. This indicates a lack of political will to conserve forests in the higher echelon of the government. Moreover, the decision was not taken with approval or in the general interest of the public. More importantly, one of the fundamental arguments against the government proposal concerns the forest’s support of rural

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50 A number of articles (see BBC News, 16 August 1999; Daily Nation, 25 February 2001; Opala 2001; 21 January 2002) and several discussions on the subject matter appeared in the media. Examples found between 1989 and September 2000 alone, involved a total of 1,394.6 acres that were hived from Karura Forest (Opala, Daily Nation 21 January 2002), which is a staggering 56% of the forest area. The government’s attempt was made public and became the focus of a public outcry, involving both environmentalists and civil society alike.
livelihoods which depend directly on the critical water catchment systems that forests protect. Besides the general understanding, there is currently no evidence on the linkages between forests and their support of hydrological functions in general, and Kenya in particular. The next section aims to contribute to the ongoing forest excision debate and also provides a solid basis for practical environmental policy in Kenya.

A model of land use-water yield linkages

Building on the recognition that forests provide a wide range of ecological services and that in particular the watershed protection function affects water supply on Marsabit Mountain, our aim here is primarily to investigate economic and ecological linkages on the mountain using time-series data on annual rainfall (see Figure 15.3b), volumes of water generated, the costs incurred on the production of urban water supply and the area of cultivated land over time in order to assess the arable land-rainfall interaction effect.

We expect, a priori, that interdependence exists between total costs and the production of urban water supplies and the expansion of arable land to the relatively drier areas, which indirectly depend on the ecological constraints and watershed conditions of the forest ecosystem. The environmental constraints to water production may be a combination of rainfall amount, forest cover (including woody vegetation as a buffer for the watershed function), the structure of subsurface rocks and the capacity of underground water aquifers. In terms of the parameter values, high rainfall levels and increased costs of water production are expected to be associated with better urban water yields. Hence they would positively influence the volume of water generated. On the other hand, the expansion of arable land on the mountain is likely to lead to a fragmentation of the mountain vegetation and would therefore be expected to reduce the buffer capacity of the forest ecosystem. In the long run, the clearance of vegetation cover and its conversion to arable land are likely to have negative feedback effects on the watershed function of the forest. The consequences of the interaction between rainfall and crop acreage on the urban water production would depend on the rate of expansion of the cropland and rainfall amounts. However, these variables may affect water production in lagged periods but are excluded from the final model because there influence is not significant.

One objective in the provision of urban water (albeit with little success) is to keep pace with population growth on the mountain and especially in the township. Thus, the change in human population over time is expected to have some influence on the volume of water produced. Based on information on changes in water production as a result of population increase and technological change in water production (both variable cost and capital investment) we investigate land use-water yield linkages using ordinary least squares (OLS) – and semi-log regression specification.51

Figure 15.3 above illustrates trends in the amount of water produced for the urban population since the mid-1970s. It shows exponential growth in water production as the

51 This form is analogous to models commonly used to study the problem of returns to schooling, where the semi-log functional form is typically employed (Light 2001; Allen 2001). The linear specification has been tried and this form leads to highly inaccurate estimates. White’s general test reveals the presence of heteroscedasticity in this original regression relationship (see Kmenta 1986; Greene 1993). In the presence of structural change, a Chow test would have been appropriate but the limited data set after the change is insufficient for this test to be performed.
underlying trend. The water function relates the water produced (Q) for the urban population to the total cost of water production (TC), annual rainfall lagged once (AR_{t-1}) and changes in the woody vegetation cover into arable farmland$^{52}$. The total cost of water production is a measure of the value of inputs in the process, while the dummy (explained below) is a measure of a discrete investment in water infrastructure.

\[
(15.1) \quad \log(Q_t) = \beta_1 + \beta_2 AR_{t-1} + \beta_3 (AL_{t-1})^2 + \beta_4 TC_t + \beta_5 D_t + \epsilon_t
\]

Where:

- $\log(Q_t)$ = the volume of water produced at time $t$
- $AR_{t-1}$ = the annual rainfall for the mountain in year $t$, based on a year lag
- $(AL_{t-1})^2$ = the total cultivated land (ha) in year $t$, based on a lag period of one-year
- $TC_t$ = the total costs of water produced during year $t$
- $D_t$ = a dummy variable, 1 if year is before 1993, and 0 otherwise

$\beta$ i's ($i=1, 2 \ldots 5$) are parameter estimates, $\beta_1$ a constant and $\epsilon_t$ an error term.

We investigate the relationship between the variables using an ordinary least squares regression model (OLS), in semi-log functional form. The result of the parameter estimates of the model are as shown below (Table 15.6).

| Table 15.6 |

OLS test for interdependence between urban water production, rainfall and crop acreage

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\beta$-estimates</th>
<th>t-statistics</th>
<th>P-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>7.875</td>
<td>36.504</td>
<td>0.000</td>
</tr>
<tr>
<td>$AR_{t-1}$</td>
<td>$4.490 \times 10^{-4}$</td>
<td>3.364</td>
<td>0.003</td>
</tr>
<tr>
<td>$(AL_{t-1})^2$</td>
<td>$-1.828 \times 10^{-5}$</td>
<td>-2.103</td>
<td>0.048</td>
</tr>
<tr>
<td>$TC_t$</td>
<td>$8.985 \times 10^{-4}$</td>
<td>6.29</td>
<td>0.000</td>
</tr>
<tr>
<td>$D_t$</td>
<td>0.447</td>
<td>3.210</td>
<td>0.004</td>
</tr>
<tr>
<td>Other statistics:</td>
<td>$R^2 = 0.727$, Adjusted $R^2 = 0.672$</td>
<td>$RSS = 0.2287$</td>
<td>Sample size = 24</td>
</tr>
</tbody>
</table>

Notes:

- The $\beta$'s are significant at the probability (P) levels specified.
- Source: Meteorological Station, Ministry of Water Development and MDARs, various years.

As shown in the table, all the explanatory variables have the expected sign. Moreover, the amount of annual rainfall and the total costs for the variable factor input in water production and financial capital investments all have a positive sign. In other words, these variables positively influence the (potential) amount of water that can be generated. In particular, capital investment and the total factor cost are very significant (as shown by p-values). The parameter estimate of arable land on the mountain has a negative sign and this is also significant (see t-statistics). The dummy variable is a discrete government investment in water infrastructure and it captures financial capital investment independent of the value of

An alternative way of using crop-cover change is to use a complementary variable: subtracting the crop area changes for each year from the total protected area on the mountain. The total protected area on the mountain is a constant variable and we obtain similar results when we use crop-cover area only, as above.
inputs in water production such as chemicals and salary costs. Direct capital investment in water enhances water abstraction rates and is thus a positive sign of the dummy variable.

The lagged variables, rainfall and cultivated arable land, are utilised to capture time delay in water production. In other words, water produced in the current year is a decreasing function of cultivated arable land (i.e. cultivated crop area squared) and rainfall in the previous year (t-1). From the model result, a unit increase in cultivated land area (in ha) in a given year might potentially decrease, other factors remaining constant, the amount of water produced (in m³) in the next year at a rate of 0.001828 per cent per year. This means that, on average, a marginal increase in the area of land cultivated in a year might be associated with a fall of 175.0 m³ in the water supply in the subsequent year (or every two years). Put another way, this shows that continued processes of human settlement and the subsequent expansion of arable land on the mountain might have adverse effects on the hydrological function of the forest in the long run. In monetary terms, we estimate the economic loss of water revenue associated with a unit increase of cultivated land on the mountain (which is equivalent to a decrease in forest habitat size) to be about Ksh. 35,000 every two years. In other words, the forested land (including vegetation cover outside the protected forested area) functions as a single ecosystem. Removal of the vegetation cover therefore indirectly affects ecosystem functions in the long-term through decreased watershed or hydrological services and has therefore a negative impact on the economics of water production. This finding reveals that the expansion of cropland, even in areas outside the legally protected forested areas, leads to deforestation (i.e. as one of the proximate causes of) and thus the loss of forest functions. The thinning effect of the mountain’s vegetation cover through forest-cover conversion to permanent cropland might also interfere with special characteristics of the cloud forest to intercept water from clouds and mists, thereby reducing recharging of groundwater system.

However, the cost of water production may not necessarily influence water yield but is likely to lead to an increase in user charges. A unit increase in the annual amount of rainfall (in mm) in a given year might, on average, increase the amount of water production by a rate of 0.0449 per cent in the next year which potentially translates into about 4,300 m³ litres of water every following year or two years (using the overall mean of 95,732.8 m³ per year). The marginally higher rainfall effect on water production relative to cropland is consistent with our estimates of the interaction variable on the water yield, although this is statistically not significant and not reported here. We also found that the price of water has no influence on the level of water production (this result is not reported in the table either). Since the provision of water services is handled by public utilities, neither profit nor price is a fundamental objective in the economics of production of water. The inefficiencies in the

53 The original equation (on a year-to-year basis) has a serial correlation as shown by the F-value (i.e. 6.096) and inconclusive Durbin-Watson Test (DW = 1.715). This problem caused us to include lagged forms of the explanatory variables (rainfall and cultivated crop area) in the model.

54 Note that lagged rainfall and lagged crop area correlate with lagged interaction effect and thus we could not use the lagged form in the model. In the model estimation we also tried other lag forms, but one-year lag gives the best model fit.

55 In the present model we use the total area of land sown with crops each year. However, we also obtain the same results (i.e. R-squared of 0.727) when we use first differencing of crop area instead, which captures the net effect of bringing an additional area under cultivation on water production. This means that the gross and net area cultivated with crops each year exhibit some variations over time.
water provision reported earlier and other public services may in part be attributed to poor regulation of government policies.

The dummy variable captures capital investment associated with the government's decision to increase the economic efficiency of water production following the 1996 economic reforms in government policy. This policy also included the electrification of water pumping from the source wherever high expenses were incurred upon installation of electricity compared to the earlier period of fuel (i.e. diesel). The financial investment and the shift from diesel to the more expensive electric power source took place concurrently. This unfortunately causes the model to be collinear as regards the dummy and the total fuel cost. However, the condition index (also variance inflation factor) remains relatively low at about 2, which is lower than the general tolerance condition index of 4 in the literature (Gujarati 1995; Kennedy 1998). Moreover, all the t-statistics of the explanatory variables of the model are significant and exhibit the expected signs. Overall, about 73 per cent of the total variability in the urban water production is explained by the dependent variables of the OLS model in semi-log specification.

The F-test for the overall significance of regression coefficients reveals statistically robust results for the model, which is significant at about 1 per cent level (F_{0.01}(3, 20) = 13.308, p<0.0001 compared against the critical value of F_{0.1}(3, 20) = 4.94). The time trends of discrete government financial investment and total cost of water production do not show zero variances. Thus, there is some evidence of heteroscedasticity, (i.e. the time dependence of conditional variances), but we believe it poses no serious problem for the set of partial coefficients in the model. In the final model we tested for serial correlation using the Breusch-Godfrey (BG) Test, which is considered statistically more powerful not only for a large sample, but also for small (finite) samples if compared to the Durbin h – test (see Gujarati 1995: 607). The BG test follows a chi-square \( \chi^2 \) distribution, so we conclusively do not reject the null hypothesis of no autocorrelation of up to the fourth order. In other words, the model indicates no auto-regression. The estimates of the standard errors are unbiased and parameter estimates are not precise but are adequately efficient.

The standard view of a protected area, as defined in guidelines for protected area management categories, implicitly assumes disconnectedness between the micro-level ecological units and the broader ecological functions. In this respect, we note that the critical support of the vegetation cover for a multiplicity of ecological services embraces more than

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56 According to our informants, the water supply water uptake increased considerably after the installation of electricity to the extent that it is much higher than the natural discharge rates of the sources. This problem indicates that limits to water production are not so much imposed by technological investments but rather by environmental constraints (or thresholds).

57 The variance inflation factors of 2.143 for the annual cost of water production (or total water expenditure) and 2.138 for the dummy variable – a measure of discrete investment in water infrastructure – might indicate some heteroscedasticity in the model. These values are still lower than the level considered of any serious effects on model estimates.

58 This refers to the computed values (i.e. \( n - \rho (\text{rho}) \times R^2 \)) of 1.794, 6.226, 6.279 and 6.04 at 5 per cent up to the fourth autoregressive order (AR (4)). These results are obtained from the application: \( (n - \rho) \cdot R^2 \sim \chi^2_p \); where \( n \) is the degree of freedom, \( \rho (\text{rho}) \) is the length of the lag (1 to 4 in our case) and \( R^2 \) is the coefficient of the each auxiliary regression result (see Gujarati 1995).
so-called special legal status areas and transcends their simple definition. Besides the local communities’ exclusive use of the protected area resources, human removal of vegetation cover disrupts wider essential ecological functions of the natural habitat.

The rapid settlement process on the mountain and growth of human population, the clearing of woody vegetation for agriculture to create ecologically marginal frontiers and the signs of a decline in rainfall are bound to limit the buffering capacity of the ecological services of the forest ecosystem. The section on water demand estimation above showed a rise in the total land area under crops on the mountain from about 4,000 ha to more than 8,000 ha in the last decades. The growing human settlement on the mountain not only raises demand for arable land but is also accompanied by a shift in demand for other local resources, including demand for fuel wood and timber poles for construction. If the expansive trajectory of the cultivated land through conversion of bushy vegetation into cultivated land and the increasing settlement process on the mountain continue unchecked these may in the long run indirectly impair the forest functions. These processes in turn may result in dire setbacks for economic activities on the mountain, upon which many rural livelihoods depend, as well as on the diversity of life forms permitted by the forest ecosystem. Farmland expansion impinges on direct and indirect functions linked to the forested area over time, through a negative feedback effect on forest ecosystem functions. Therefore, based on the model’s results, water and land use have reciprocal effects on forest services and strongly suggest that the various environmental resources should not be treated separately, but jointly instead.

**Accounting for trends in arable land areas on the mountain**

Before we turn to the policy implications of the model results, we will first deliberate on some trends in arable land areas. Chapter 5 reported on changes in the area under arable farming on the mountain. A very interesting point, particularly in relation to the model estimation above, is that the land area actually cultivated in around 1991/92, and the cultivated land area after 1995 dropped to the level of the mid to late 1980s and early 1990s. This is a rather unexpected finding given the continued human population growth over the years. This subsection puts forward some possible reasons for the diminishing land area for cereal farming on the mountain since 1991. The two main reasons for this surprising trend seem to be problems with the data and the substitution of main cereal (food) crops with other farming options or land uses.

- **Possible data problems**

The targeted and achieved crop areas are the main data types given in the Marsabit District Annual Reports by the Ministry of Agriculture, though these not always consistent. The former area is always larger than the latter and we used the achieved crop area in the model estimation. We cannot rule out the possibility that the low crop area on the mountain in the 1990s is a result of poor assessment by the Ministry of Agriculture, Livestock Development and Marketing (MoALD&M in short). Alternatively, it is likely that in the past crop area figures are the incorrect sum of two annual crop seasons on the mountain.

- **Growing importance of other crops and land uses**
The farming activities related to the main cereal crops rely largely on rain-fed crop production, except in the case of micro-irrigation agriculture. During the last decade, the mountain has experienced a number of years with rainfall amounts which were insufficient for crop production, as well as drought years characterised by total crop failures (Chapter 4). The recent series of droughts and associated crop failures might have reduced the attractiveness of the farming activities on the mountain and acted as disincentives for farmers to cultivate arable land to the fullest potential, which has led to an increase in fallow lands. Closely related to this is the fact that the gaps in farm size inequalities are wide and large farm owners have often left huge tracts of land fallow, even though such areas had been previously cleared of vegetation and expanded for crops. Moreover, most of the areas which are attractive for farming and also closer to the protected forest area are fully occupied. Large areas of land beyond the currently settled areas have been marked and are 'owned' by individuals, despite the fact that they are occasionally left fallow.

Another factor might be that more profitable activities, such as commercial enterprises, are growing in importance. Many of these are related to the growing demand for manufactured plastic containers, detergents, tealeaves, etc. in Moyale (Ethiopia). This view is supported by the slower inter-censual growth rate of the mountain population compared to the growth rate for Moyale town between the last two censuses, which suggests emigration of the mountain population.

Marsabit town has expanded outwards as a result of human population growth and has extended to former adjacent farmlands. These areas have been divided into smaller parcels of residential plots. Evidently, other crops such as mirraa and horticultural crops under irrigated agriculture are gaining in importance. These crops are labour intensive and guarantee a higher productivity per unit area while also ensuring a stable income compared to the cultivation of the main crops. Therefore, a preference for small-scale crops over the main cereals is conceivable in view of the recurrent droughts and crop failures. The net effect of changes in land use and crop type is the low achievement of the total land area under the main cereal crops.

The latter set of reasons, the expansion of Marsabit town into former farmland and the increasing adoption of horticultural crops, are in our view more important in explaining differences in land area for farming on the mountain over the last decade than the emigration of the mountain population. However, the diminishing area of cultivated land might be the result of combinations of the above explanations. Even so, our model results still represent a good approximation of the ecosystem fragmentation since the ‘achieved’ crop areas provide a lower limit of the total land cleared of vegetation for human settlement and crop area. Even with the above considerations regarding trends in arable land area in mind, the outcome of the model implies that the fragmentation of the forest ecosystem carries serious consequences for the forest and its functional diversity. Such negative impacts also affect the long-term survival of the habitats of plant and animal species that are well suited to the mountain’s climate and ecology. The changes in the forest functions could in the long-term also negatively impact on the livelihood of the local mountain population.

Policy implications of the model results
- The need for integrated resource management

The management of the forest ecosystem requires the reconciliation of ecological constraints to the ecosystem functions and the forest's support of human economic activities. The model outcome makes it clear that there is an urgent need for an integrated resource-based approach, as opposed to the current multi-sectoral approach, aimed at the long-term conservation and management of the water catchments and forest resources, along with other ecological services. Such an approach would, if adopted (i) remove the separation of delivery functions of the forest from those of management and (ii) address the sustainable management of water resources. This suggestion is in line with an ecosystem approach\(^{59}\) to forestry conservation, which has long been neglected in the region and nationwide. The recognition of the ecosystem approach in nature conservation emphasises interrelations between various resources and shows how disjointed resource policies are unlikely to achieve sustainable resource utilisation. The government's recent decision to charge water abstraction directly from natural sources under the newly enacted Water Act (UN-DPMCU 2002; GoK 2002; Otieno 2003) with a view to improving revenue collection and to plough back the accrued revenue to conservation is a timely move in the right direction.\(^{60}\)

- The need for the FD to be better equipped and for improved collaboration with the KWS

In line with the foregoing, there is need for better coordination of the mandates and activities of the Kenya Wildlife Service (KWS) and the Forest Department (FD), which are currently the main parties that oversee the forested areas in Kenya. The responsibility for forest management in Kenya is the duty of the FD. The department is currently much maligned and requires additional resources to manage forest resources in Marsabit more effectively (see Chapter 9). The Marsabit Forest station had only one run-down Land Rover at its disposal in 2000. In the legal sense, the department has never had official authorisation to prosecute people illegally harvesting forest products and still lacks the capacity to enforce forest laws. Conditions under which the Kenya Wildlife Service performs its mandate are slightly better (KWS 1990, see also Forest and Wildlife Conservation and Management Acts of Laws of Kenya). The goal of the KWS is mainly to conserve biodiversity and the agency's tangential interest in forests arises from the large amount of wildlife biodiversity found in indigenous forests. It follows, therefore, that it is in the interest of the KWS to play a key role in conserving the indigenous forest as well. In Marsabit Mountain, a joint conservation venture between FD and the KWS is supported by a Memorandum of Understanding (MoU) drawn up in 1991, at least on paper. As we already noted in Chapter 9, the collaboration envisioned in the document has been undermined by differences in remuneration between the employees of the main conservation authorities, financial resources and the expertise of the officers − divided between wild plants and animals. A few recent forestry studies in Kenya have indicated better management under the KWS based on the curtailing of illegal harvests of forest resources and, as a result, have suggested the transfer of forestry management from the

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\(^{59}\) According to the CBD, the ecosystem approach entails a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable manner (UNEP 1992; White et al. 2002; Smith & Malby 2003: 10)

\(^{60}\) The implementation, rather than an enactment, of law is needed to attain sustainable resources and the full enforcement of the law is therefore yet to be seen.
Forest Department to the KWS (Walubengo 2002; Gachanja 2003). An analysis of the legal implications of such transfers brings a number of important issues to light. The wildlife conservation laws are more restrictive since they do not allow the consumptive use of forest resources, unlike the forest laws. This consideration overlooks the importance of forestry resources in the economies of the local communities. This poses a particular problem for the local communities and is often a source of conflict over resources.

There is a case for strengthening collaboration between the existing (but currently very weak) conservation agencies aimed at improving management practices and enforce conservation laws as articulated in the MoU of 1991. However, this option is unlikely to attain sustainable resource use and enhance broader forest ecosystem functions, judging by the few achievements made after the MoU has been drafted. The need to increase collaboration between the KWS and the FD is an important aspect at present in the face of differences in training and expertise of the staff of the conservation authorities in terms of biodiversity conservation and management issues. This would mean that, as conservation issues stand today, both agencies need each other. Moreover, the current chapter’s evidence that the expansion of cropland outside the restrictive definition of the protected areas might undermine forest functions suggests that concerted conservation efforts should also be based on support from the local communities.

- The need for an autonomous water body

The current sector-based conservation practices and legal frameworks are insufficiently coordinated to generate the much-needed integrated forest and water resource management policies (Ogola 1992; Mugabe & Krhoda 1999). A suggestion put forward in this respect is the establishment of an umbrella body institution – a Watershed Management Authority – that aims to harmonise the goals of various institutions and would be responsible for the overall conservation of water-related forest ecosystem resources. The watershed functions of the forest ecosystem would be of considerable interest to such an authority. We argue that current legislation needs to be amended in order to set up such a watershed authority, which should play a leading conservation and management role in watershed areas and whose main responsibility would be to protect water catchment areas that feed water points for domestic and irrigation in the region and in Kenya as a whole. Such a body should liaise closely with various interested parties in conservation programmes in order to be effective. The authority should also have greater autonomy as regards development policies, the regulation and the pricing of forested-related resources in accordance with the conservation priorities stipulated. Once established, the authority should honour underlying ‘public good’ attributes embedded in forestry conservation and thereby promote the sustainable use of resources. This suggestion is in line with the current study’s finding about the importance of the forest and vegetation cover on the mountain (also outside the legally protected areas) for urban water production (hence water availability). If created, such an authority would also have to address the economic efficiency of water production and improve access to, and the effective delivery of, water resources.
- The need to tackle water shortages and impose water charges

The above findings show that there is a genuine need to tackle persistent water shortages and to improve human access to water resources on the mountain. Besides the problem of water provision, the distribution and pricing of water resources also need reform. If nothing is done to control the effects of human settlement on the mountain, this might work against the watershed functions of the forest ecosystem. Although the drip irrigation agriculture on the mountain benefits both local farmers and local consumers, irrigation accounts for the largest share of the water use. In this connection, we support the imposition of charges on water abstraction from the source and for irrigation purposes and the re-investment of some of the revenue in the protection of the watershed area. Such water charges (through a water permit/fee) should be based on the irrigated crop area and on the volume of water used. Such a mechanism ought to take into account the distribution of benefits and costs of irrigation between the upstream and downstream farmers, based on economic valuation. It is likely that without such charges the local farmers will not be motivated to make efficient use of water abstracted from the source.

However, in practice it is difficult, if not impossible, to estimate the full cost of water resource use through conventional (prices-oriented) markets. User fee charges can be used to make prices reflect costs of resource use on society. The market-based approach can be used to adjust environmental charges so as to reflect social and environmental costs associated with forest resource use (Watson et al. 1998). One way to achieve sustainable forest management and appreciate the value of forest resources is to recognise and take note of (and/or when feasible create) markets for ecological goods and services that forest ecosystems provide. Charging a (low) monetary value on water as proposed in the 2002 Water Act might act as an (economic) incentive that reflects the extent of resource availability and encourages efficient resource use. The adoption of specific forest-related resource fees might also help to conserve natural resources and in addition generate revenue. Such a policy could consider exempting the poorest households from paying user fees for the forest resources.

The government's strategy to charge for the delivery and maintenance of water services – a decision to which it was forced by donor agencies like the World Bank and the IMF (GoK/IMF 1996) – assumes that the realisation of higher financial returns on water provision is attainable. Given that water is a basic resource, the government's decontrolling of water resources – i.e. the total privatisation of water delivery – can expected to be beneficial and lucrative as well. It is equally true that it will be difficult to remove the monopolistic barriers in the delivery of water supply.

The question is how privatisation of water resources will cater for the poor. The profit maximisation motive of a private firm contrasts sharply with the interests of the poor and there is no moral in decontrolling water prices at the expense of these poor by turning essential services into a source of profit for private enterprises (Aegisson 2002). A policy shift to privatisate water services that fails to recognise the rights of the many rural poor is at odds with the general will of the people invested with the state – the public provision of essential services. There is, however, a difference between the privatisation and commercialisation of water services. The latter aims to improve efficiency as regards the collection of water revenue, improved delivery and cost recovery of water services. If properly organised, the commercialisation of water services may enhance asset maintenance, encourage water
management and perhaps generate additional funds to augment environmental conservation efforts and the protection of watershed areas.

In Kenya, the water management and delivery services relating to urban water supplies have been in the hands of the state since independence. Government control of the water service is based on the general interest of public provision of essential services and concern about the provision of water services to the general public is also a reason for state subsidisation of water tariffs and water asset maintenance costs. Although such policies are well-meant, the majority of the poor live in rural areas where piped water is non-existent and thus the interests of the poor are not represented in state-controlled water supply. Moreover, state-controlled water supply has had to contend with problems related to large volumes of water that were unaccounted for and inefficiencies that have led to low cost recovery and poor quality water assets. These aspects, in turn, are associated with a substandard public provision of water services (GoK/IMF 1996; MDAR 1997; Onjala 2002; Aegissson 2002). Today, the commercialisation of water provision aimed at improving deliveries of water resources and developing a rural water supply are central to the water policy. Within this framework, the concern about efficient delivery of water services and determination of water tariffs ought to consider the economic circumstances that the local economies face nationwide.

- The need for political will to address the underlying forces of forest degradation

Thus far, we have mainly used economic and ecological arguments to highlight the local benefits of forest conservation. Yet, the ramifications of international forestry agreements and the imposition of environmental resource fees are being effectuated at the national level (see Watson et al. 1998). This makes conservation efforts a ‘political’ process and efforts to improve resource conservation part of the government’s political machinery. This, in turn, means that political will is needed to enforce decisions regarding conservation goals. Accordingly, political decisions can either influence access to local forest resources or threaten forest conservation through government action which results in the conversion of forests to other land uses.

The protected forested area, including the Marsabit Forest area, covers less than 2 per cent of the district’s total land area and harbours a disproportionately large amount of the region’s biodiversity. The importance of the mountain’s biodiversity is indicated by the presence of a National Reserve, Forest Reserve and a National park.

Marsabit Mountain is a highly productive, niche area at a relatively high altitude, with fertile soils and relatively high amounts of rainfall in comparison with the other regions in the district. As a result of these enabling conditions, the mountain has experienced rapid population growth during the last three decades. The fast growth of human settlement has led to farmland expansion into areas of marginal agricultural production. This process will exert pressure on the forest ecosystem in the long run and might have severe ecological

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61 Kenya is party to a number of international treaties, including the Convention on Biological Diversity signed at the Earth Summit in Rio de Janeiro in 1992 (UNEP 1992; Watson et al. 1998). The treaty recognises the importance of animal and plant diversity in the proper functioning of the agro-ecosystems. Kenya is also party to the closely related Framework Convention on Climate Change (FCCC), the International Tropical Timber Agreement (ITTA) of 1983, renegotiated in 1994, and the Convention to Combat Desertification, originally signed in June 1994.
repercussions leading to soil erosion, damage to watershed areas and water supplies and negative effects on wildlife. Indeed, our estimates show that a 20 per cent increase in the total land area under crops might result in about 60 per cent decrease in the volume of water produced. The settlement process on the mountain is accompanied by increased aggregate demand for a wide range of environmental resources. This is also feared to have an undesired outcome. The constant demand for forest products and services might exert pressure on the resource base as a result of illegal harvesting of wood for charcoal production, construction timber and firewood. The nature and extent to which forest use affects the indirect values of the forest are not known. What is certain, however, is the long-term consequence of human activities for the ecosystem’s goods and services and this is critical since it has a greater proportional impact on local livelihoods than global effects. Since successful conservation would also benefit the local communities, there are strong incentives for local communities to make sustainable use of forest resources.

The chapter’s findings with respect to inter-linkages between the watershed function of the forested area and human activities imply that the legal definition of protected areas in conservation programmes is unduly restrictive (Folke et al. 1996). The results show that preservation of the forest ecosystem for watershed functions and the local communities’ needs for forest resources are equally important reasons for forest conservation, and the challenge lies in ways to reconcile them. Available sources show that up to about 80 per cent of the rural population in the region live below the poverty line of US$ 1 per day (GoK 1998; Thorton et al. 2002; IPAR 2002). There is therefore a great need to address the underlying forces of human demand for forest resources that endanger the flow of ecosystem services directly.

The ecosystem approach to environmental conservation

The results above highlight the importance of an ecosystem-based approach to environmental conservation programmes and are in line with the concept of biodiversity conservation extending beyond the protected areas, which are usually narrowly defined. The ecosystem approach considers how human activities affect the environment in terms of ecosystem functions and productivity and how conservation and sustainable use of natural resources can be promoted in an equitable way.\(^\text{62}\) In keeping with the ecosystem approach, this study focused on the following aspects of management and conservation of protected areas around Marsabit Mountain:

1. The entire mountain area is an integrated unit, which directly and indirectly provides goods and services which benefit the human population.
2. In the model estimation we looked into how factors such as rainfall trends, removal of natural vegetation and conversion of forest to farmland might have potential synergy effects on water production. Here, we took the forested area as only one element of the mountain ecosystem, which functions as an interconnected whole rather than as

\(^{62}\) The key role of the ecosystems approach in natural management is widely recognised, and particularly emphasised in the Convention on Biological Diversity (CBD) and endorsed by the fifth Conference of the Parties to the Convention in 2000 in Nairobi (White et al. 2002; Alcamo et al. 2003; Smith & Maltby, 2003).
independent parts. Recognising the functioning of the mountain ecosystem as a whole, rather than as pieces, challenges a restrictive definition of 'protected areas' only to areas within arbitrary boundaries.

3. As regards management issues, limited revenue proceeds and high conservation costs\(^{63}\) coupled with low manpower appointments and a weak morale among those who are supposed to police the process are partly responsible for institutional failure. These problems hamper the effective management of the protected areas.

4. The present conservation efforts in Kenya tend to exclude forest-adjacent local communities from daily management and decision-making, and control their access to forest products. Poorly coordinated natural resource management practices, and perhaps a cause of their flaw, further worsen the problem. The regular resource policing and economic-driven local households' demand for resources are miles apart. In viewing the local people as a part of the ecosystem, the social and economic characteristics of the households indeed affect how natural vegetation resources are utilised (Chapter 13). Forest conservation efforts should therefore take socioeconomic characteristics of households and their need for forest products into account and link management practices and resource and revenue policing with the need to improve the provision of forest goods and services. Conceivably, any conservation effort will be successful if it increases the provisioning capacity of a specific ecosystem and preserves the integrity of the entire ecosystem.

These aspects, combined, give a broad approach to concerns regarding factors that influence ecosystem conditions and the provision of goods and services over time. The main purpose of the ecosystem approach is to contribute to policy decisions and improve current management practices and sustainable use of natural resources. Crucial in this respect is the call for the inclusion of areas outside the legal status areas in the management and conservation agenda. This approach favours a strengthening of cooperation between stakeholders in the conservation exercise. There is also concern that the exclusion of the local communities in forestry conservation is bound to make them indifferent because they lack a sense of belonging or cooperative responsibility (Wily 2002). Forest conservation may seem unprofitable to them because of the ‘hidden’ returns on forest ecosystem services and extremely limited accrual of tourist revenue and constrained benefits sharing. Yet the main reason for carrying out forest conservation is the long-term benefits to society.

Below, we synthesise the findings which are particularly related to local communities’ forest use and their inclusion in conservation efforts.

**The provision of goods and services to the local population**

As we have seen in Chapter 13, local communities derive a wide range of direct use values from the protected forest and woody vegetation resources. The forest provides timber poles for construction, firewood, material used for making charcoal and other products. The

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\(^{63}\) The protected areas around Marsabit Mountain lie outside the main tourist circuits (see Chapter 9) and as a result receive low numbers of tourists and generate low revenues. The possibility for matching funds from line ministries concerned with natural resources is also minimal due to low budgetary allocations, which are fuelled by general misconceptions about arid areas that they are unproductive and cannot support biodiversity (see White et al. 2002: 3).
majority of the households on the mountain rely substantially on firewood and charcoal for cooking and for heating their homes. However, only a few households (about 10 per cent) depend on the sale of forest and woody vegetation products, especially charcoal, to earn cash income during times of stress; when returns on capitals are low or alternative sources of livelihood fail (e.g. crop failure). The rural households predominantly use firewood for domestic consumption. The urban poor sell charcoal and firewood in the urban centre of Marsabit town to make a living and to generate additional cash income. Those who sell the vegetation products on the cash market also turn out to be the most asset-poor households and this reveals, in particular, the crucial role of the vegetation resources in the livelihoods of the resource-poor households.

The forest and vegetation resources are also a source of a number of ‘minor’ products such as fodder, grasses for thatching houses and honey. Hence, the forest products benefit the rural households through sales, purchase or harvest for own consumption. These products may be obtained via a permit license or open access. These uses make direct a contribution to local production and consumption.

We have also shown that the households benefit from the flow of goods and services to a varying degree: those close to the forested area rely on the forest ecosystem for fuel wood and other uses more than the households further away from the forest. Thus, the direct benefits of the forest conservation on the mountain are unequally distributed across the households. Similar disparities among the households living adjacent to the forested area and those distanced from it have been revealed in relation to access to water for irrigation and arable production.

Rainfall is the only means of recharging the underground aquifer system. Therefore, all the households on the mountain (about 8,344 households by 1999) — whether they own or lease farm plots or benefit from water supply as urban residents — benefit directly or indirectly from the forest-linked rainfall. Moreover, rain-fed arable production also accrues to the pastoral households in the region through lower cereal prices and on-farm wage employment in weeding and harvesting activities during peak crop seasons. However, farm outputs vary across the moist and dry zones on the mountain. Besides the settled households, pastoral households in the surrounding lowlands also water their animals and fetch water for domestic needs from the water sources on the mountain during dry seasons. This highlights the accrual of forest conservation and its ecosystem services’ benefits to the region.

In sum, farm productivity (Chapter 12), the household use of water sources within the protected forested areas (Chapter 8) and the harvest of forest products (Chapter 13), ceteris paribus, decrease longitudinally with the distance from the protected forest area. In contrast, the forest-adjacent farmers often suffer high wildlife-induced property, crop fields and livestock losses. Although the benefits of arable production accrue to the households in

64 The human population on the mountain is largely attracted by the possibility of crop production, which depends on fertile soils and rainfall. However, the use of natural vegetation or the removal of indigenous plant species for agriculture causes fragmentation of the ecosystem. Negative rainfall trends also have potential adverse effects on water supply and crop production, as well as on woody biomass production and biodiversity — although further research is needed in this respect. More explicitly, we have shown that the adverse impacts of weather (i.e. recurrent droughts, El Niño) significantly reduced the livestock population in the region (see Chapters 4 and 7 in particular).
different proportions, the forest-enhanced indirect services create positive externalities and thus have the characteristics of a local public good. On the whole, the social forest benefits definitely exceed private benefits to a household or individuals (see FAO 2003).

The distributional differences between conservation benefits and wildlife-induced property and asset losses arising from the (protected) forested areas-community interactions create a layered local community. This result challenges the view about rural households being homogenous in access to resources and identical interest groups and reveals diverse societal units instead. Viewing communities as homogenous in relation to protected areas poses a danger of generalising the distributional pattern of costs and benefits of conservation programmes. Overall, there is a clear difference between benefits and costs of conservation on the mountain across the households.

It is also evident that efforts to improve irrigation activities and increase production on the mountain are likely to lower consumer prices and in so doing benefit the local economy as a whole. In our view, the most crucial consideration of forest ecosystem conservation should be the societal benefits rather than forest uses for private gain. The development of the buffer zone, \textit{inter alia} the settled areas, is required so as to ease household demand for the various forest products in the future.

To sum up, the forest ecosystem benefits exhibit characteristics of private and public goods. The flow of forest resources can either be a direct use (private) to individual household needs, or indirect use in terms of the forest's support of arable agriculture, maintenance of the microclimate and generating rainfall.

\textit{Some thoughts on the inclusion of local communities in forest resource management}

If conservation has to conform to the circumstances of local resource users, the forest management decisions should be partly delegated to the hands of the user communities themselves. Such a move requires placing resource users at the centre of the decision-making process, especially the women and girls on whom the burden of resource harvesting falls and the poor members of the communities who rely on the natural environment for immediate survival. The inclusion of the local communities requires an ending of governmental heavy-handed control over natural resources and the acceptance of contractual responsibilities and allocation of forest resources to the local resource users. These happen to be the poor segments of rural households who depend on natural resources, but lack management and policy decisions over protected resources. The partial involvement of the local communities in conservation and management decisions is crucial (i) to reflect on the realities of resource

\textsuperscript{65} The two classic characteristics of a public good in relation to rain-fed agriculture are (i) it is difficult to exclude any farmer from the benefits of rainfall (\textit{i.e.} non-excludability) and (ii) the benefits of rainfall on the field of a specific farmer do not reduce the amount available for other farmers (\textit{i.e.} non-rival in consumption) (Cornes & Sandler 1995).

\textsuperscript{66} At present, the government has dominant control over environmental resources in Kenya, and alteration of the existing rights over resource to achieve sustainable resource use is likely to meet resistance. However, this option is crucial for effective public participation in decision-making concerning forest conservation. This suggestion is line with Principle 10 of the 1992 Rio Earth Summit declaration (UNCED 1992). This Principle recognises the key contribution of partnerships with development agencies and identifies the participation of all parties concerned, appropriate access to environmental information and participation in decision-making processes as being fundamental to development programmes relating to the environment (\textit{ibid.:} 2).
availability on the ground; (ii) to minimise looming open-access problems in forest resource use; and (iii) for the endowment of the local communities with legitimacy to manage resources and to offer incentives to manage resources in a more sustainable manner. This means that the conservation agencies should scale down their involvement in environmental protection to a necessary minimum and that the state should provide an enabling environment for the healthy exchange of ideas about forest conservation and management issues.

The starting points for future changes would be an assessment of the ‘willingness to pay’ for the value of forest services in order to capture non-marketed and difficult-to-quantify forest values; an elicitation of the local communities’ preferred approach of forest and nature conservation; and an identification of the forest resource users’ most urgent needs.

The main underlying causes of environmental resource use, and thus threats to conservation, are economic ones. Yet regulations and the control of environmental resources have focused on monitoring and penalising people who used protected resources without valid permit licenses. Any attempt to improve rural welfare and reduce economic demand for forest products would be desirable. Efforts that enhance rural (farm or labour) productivity are bound to reduce economic demand for forest products, hence conserve biodiversity and increase the forest’s capacity to provide essential public goods and services that support human activities in the long run.

The revenue side of forest conservation
At present, the forest permit charges are determined centrally at national level and the same applies to water tariffs. This system of resource pricing is far removed from the local realities of resource scarcity and price levels faced by the resource users. As a result, resource prices fail to provide incentives to adjust resource-use behaviour. The government subsidised resource-pricing mechanisms to favour the low purchasing power of the majority of the environmental resource-dependent households. However, this is ecologically unsustainable in terms of forest resource use. For example, although forest permit fees are constant across products, harvest of firewood, poles for timber and charcoal have different impacts on the removal of the vegetation cover (i.e. deforestation) and the ecology.

The forestry sector contributes less than 2 per cent to the gross national product in Kenya annually (Mbugua 2000; Odera 2001). This low percentage economic contribution shapes the perception of and imposes challenges for forest conservation. Seen this way, forests contribute a small percentage to the gross national product, play a minor role in economic development and are conserved at the expense of local communities. However, a lot of forest-related goods and services have no monetary value through conventional market prices and are therefore not reflected in the national production statistics, in spite of providing significant

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67 Nor is the permit system responsive to economic factors as it fails to keep pace with the prevailing high inflation.

68 The government may charge low forest fees for social reasons (in the general interest of the forest users), which lowers forests revenue and financially supports wood fuel consumption. The permit fees remain undifferentiated between forest products and thus do not address potentially different harmful impacts of harvesting forest products on the ecosystem nor do they encourage efficient allocation of forest resources. The low fees reduce the forest government revenue and do not reflect the social cost of forest resource use (FAO 2003: 112). The low prices of environmental resources tend to undervalue resources and send a wrong price signal to the market about forest-related resources, which may result in their over-exploitation.
input to people's subsistence use, income and (informal) employment, cultural and religious sites and a habitat for wildlife. In this regard, about 3 million people live adjacent to forested areas in Kenya and derive cash income from forest resources (Mbugua 2000: 62). It has been estimated that the often unaccounted for economic value of forests to the local communities in rural Kenya is about US$ 132 million annually (Mbugua 2000: 63). This source revealed that about 62 per cent of the total forest contribution to the gross national product is usually unaccounted for. The underestimation of the economic values of forests would create the impression that forests have little economic value and negatively influence policy decisions regarding conservation.

The forest reserve and the protected areas on the mountain also generate limited economic revenue that supports conservation efforts. The few tourists and local residents benefit from environmental conservation programmes through recreational services. However, the tourism revenue from the protected areas on the mountain, generated from the sale of forest products and recreational visits, scarcely pays for their conservation maintenance let alone compensates property damage and losses sustained by the communities living close to the protected area (Chapter 9). The forest reserve was also exploited in the past for timber and it was realised that the forest generates only limited financial benefits. The discrepancy between the management costs and financial revenues of protected areas in Kenya is considerable and the revenues from the protected areas on the mountain, in particular, are much lower than the management costs (Emerton & Tessema 2000). This severely limits a fair and equitable sharing of financial revenues from forest conservation with other parties.

Assuming that the forest ecosystem is accorded a better protection status
At present, forest-based resources are critical for production in local economies. Stricter regulation and environmental conservation imply that forest-based resources like water could be channelled out of the forest for livestock and other local uses. We could also assume that there is an efficient compensation scheme for wildlife-related losses suffered by the local communities. Piping water outside the forested area into the open air would require significant capital investment and the establishment of a robust compensation scheme would involve funding outside the conventional economic revenue from the protected areas. Moreover, such conservation measures cannot succeed without well-motivated personnel.

However, should these funds be granted and should stricter regulations and controls be imposed on the protected areas, two groups of potential users are likely to be eliminated.69 First, stricter access rules to the forests would exclude marginal farmers pushed beyond the cultivation frontiers on the mountain. These farmers occupy a relatively drier zone and distance hinders frequent access to and harvest of forest products. Secondly, tighter regulation of conservation measures dislodges the rural poor who depend on burning and producing charcoal to derive income. If forest products were governed by strict access rules, poor households will lose a source of income. These two groups, together, constitute the poorer segment of the local communities without a voice, political influence and responsibilities regarding policy decisions about conservation projects. Yet ignoring these groups is at odds

69 Similarly, a shift in wildlife conservation policies that eventually led to the total ban on game hunting in Kenya in the 1970s witnessed the end of the hunter-gatherer groups like the Waata in Marsabit (see Isack 1987).
with the interest of the general good of the public embedded in conservation programmes and it also makes them obvious losers in the face of stringent conservation measures.

Conclusions

The forest directly or indirectly supports the local economy in a number of ways. In addition to providing private benefits to a household or individuals in the form of fuel wood and other forest products, the forest provides indirect functions such as biodiversity conservation, providing a habitat for wildlife and animals, soil erosion prevention and watershed protection. This chapter focused on the forest's watershed function.

On the basis of an analysis of long-term rainfall variations in the northern Kenya region we noted a downward trend in annual rainfall for Marsabit, which has consequences for the production systems in the region (see Chapter 4). A surprising downward trend in long-term annual rainfall is recorded for Marsabit station only from a number of meteorological stations in the northern Kenya that we compared. As stated in Chapter 4, the growing of cereal crops under rain-fed conditions in arid and semi-arid areas normally needs 100 mm of rains for three months in a row (Critchley & Siegert 1991; Mati 2000, Kipkorir 2002). Owing to rainfall variability, water requirement is a primary and influential constraint on arable production. Recently, severe moisture stress at critical stages of crop growth reduced yields substantially up to 90 per cent (MDAR 1998). On this note, an assessment of crop water requirements for successful growth and better yields requires different diagnostic analyses of rainfall on a month-by-month basis and on a bi-annual basis (crop season) as well. The monthly rainfall data shows that only very few months, and even fewer years, fulfil crop-rainfall requirements prescribed in the literature. However, apart from insufficient amounts of rain, a partial crop failure could also be caused by other whims of nature like the 1997/98 heavy El Niño rains and crop diseases (worms) in 1999. Nonetheless, on average, rainfall remains the most critical factor that affects regional crop and rangeland production and water availability.

In Chapter 5 we saw that although the rate of the arable land expansion on the mountain did not keep pace with population growth. Since the 1950s, the mountain population has grown 18 times in comparison to six times for the district as a whole, and as result the cultivated land area increased annually by about 177 ha between 1977 and 1995. This may be interpreted as representing the removal of vegetation cover (or deforestation) at about 2 km² per year. The growth in the cultivated cropland denotes fragmentation or forest destruction in the area around Mt. Marsabit that was originally designated as wildlife habitat. However, the estimated total cropland areas do not mirror all the land cleared of vegetation for human settlement and farming needs. There is also change in land use as areas formerly cleared of vegetation for farmland are allocated to settlement because of growing human population on the mountain (MDARs various years). In other words, the changes in the cultivated land area do not include vegetation removed for other land uses such as settlement and non-cereal crops, and thus underestimates the total forest area converted to other land uses. As the mountain population increases the demand for forest products and forest-based resources also
increases over time (see Chapter 13). The household use of forest and vegetation resources also causes an additional thinning effect on the vegetation ecosystem on the mountain.

This chapter has attempted to focus on the economic and ecological functions of Mt. Marsabit forest ecosystem, with a focus on the forest’s watershed function, and attempted to link these functions to economic benefits of water resources. We demonstrated that irrigated agriculture and urban water production are examples of economic values indirectly supported by the forest’s watershed function. The indirect forest functions typically accrue over the medium and long-term and yet the short-term human economic activities might place forest functions under stress, which are essential to the integrity of the ecosystem, the deliverance of goods and services and biodiversity conservation. These concerns are illustrated through the likely synergies between human economic activities related to arable land expansion and their feedback effect on the broader ecosystem’s functions, which we attempted to capture in a forest cover-water yield model. A number of interesting and insightful remarks can be drawn from the results.

The provision of water resources also illustrates the ability, by any standard, of a small forest amid a semi-arid ecological area to favourably influence climate and rainfall, retard soil erosion and naturally reserve rainfall water for use during many months into dry seasons and prolonged dry spells. Despite the downward trend in rainfall, the improved water production and increased revenue following technical investments in the last decade support this assertion.

We also investigated micro-level disparities in natural resource endowment and highlighted how specific local institutional arrangements (e.g. ethnic-based access to land and water resources) are used to sanction access to arable land (see the section on human population growth in Chapter 9 and the section on rules of access to vegetation products in Chapter 13). These differences are evident as mountain sides with thick forest cover are associated with more water sources relative to other areas – thus emphasising the link between forest cover and water resources. Closely related to this, the micro-level differences in natural resource endowment present unequal possibilities for rural production. We also showed how well-intended development interventions on the basis of water resource endowment on the mountain, aimed at improving rural welfare through irrigation, seem to inadvertently widen, rather than reduce, rural inequality in means and sources of income. This difference is particularly demonstrated by the irrigation possibilities around the mountain as dictated by the distribution of water sources (see Table 15.1). Using arc-elasticity, we found evidence that promotion of the irrigation potential has local benefits since an increase in irrigated agricultural activities and related crop output result in welfare improvements of local consumers. An inquiry into household level monetary benefits and welfare gain from irrigated agriculture (cf. the sections on land cover, yields and marketed value of irrigated crops), and how such benefits link to environmental hydrological functions of the watershed area (see the sections on urban water production and a model on land use-water yield linkages), provides powerful evidence in support of local benefits of the protected areas, as well as a strong justification for forest conservation. This still remains an important area of investigation for future research.

As we have shown, pushing the cultivated land outside the existing cropland is likely to have a negative effect on the forest’s vital water catchment. However, the enhancement of
irrigated activities, unlike the expansion of cultivated land, may be realised without jeopardising environmental conservation. Moreover, the irrigation system enables farmers to grow crops outside the rainy seasons, which are usually unreliable, and also to plant high market value horticultural crops relative to the common maize and beans varieties. Doing so not only raises irrigated production (and productivity) and rural farmers' income, but also benefits local consumers on the mountain in terms of reduced prices of crops grown under irrigation. Thus, we begin to see relationships between hydrological cycles supported by the indirect forest functions and human welfare. This result is attractive in view of the many low-income households in the area and their limited purchasing power.

In addition to forest-related resources benefiting the rural farmers and local consumers, the forest ecosystem is also a source of urban water supply on the mountain. This function clearly illustrates that the forest ecosystem strongly supports the urban population and offers one of the strongest testimonies of forest support of watershed functions. The rapid population increase on the mountain over time reflects a tremendous need for technological improvement to harness water resources. However, the fact that water supply is heavily state-controlled and water delivery is generally inefficient suggests the dire need for reforming the water-pricing system. This result is apparent from both inefficiencies in water production and delivery of water services, while in general it reflects the poor pricing of environmental resources.

One of the hydrological functions of the forest is recharging of the groundwater, and also regulating water supply in the dry season. In our model this is highlighted by the lagged influence of rainfall on urban water production. While forests (or tree) canopies are widely acknowledged to intercept rainfall better than other vegetation types, we also need to note that Marsabit is a cloud forest and that its location in an arid environment makes it unique. The forest vegetation and its mosaic niches can intercept water from clouds and early morning mist and this adds water to the subsurface water reservoir. The model also shows how land-use change might adversely impact on hydrological processes of the watershed functions of the forest. This in particular highlights risks of time delay between the time of the removal of the vegetation cover (forest destruction) and the time when such negative impacts might be felt.

The capacity of the forest ecosystem to deliver economic-ecological functions should be placed in a long-term perspective. The earlier confirmed rainfall decline, adverse risks of crop failure and the expansion of arable land through the removal of vegetation cover are bound to have a negative effect on the forest functions. In terms of policy implications we found that an increase in the total cropland area by about 20 per cent might result in a more proportionate decrease (about 60 per cent per year) in the forest-supported water production. The results present a strong argument for supporting the expansion of irrigated agriculture, since this option involves intensive land-use practices and is characterised by high resource inputs (e.g. labour, capital, water) and productivity, unlike the subsistence rain-fed arable farming. The expansion of irrigation agriculture is therefore currently a top priority.

For example, kale, tomatoes and onions had outputs of 20, 12 and 9 tons/ha in 1998 (see Table 15.3), while maize, beans and wheat (the main food crops) achieved only 0.3, 0.1 and 0.4 tons/ha respectively (MDAR 1998). In addition, the horticultural crops entail labour-intensive production with low food value compared to the main food crops on the mountain. Yet in terms of income earnings, the irrigated crops have very high cash value compared to the food crops.
Unfortunately, the expansion of arable land on the mountain has not reduced the number of food insecurity households. Chapter 5 reviews trends in crop production and Chapter 12, which deals with crop production on the mountain at farm level, confirm this result. For example, the number of food-insecure families has increased in the last decade (FHI 2001) and this corresponds to the low annual rainfall. In 1999 alone over 200 metric tons of relief food aid has been distributed on average per month in the region (MDAR 1999: 14).

This generates a paradox. Although the need to increase crop coverage has grown over time, today the total land under crops has remained lower than what it was in the 1970s and 1980s. However, the number of farming households has drastically increased in the course of time (Marsabit County Council 2000: raw data). The growth in the number of farming households suggests either a sub-division of already cultivated land, or alternatively, an expansion of farming activities on the mountain into relatively ecologically marginal areas. The latter may not necessarily result in increased arable production in the face of erratic and unreliable rainfall patterns that arable activities depend heavily on. Hence, the growth of arable land, through the conversion of the former woody vegetation into cropland, unluckily has little to no association with the arable production. Yet, the human activities related to agricultural expansion are still a source of pressure on and risk for the habitat and the natural ecosystem’s functions.

In the long term, the removal of woody biomass and the diminishing of the habitat might have negative impacts on the watershed function of the forest ecosystem, including water used in irrigation for crop production. Our simple land-use and water-yield linkages model confirms this. The chapter’s results are in a sharp contrast at a time when proportionately large forests in Kenyan have come under threat of excision (Mwale 2001; Mbaria 2001; KFWG 2001; Opala 2001, 2002). This study argues against this move and advocates an extension of biodiversity conservation and management decisions beyond currently legally defined territories. The study’s results emphasise interconnectedness in the natural system and favours an ecosystem approach to resource management and conservation programmes. It opposes the sector-by-sector approach to natural resource management in Kenya and recognises relevance of coordination and integration of disjointed environmental resource practices across ministries and departments as challenges ahead. Thus we propose the institution of an autonomous Watershed Management Authority with a key role in forests ecosystem conservation and a leader in resource pricing. Such an authority, if established, should liaise with conservation agencies and local communities in a way that is commensurate to the ecosystem approach to forests conservation and management. Thinking in line with the ecosystem approach, we showed how a number of factors (e.g. manpower appointment, the division of management responsibilities, distribution of revenues etc.) might affect the outcome of forest conservation. In addition, several and multi-layered players (e.g. local communities, conservation agencies etc.) have overlapping interests and are all likely to benefit from successful conservation efforts, and yet poorly communicate in practice. These issues challenge a broader set of conservation goals and unnecessarily hinder successful management of protected areas. In connection with this, we see governmental political will and genuine commitment to be critical, both in terms of improved budgetary allocation and effective enforcement of conservation policies to forest management.
As we have seen, the local communities gain their livelihoods from forest and other natural vegetation products. In spite of this, the present structure of conservation programmes in Kenya lacks coherence with local communities’ needs because regulatory control measures and policy decisions regarding natural resources are determined at national level. Even though, the success of the regional policies and long-term realisation of forest ecosystem benefits is necessarily a by-product of local actions. While recognising the centrality of forest-based resources in the economies of rural households, the inadvertent impacts of the rural households’ activities are equally crucial in shaping the ecosystem services. This brings to mind the complex links between rural welfare, rural development and the environment and hence the local communities’ direct involvement in management, while the policy decision process is central to conservation goals. Surprisingly, the key role of natural resources in addressing prevalent rural poverty is not being dealt with in the poverty reduction strategy paper (PRSP-Kenya 2000). Future efforts aimed at the promotion of efficient use and sustainable management of natural resources are central to rural development and inseparable from means for supporting the livelihoods of the poorer section of the rural populations. Such efforts should also take note of the heterogeneity in resource endowment among the seemingly homogenous households.