Water, environment and development in mountain areas and surrounding lowlands

Francis N. Gichuki

University of Nairobi

2002

Keywords: mountain communities, mountain areas, environment, biodiversity, livestock, fisheries, forests, crops, water, watershed development, climate, rainfall, socioeconomic factors, tourism, Africa.

Abstract

The mountain areas of Africa are scattered throughout the continent and occupy approximately 2,960,997 Km^2. Mountain areas of Africa have a high diversity in terms of ecological conditions, resource use, physical constraints to resource use, socio-economic characteristics of resources users, biodiversity and biodiversity and scenic beauty. The immediate challenge for sustainable development of mountain areas "is how can we slow the process, reverse the trend and move towards sustainable development in mountain areas". This paper highlights the environmental and socio-economic importance of mountain areas, the constraints and opportunities and the way forward.

Environmental benefits from mountain areas related to climate moderation, mountains as water towers and mountains as biodiversity reserves are discussed. Socio-economic benefits highlighted include settlement, food security, wood and non-wood products, water sources and hydropower, tourism and aesthetic values, cultural and spiritual values and source of livelihood to lowland communities. Threats associated with resource utilization and their causes are identified and the way forward identified.

INTRODUCTION

MOUNTAIN AREAS OF AFRICA

According to Kapos et al., 2000, mountain areas are areas with the following topographic attributes: elevation greater or equal to 2500 m, elevation range of 1500-2500 m and a ground slope greater or equal to 2 degrees, elevation range of 1000-1500 and a ground slope greater or equal to 5 degrees ground slope greater or local elevation range greater than 300 m and elevation range of 300-1000 m and a local elevation range greater than 300 m. According to

this topographical classification the total mountain area of Africa is 2,960,997 Km^2 (see Table 1).

Table 1: Mountain areas of Africa

Topographic attribute	Area in Km^2
Elevation greater or equal to 4500 m	73
Elevation range 3500-4500m	4,859
Elevation range 2500-3500	101,058
Elevation range of 1500-2500 m and a ground slope greater or equal to 2 degrees	559,559
Elevation range of 1000-1500 and a ground slope greater or equal to 5 degrees ground slope greater or local elevation range greater than 300 m	947,066
Elevation range of 300-1000 m and a local elevation range greater than 300 m	1,348,382
Total	2,960,997

Source: Kapos et al., 2000,

The mountain areas of Africa are scattered throughout the continent as shown in Figure 1. The well-known mountain ranges include those found to the North Africa, particularly the Atlas Mountains and the Saharan Highlands. The prominent mountain areas is Western Africa are the Fouta Djallon and the Mount Nimba in the Republic of Guinea, the Adamawa Highlands in Nigeria and the island mountains of Cape Verde. In central Africa, Mount Cameroon and Mount Febe and the mountain areas of the Democratic Republic of Congo (RDC) are the main mountain areas. In Southern Africa the Cape folded mountains of Drakensberg, the Table Mountains, the Soutpansberg Mountains, Thabana Ntlenyana (Lesotho Mountain) are the most prominent. In Eastern Africa, Ethiopia mountains include Mount Ras Daschan, Mount Abune Yosef, Mount Choke and Mount Guge; Central and Western highlands of Kenya which include Mount Kenya, Mount Nyambene, Aberdare and Cherangani Hills; Central and Northern Highlands of Tanzania which include Mount Kilimanjaro, Mount Meru and Usambara in Tanzania; and Mount Elgon and the Ruwenzori in Uganda. Apart from these, there are many other smaller ranges and highlands in all countries in Africa.

Figure 1: Mountain areas of Africa [figure not included]

DIVERSITY OF MOUNTAIN AREAS OF AFRICA

Due to the latitudinal location of the mountain and its geological formation, mountains areas of Africa have a high diversity which is also influenced by:

- Ecological characteristics - latitude, altitude, land form, slope, altitudinal and ecological gradient, orientation, soil, rainfall,

temperature, biomass productivity, surrounding ecosystem (lowlands or highlands), lee and windward sides;

- Physical constraint to human utilization brought about by inaccessibility, vulnerability to irreversible damage and marginality;
- Main uses of mountain resources (agriculture, tourism, forest, grazing, water catchments, hydropower generation);
- Socio-economic characteristics such as population density, literacy, level of poverty, access to resources and dependency of mountain and lowland communities on natural resources in mountain areas as the main source of their livelihood; and
- Bio-diversity and scenic beauty of the mountain ecosystem.

The mountain areas of North Africa are the only areas that receive reliable rainfall. The Moroccan mountain areas in North Africa have a higher potential than the surrounding lowlands in terms of average annual rainfall, availability of surface and groundwater to local communities and biomass production. The mountain environments are therefore superior in terms of favourable conditions for agriculture, herding and water catchments.

Equatorial mountains such as Mount Kenya, Kilimanjaro, Cameroon, and Fouta Djallon have a steep altitudinal gradient with more favourable plant production environment between 920 m and 3000-3500 m a.s.l. This altitudinal belt supports a highly diverse mountane woodlands and forests. Above the tree line is the sub-alpine (heath and moorland belt) dominated by *Philippia*, *Anthospermum*, *Artemisia* and *Stoebe*, the alpine zone made up of the alpine tussock dominated by *Helichrysum* and the alpine desert dominated by bare rock and ice.

The southern Africa regional mountains of Drakensberg, Chimanimani, Inyanga, Mulanje, Thabana Ntlenyana (Lesotho Highlands) have cool, wet and misty climate making them high water yielding catchments. Afro-sub-alpine and Afro-alpine vegetation belts occurs above 2000-2200 m a.s.l. and sub-alpine and alpine grassland and heath communities form the climax vegetation of these ecologically sensitive areas. Climatic hazards such as more than five months of frost, episodic snowfall and severe storms, hamper permanent human occupation which is nevertheless expanding.

THE CHALLENGE

Literature on mountain areas in Africa is replete with illustrations of unsustainable development attributed to increasing population pressure and poverty induced resource degradation. The immediate challenge is how can we slow the process, reverse the trend and move towards sustainable development in mountain areas. This paper highlights the environmental and socio-economic importance of mountain areas, the constraints and opportunities and the way forward.

ENVIRONMENT AND SOCIO-ECONOMIC IMPORTANCE OF MOUNTAINS

ENVIRONMENTAL IMPORTANCE

Environmental importance of mountain areas is discussed in terms of the mountain influence on local and regional climate, water resources and biodiversity.

Mountains as moderators of local and regional climate

Mountains influence the local and probably global climates. In the global and regional circulation of air masses, mountains intercept air masses and force them to rise. As the air rises, it cools and water droplets are formed thereby triggering precipitation. Part of this precipitation falls in the mountain areas and the other in the surrounding lowlands. Generally, elevation controls the quantity of rainfall at the regional scale, whereas topography strongly influences rainfall distribution at the local scale. Mountain vegetation also transpires a huge amount of water which contributes to the return of the water to the atmosphere. Forests have important functions in relation to climate. Cloud forests in mountain areas capture water that is mists and moving clouds (Hamilton, 1996). Vast forest cover helps to regulate rainfall, relative humidity, temperature and wind regimes.

Due to the altitudinal gradient, the mountains moderate the diurnal range of air temperatures and maintain atmospheric humidity levels. Due to the low temperatures and high relative humidity, mountain areas have low evaporation rates. The combination of low evaporation and higher rainfall makes highlands and mountains areas the main areas for runoff generation and groundwater recharge, particularly in the African continent which consists of extensive lowlands with scattered highlands and mountains.

Since most mountain areas have dense, vigorously growing vegetation mountain vegetation constitutes an enormous carbon reservoir and which absorb carbon dioxide thereby reducing the risk of global warming. When the vegetation, particularly the trees, are burnt or cut down, the carbon stored up over many years is released into the atmosphere, thereby increasing the level of carbon concentration in it and thus aggravating the greenhouse effect. Hence, the dense mountain and highland vegetation absorb atmospheric carbon and replenish the oxygen we breathe.

Highland and mountain areas – major source of freshwater

Mountains are important sources of freshwaters as almost all major rivers have their source in mountains. Although mountain areas constitute a relatively small proportion of river basins, they provide the greater part of the river flows downstream. Seen from a basin perspective, mountain and highland area which constitute 5-30% of the basin area can yield 30-60% of the river flows at the mouth of the river. The yield in the dry season may vary from 40-90% as the groundwater recharged in mountain areas and snowmelts are the main source of dry season flow. The Ethiopian highlands supplies as much as 80% percent of the flows into the Aswan High Dam mainly during the months of May to September while the highlands and mountain areas of Kenya, Tanzania, Burunid, Rwanda, Democratic Republic of Congo, Uganda and southern Sudan by 20% uniformly distributed throughout the year. The Fouta Djallon Highlands are of important regional significance as they contribute over 70% of the waters of Niger River.

Water balance in mountain regions is more favourable than in the surrounding lowlands. This is attributed to the high rainfall and lower evaporation rates. Analysis of rainfall data for 808 rainfall stations in Africa shows that in general rainfall increases with elevation and evaporation rate decreases with increasing elevation (Figure 2). (Mountain Agenda, 1999 reported that rainfall thus generally increases with altitude (from 5 mm/100 m to 750 mm/100 m elevation, depending on the climatic zone), reaching maximum values between 1500 and 4000 m altitude. Closer analysis of rainfall-elevation relationship of the western side (rain shadow) of Mount Kenya shows that rainfall increases with elevation up to an elevation of 3300 m a.s.l. from where it decreases as elevation increases.

Figure 2: Evaporation and rainfall as a function of altitude [figure not included]

Mountain Agenda (1999) reported that Rainfall in the headwaters of the Blue Nile and the Atbarah River in the Ethiopian mountains decreased by 9% between a first observation period from 1945 to 1964, and a second period from 1965 to 1984. At the same time, runoff decreased by 25% due to changes in the water balance. The consequences for water availability are manifold, both in the mountains and in the lowlands. These changes may be more a phenomenon of climate oscillation and land use dynamics than an effect of climate change. However, it has been noted that mountains are very sensitive to short-term and long-term climatic changes.

Mountain and highland areas also serve as natural water storage sites. Precipitation is stored naturally by retaining it as snow, ice or in mountain lakes and bogs and/or recharging the groundwater in the higher altitudes for delayed release as dry season river flow. Though the total water reserve in snow and ice in African Mountains is small, this ice stored in the snow-capped mountain peaks that plays a key role in maintaining dry seasons river flows. Mountain and highland areas also have a high potential for artificial storage.

The geomorphology of the mountains presents tremendous opportunities for constructing artificial storages to enhance the capacity of the mountain areas to store water during flood periods for release during the low flow periods. Storage of water in the mountain areas is beneficial to the foot hills and the plains through flood-control effects, from non-consumptive uses such as hydropower generation, fisheries and recreational activities (Bandyopadhyay, 1995). Due to the low evaporation in mountain areas the water loss by evaporation is also low compared to a reservoir of similar size in the lowlands. Also, where mountain areas are not degraded, water quality is high making mountain area the most important sources of un-polluted high-quality fresh water.

Mountains as biodiversity reserve

Mountain areas have a special role in the conservation of biodiversity. Different elevation gradients, slopes, orientation produce a variety of microclimates that allow unique plant and animal communities to flourish. The mountain forests are home to a high diversity of plant and animal life. Roper and Roberts, 1999 reported that mountain and highland areas contain 70 per cent of the world's vascular plants, 30 per cent of all bird species, and 90 per cent of invertebrates. In tree species alone, tropical rain forests are extremely diverse, often having more than 200 species per hectare. Mountain and highland forests are home to many of the mammals are among them, the famous elephant, buffalo, and gorillas.

In the past, the survival of these varied but fragile repositories of life has been aided by the fact that mountain areas have remained mostly inaccessible to humans. But now, protection measures such as declaring these areas as World Heritage Sites, National parks and/or protected areas are prerequisites not only for the preservation of these habitats and their bio-diversity, but also to safeguard natural, undisturbed headwater catchments.

SOCIO-ECONOMIC IMPORTANCE

Socio-economic importance of mountain areas include: human settlement, agriculture (crop, livestock and fisheries), wood and non-wood products, tourism and aesthetic values, culture and spiritual values, water source and hydropower.

Human settlement

Mountains in tropical and sub-tropical regions have more favourable environmental conditions and greater resource potential than the surrounding lowlands. Demographic maps of countries in the tropics in general, show that human settlement in the rural areas is often highly concentrated in mountain influenced areas, where living conditions are relatively more favourable and

soils are relatively fertile. According to 1994 population estimates, mountain areas supported 81, 64 and 37% of the population in Ethiopia, Kenya and Madagascar respectively. Also the Fouta Djallon Mountain and highlands areas are one of the most densely populated areas in West Africa. Over 70 per cent of this population lives in rural areas and survive mainly on land-based sources of livelihood.

Crop, livestock and fisheries production

Historically, different communities have occupied different ecological niches giving rise to distinctive cultures and ways of life (high mountain communities of hunters and gatherers; agropastoralists in the mountain slopes and highland areas; agropastoralists in the foot slopes and surrounding highlands; nomadic pastoralists in the highlands and lowlands). With advances in technology, commercialization of agriculture and lack of alternative sources of livelihood agriculture has become the back-borne of the economy in most African countries. This is particularly so where the mountain and highland areas have a high agricultural potential. Ethiopia is one such country where it was reported that in 1986, Ethiopian mountains areas accounted for 95% of regularly cropped land. Crop production accounts for over 80% of the food needs in areas suitable for agricultural production, particularly the highlands of eastern and southern Africa. Tea, coffee, ananas, maize, barley, wheat, tef, rice, cassava, pyrethrum, horticulture are the major crops grown in the equatorial mountain areas. Even with the small farm holdings (<2 hectare per household) most families are able to meet their household requirements most of the times.

"Slash-and-burn" farming which includes a diverse collection of farming systems from long fallow shifting cultivation to short fallow shifting cultivation is practiced by some of the poorest and marginalized mountain communities particularly in Cameroon and Madagascar. In times of low population density and land abundance, slash-and-burn farming has been an environmentally sustainable and economically sound alternative for growing food crops on fragile tropical soils. Typically, they cultivate less than two hectares in a year and their important crops are corn, beans, cassava, plantains, and upland rice, depending on the region. Secondary crops include coffee, cacao, citrus and other fruits, vegetables, and a few head of livestock. However, as populations have grown and land has become scarce, farming has become more intensive, making it unsustainable with diminishing economic returns. Agroforestry techniques have become a viable alternative in many regions.

Livestock production is a major source of livelihood for mountain communities. In 1986, Ethiopian mountains areas supported 67% of the Ethiopia's 70 million livestock population. Livestock contributes to food security through sale of livestock products (meat, milk and leather) and in provision of manure that enhances soil fertility. Grazing in sub-alpine and alpine grasslands of Lesotho is increasing mainly due to the high population pressure in the highland plateau.

This increase signifies the communities' dependency on the sub-alpine and alpine areas for enhancing their food security. Forests have traditionally been used as dry season grazing land. However, with increasing human and livestock population, and degradation of traditional grazing areas pressure on dry season grazing areas is increasing even during the wet periods. Where the herd populations exceed the allowable grazing capacity of the forests, the forest is degraded in terms of the specie composition and quality of the ecosystem.

Fisheries particularly in the upper reaches of mountain streams are not widely practiced but have a considerable potential for enhancing food security. In the western slopes of Mount Kenya, fresh water from mountain springs at favourable temperature is being used for trout fish production.

Wood and non-wood products

Due to more favourable climate, mountain area in the tropics have a higher biomass production creating a more suitable environment for vegetation production. Consequently, these areas are important sources of fuelwood and charcoal which accounts for 50-80 per cent of all wood used. Most of the inhabitants of mountain and highland areas derive their livelihood, directly or indirectly, from plant and animal resources found in mountain and highlands areas. Mountain forests provide us with a wide range of industrial wood products that we use in daily life -- lumber, panels, posts, poles, pulp, and paper. Mountain forests also give us a wide range of non-timber forest products, such as fibres, resins, latexes, fruits, and traditional medicines. Mountain forests are often important sources of foodstuffs, particularly in times of drought and famine when conventional agricultural crops have failed. Mountain forests are also very important sources of traditional medicine and have a potential for new pharmaceuticals drugs. The periwinkle plant from the Madagascar forests provides a drug that has proven very successful in treating lymphocytic leukemia. The bark of *Prunus africanum* in the highlands if Central Africa is now an important commodity in world trade as a pharmaceutical for the treatment of prostate disorders.

Tourism and aesthetic values

Vast areas have been set aside as national parks or game reserves in mountain areas of Africa for their scenic beauty or for the protection of the endangered fauna and flora. These areas are important destination for tourists particularly in Kenya, South Africa, Ethiopia, Tanzania, Uganda, Rwanda. These areas also contribute to food security through employment opportunities and in some case through programme aimed at revenue sharing between the park agencies and the communities. Even in areas with no wildlife, mountains are visited for their aesthetic values. Mountaineers use mountains for recreational purposes.

Water source and hydropower

The people of Africa places high hopes on water for economic transformation and the possibility of harnessing this vast potential for power generation and irrigation, and for controlling floods by constructing multipurpose storage dams on both mega and small scales. High quantities of water flowing from the mountain areas and favourable gradient make it possible to develop small hydropower plants. This potential has not been fully utilized but it present opportunities for increasing local revenue which will ultimately contribute to enhancing food security.

Livelihood for lowland communities

Mountain Agenda, (1999) reported that in 1960, there were 60 million people living in the entire Nile Basin. By 1995, the total population increased to 140 million, and it is expected to reach 300 million by the year 2025. About half of the present population depends directly on irrigation. The lowland users, Egypt and Sudan, rely up to 97% and 77%, respectively, on the water resources generated in the headwaters, approximately 80% in the Ethiopia highlands and mountain areas and 20% in the mountain and highland areas of Southern Sudan, Kenya, Uganda, Tanzania, Burundi, Rwanda and Democratic Republic of Congo. With water brings with it sediments which contribute to siltation of reservoirs, water works and canals and also provide the lowland farmland with a valuable source of nutrient laden silt.

In some mountain areas, lowland communities utilize the mountain areas as dry season grazing areas. Small mountain areas, such as Mount Marsabit and Mount Kulal in Northern Kenya lowlands are particularly useful for this purpose.

Cultural and spiritual

Mountain areas are an integral part of their culture and spiritual traditions. People throughout the world have always looked to mountains as the source of water, life, fertility, and general well being. Mountains have been, and in some places still are, worshipped as the home of weather deities and as the source of clouds and rain that feeds springs, rivers and lakes on which societies may depend for their very existence (Mountain Agenda, 1999).

THREATS AND THE DRIVING FORCES

THREATS

Land and water resources degradation

Studies in the Mount Kenya area have shown that soil resources degradation is taking place at different intensities in different locations. Soil erosion is the most extensive soil degradation problem in the upper Ewaso Ngiro North Basin (Mati, 1998). Liniger (1991), reports soil loss in small scale farming areas of

Kalalu (ferric Luvisols) and Matanya (verto-luvic Phaeozems). Within a growing season, high soil losses were reported from both crop land (24.8 t/ha) and grazing land (19.7 t/ha) for a gently sloping (5%) site. Gichuki et al., (1998) reported that the basin experiences a high soil loss as evidenced by the high suspended sediment load of 1538 ppm at Archers Post.

Reduced infiltration rate is another form of soil degradation taking place in the denuded rangelands as surface sealing and crusting takes place. In cultivated wetlands, soil degradation is taking place mainly in the form of loss of organic matter and salt build-up (salinity and alkalinity).

Water resources degradation is taking place mainly in the form of changes in flow regimes and water pollution. Changes in flow regime are taking place mainly in the form of increased flood flow peaks and reduced low flow. This is attributed to land use and management changes that reduce infiltration and ground water recharge. Decline in water yield from the glaciers on Mount Kenya and drainage of swamps have aggravated the situation. The main form of water pollution is sediment load associated with the high rates of soil erosion. Pollution by agricultural chemicals, industrial and human waste is increasing in localized areas. Destruction of riverine vegetation and drainage of swamps is reducing the natural capacity of water quality amelioration.

Degradation of vegetation resources is taking place in the mountain areas mainly through deforestation and in communal grazing areas mainly through over-grazing. Over-grazing is mainly attributed to (a) reduced access to grazing resources through agricultural expansion, urbanization, gazetting land for conservation, and insecurity in the Lower basin; (b) increasing livestock numbers; (c) increased sedentarization; (d) low productivity of grazing land; (e) conversion of swampland previously used as dry season grazing land to cropland; and (f) additional grazing pressure imposed by wildlife.

Hurni, 1990 reported that favourable climatic and ecological conditions of the Ethiopia mountain areas were the basis for the early development of agricultural systems. Gradually agriculture expanded from the gently sloping land onto the steeper slopes as forests were cleared for crop production. Cultivation of these fragile ecosystem has gradually destroyed the soil resources and the degradation processes continuous to this day in some areas. Hurni reported that Ethiopia was loosing soil at an average of 12 t ha^{-1} $year^{-1}$. Gete 19xx, reported that land use/land cover changes had occurred between 1957-1995 in the Dembecha area, Gojam, i.e. in the Northwestern highlands of Ethiopia, to cater for cereal production for local consumption and export of surplus to major cities of the country. The natural forest cover declined from 27.1% in 1957 to 1.7% and 0.3% in 1982 and 1995 respectively. The total natural forest cleared between 1957 and 1995 amounts to 7,259 hectares; this is 98.9% of the forest cover that existed in 1957.

Mountain Agenda, 1999 reported that any land use changes in the headwaters of the Nile Basin are of paramount importance to downstream irrigation. For example, land degradation in the mountains of Ethiopia has increased significantly in recent years due to expansion of agriculture, overgrazing, and subsequent soil erosion. This threatens both the local land users, through a reduction in soil productivity, and those living downstream in the lowlands, through sedimentation which has increased rapidly since the late 1960s. On average, sediment concentration in the Atbarah increased by 60% within 20 years, from 5 g/l in 1969/70 to 8 g/l in 1989/90. This will significantly reduce the original life span of Lake Nasser.

Land use intensification and soil fertility decline

Increases in human population and consumption per capita calls for increased agricultural production. Increases can be achieved through horizontal expansion (open up more land for crop production) or vertical expansion (increasing productivity per unit land through intensification). In most cases where land is available for horizontal expansion, this is the preferred option as it makes more land available and it is also cheaper. For resource poor farmers, vertical expansion (intensification) is difficult to achieve due to the high input requirements. Land use intensification puts heavy pressure on the soil resources particularly in areas with bimodal rainfall where two crops can be grown per year. Two crops per year and soil and water conservation (by increasing supply of soil moisture) increases the potential for mining of the remaining soil nutrients by crops. The problem is exacerbated by low level of nutrient replenishment due to unaffordability of chemical fertilizers and the high labor requirements of nutrient replenishment using organic fertilizers. Grosjean and Messerli, 1990 reported that mountain areas of Africa under the current conditions of low input levels, rainfed agriculture and subsistence production, loses 73% (55% loss attributed to fallow requirements and 18% to irreversible land degradation) of the climatically conditioned crop production due to soil constraints.

Declining yield and rising population

Declining land productivity associated with (a) soil degradation - the loss of the capacity of the soil to produce vegetation as a result of soil erosion, nutrient depletion, soil pollution by pesticides, nutrients and acid rain, soil compaction and crust formation (b) water resources degradation (depletion of groundwater resources, decline in water quality, sedimentation of reservoirs, increased runoff and flash floods, flooding); (c) plant resources degradation (reduced biodiversity, reduced biomass and nutritive value, reduced plant cover and growth, plant diseases); and (d) animal resources degradation (overstocking, malnutrition, animal diseases, loss of certain species, etc). The situation is aggravated by (a) prevalent poverty, marginalised and insecure livelihood systems; (b) natural resource use conflicts; (c) socio-economic and socio-

cultural diversities and disparities endangering conflict resolution and increasing power divide; (d) increasing population pressures in some areas and low population densities and high transaction costs in more remote areas; (f) low farm gate prices due to long distance to markets, poor transport infrastructure, high transportation costs and exploitation by middlemen and traders ; (g) non-optimal productivity levels and inappropriate land use systems; and inequitable allocation and access to natural resources.

Freshwater scarcity

The experiences of the upper Ewaso Ngiro North basin are use to highlight the issue of freshwater scarcity. The analysis of Ewaso Ngiro North river flow data collected at Archers Post from 1960 shows a clear trend of decreasing dry season flow (see Figure 3). During the period (1960-2000) the maximum mean annual flow recorded was 82.36 m3s-1 in 1961 and the minimum was 6.8 m3s-1 in 1980 with a mean of 20.8 m3s-1. Ten year running mean indicates that the flow has been decreasing from 1970. During the period April 1998 and December 2000, the daily mean flow peaked at 354 m3s-1 in May 1998 and dropped to zero in February 1999 (Gichuki et al., 1998). Archer's Post experiences the lowest flows in February and the mean for this month has dropped from 9 m3s-1 in 1960's to, 4.59 m3s-1 in 1970's to, 1.29 m3s-1 in 1980's to and 0.99 m3s-1 in 1990's (Liniger, 1995). The river dried up for a stretch of up to 60 km upstream of Buffalo Springs in 1984, 1986, 1991, 1994, 1997 and 2000 (Gichuki et. al., 1998). This reduction in flow is attributed mainly to increasing water abstraction upstream and drought cycles as there is no corresponding decline in rainfall amounts over the same period.

Freshwater scarcity has resulted in increasing competition for the scarce water resources and in some cases resulted in conflicts. Water related conflicts occur in the basin at the following levels: among water project beneficiaries (project level); between different water users groups (upstream vs downstream level); and between water users and environmentalists/resource managements (use vs conservation). Project level conflicts occur within a water project where the water project beneficiaries are the key stakeholders. Conflicts at this level arise from inequitable water allocation and delivery, financial mismanagement, disputes over the unfair distribution of maintenance work, failure to observe byelaws etc. Upstream vs downstream conflicts occur between irrigation and non-irrigation water users, mainly over very low dry season river flows. Conflicts at this level arises from over-abstraction of water by upstream water users, pollution of water, lack of cooperation between different user groups, disputes generated by jealousy related to growing wealth disparities, and conflicts between indigenous resource users and recent settlers. Use vs. conservation conflicts occur between those benefiting from direct use of water and those benefiting from environmental functions (e.g. tour operators/hoteliers operating in the basin). Conflicts at this level arises from environmental degradation associated with the drying up of the lower reaches

of the river, migration of wildlife to upper reaches in search of water and grazing resources and associated loss of income.

The key actors in these conflicts fall into the categories of active or passive parties. They include environmentalists, small and large scale irrigators, normadic pastoralist and commercial ranchers, downstream hoteliers and tour operators, and downstream communities (living below Archers Post).

Figure 3: Temporal variability of Ewaso Ngiro river flow at Archers Post [figure not included]

Loss of biodiversity in mountain and lowland areas

Spatial variability in altitude, rainfall, temperature, land form, soils and human interference of the Mount Kenya mountain, highland and lowland areas gives rive to the following ecosystems: (a) the moorland; (b) the mountain forests; (c) the wet and dry savannahs; (d) wetlands in drylands; and (e) game reserves in drylands. The moorland represents a unique ecosystem combining both tropical and temperate climatic conditions. The wide altitude range (3300-5200 m) and the associated land forms give rise to a wide range of habitats and associated ecological biodiversity zones. Biodiversity in this ecosystem is relatively intact due to the limited human interference. Most of the forest ecosystem (moist and dry forest and moist woodlands) is under national park or forest reserve. This ecosystem is a good habitat for a large number of mammals, birds and plant life. Over-utilization of forest products, over-grazing and conversion of forest land to crop land in the forest reserve area has resulted in localized loss of biological diversity (Gathaara, 1999). Wetlands in plateau and lowland area are unique ecosystem with flora and fauna distinctively different from that of adjacent dryland ecosystem. The small wetlands (such as Moyok and Mutara) have been reclaimed completely and the only signs of their once existence are sodic soils and macrophytes-like C*yperus latifora* and *Malenthera scadens* along the drainage canals (KWS, 1998?). Wetland ecosystem and their biodiversity is threatened by: (a) over-grazing during the dry seasons; (b) settlement in wetland areas; (c) conversion of wetland into cropland and associated degradation of soil and vegetation resources; (d) over-utilization of water resources in the upper reaches of the swamp or around swamp fringes leading to drying up; (e) water pollution due to agricultural chemical pollutants.

Savannah ecosystem can be divided into the wet and dry savannah. Wet savannah ecosystem is experiencing land use and management change from natural vegetation to settlement, crop land and grazing land. These changes are accompanied by replacement of the native vegetation with crops and selective clearing of vegetation in grazing land to improve productivity of grazing resources. In the dry savannahs, vegetation degradation associated with over-grazing and deforestation for charcoal production are the main causes of

biodiversity loss. Samburu, Buffalo springs and Shaba game reserves are dryland ecosystems reserved for biological conservation. These reserves hold a variety of large fauna and avifauna. Riverine formation and wetlands around the eyes of the springs form good habitats for a variety of plant species. Biodiversity in these ecosystems is threatened by over-abstraction of water upstream, overgrazing during drought years and vegetation destruction by elephants.

Risks and uncertainty

Mountain farming, for instance, is always risky business, with yields that could never match those achieved in lowland areas where temperatures, length of growing season, and soil conditions are more favourable. Access to markets (for agricultural products, lumber and minerals, and migrant labour) is also problematic, since the cost of building and maintaining roads is usually exorbitant in the mountains. In addition, there are the ever-looming hazards of avalanches, landslides, and slope failure, which discourage economic activity and increase costs.

DRIVING FORCES

Demographic forces

Over the last 50 years, mountain areas have experienced an unprecedented rate of population growth attributed to normal population growth and in-migration brought about by planned settlement schemes and spontaneous settlement. Spontaneous settlement is attributed to labor demand for the forest sector (planting and caring of plantation trees and harvesting of natural and plantation trees), commercial agriculture, and tourism and to road development in mountain areas. Temporary settlement is common in area where lowland pastoralist move to mountain areas for drought period grazing.

The pressure on mountain resources due to increased dependency on mountain resources has in many places not resulted in increases in resource productivity through technological innovations partly due to inaccessibility, fragility, and marginality of the production system. As a consequence, high pressure on the stagnant subsistence-based production system has produced changes in the resource-use pattern, land use intensification and use of marginal areas as cropping is extended to steeper and more fragile slopes and overstocking and overgrazing emerge as dominant patterns of livestock management. The end result is in some cases environmental degradation.

Market forces

Since the introduction of cash crop agriculture and the opening of mountain forest for commercial logging, mountain areas have become better integrated with external markets mainly through the development of transport

infrastructure. This has lead to the transformation of the predominantly subsistence hill economy into integrated wider market economies. This has been made possible by commercialization of production systems within mountains, and linkage of the mountain economy with the mainstream market.

An increase in the extent of high-value cash crops (tea, coffee, vegetables, fruits), supported by new technologies, increased local and foreign investment and government support and by the profitability of the production systems has encouraged further commercialization of agriculture.

However, the commercial orientation has introduced imbalances in land-use patterns as better land is put under profitable cash crops and staple food crops (e.g. maize) are pushed to marginal land with low productivity. Cash crops also receive a high level of labour and farm input than food crops. This has in some cases led to localized food shortages.

The promotion of external market linkages has been driven by the need to transform or develop these areas by harnessing the mountains' comparative advantages in some products and activities, particularly horticulture, tourism, irrigation, and hydropower production. In some cases, the new market links produce an exchange between unequals and lead to exploitation of the farmer by middlemen. Consequently, mountain niches are viewed as virgin opportunities ripe for plundering and the process leads to over-extraction of mountain resources with adverse environmental and economic consequences.

Products of natural ecosystems are undervalued because: (a) they produce many different products that are consumed in many unrelated markets often outside the cash economy, thereby creating the perception that they are less important; (b) they produce many non-market goods (e.g. forest food, game, resins, fibres) and environmental services (e.g. climate control, water regulation, soil conservation) that do not enter into the national economic accounts; (c) "downstream" benefits of "upstream" conservation are enjoyed but not paid for by beneficiaries; (d) the harvest cycle (rotation) of natural forests in the tropics is very long compared to agricultural crops, even outside the realm of conventional commerce; (e) the establishment of natural forests incurs no direct costs for the exploiter hence; they are viewed as "free" commodities; (f) there is still much unknown about the potential value of the forests, a consequence of the lack of systematic research, (g) market knowledge is imprecise, except for the traditional timber products, (h) prices are often set by monopolies (government or private sector) and do not necessarily reflect society's value of forest products and services, (i) forests are important to the rural poor, a social group that has little political influence and therefore little economic influence (Roper and Roberts, 1999).

Technological and information factors

Introduction of modern technologies have had both positive and negative impacts. Introducing high yielding varieties was expected to increase crop yields without increase the cropped area. However, in some areas, an emphasis on cash crops and high-yielding food crops and high use agricultural inputs has reduced agricultural bio-diversity and introduced negative side-effects on the environment. Inappropriate land use, low levels of external inputs and inadequate improvements in human skills and an absence of non-agricultural activities lead to low levels of production.

The following information failures have made the situation worse: (a) unused innovative capacities, knowledge and skills, (b) inadequate data, information and knowledge on mountain resources and their values and on practices, tools and instruments that can promote sustainable mountain area development, and (c) inadequate mechanism for dissemination of existing indigenous and scientific knowledge.

Institutional factors

Government intervention in mountain areas include implementation of development projects (mainly transportation, schools, health and water infrastructure), promotion of cash crops and in setting up institutional framework (policy, legislation and organizational mechanisms). Government intervention has had little impact on balancing supplies with demands on mountain resources as with the increasing development efforts and there has been an increase in competition for mountain resources particularly water and forest products. Institutional failure has contributed in the following ways:

- Inadequate human and institutions capacities attributed to high level of illiteracy; inadequate financial resources allocated to government institutions and inadequate monitoring and evaluation
- Un-conducive policies and poor governance characterized by (a) inadequate government resources allocated to mountain areas, (b) corruption and inefficient use of government resources, (c) inadequate empowerment of local communities and their organizations, (d) conflicts, instability, lack of capacity and coordination among formal institutions, and (e) social and ethnic tension
- Inadequate and/or ineffective development cooperation characterized by (a) inadequate foreign investment in mountain areas, (b) inadequate involvement of mountain communities in planning and implementation of development projects, (c) and inadequate community-private sector-government partnerships in economic development
- Under-developed infrastructure such as (a) poor road infrastructure and in-accessibility of some areas; (b) high cost of transport infrastructure development; (c) under-developed hydropower potential; (d) under-utilized solar and wind energies; (e) under-developed

telecommunication and internet facilities; (f) poor housing and inefficient water delivery infrastructure

Interaction of demographic, technological, market and institutional forces

Studies in Machakos highland areas of Kenya have shown that population density and land:labour ratio are critically important because they determine the type of farming and livestock care that is practiced, and the labour resources available for remedial measures (Tiffen et al., 1994). A low population density soil and water conservation measures are neither desired nor feasible. At low population densities <= 30 persons per km^2, low input agriculture is practices until its fertility falls, when it will be allowed to revert to bush and new land will be opened. Under this conditions the scarce resource is labour, and investment in soil conservation, herding and fencing do not pay. A scattered population, poor because of distance from markets, can make little impact on major problems of land degradation. Measures that increase yield but required more labour than available are rarely adopted. In most of these low-density areas, where farming is unprofitable, most of the men will be away living the villages mainly inhabited by old men, women and children who may have little incentives to invest in resource conservation.

As population density increases, the fallow period shortens, initially increasing fertility problems. There may still not be enough cash generation to buy in fertiliser, or enough labour to invest in land improvements. Deterioration of the land may be apparent, but farming may still not be very profitable. Improving access to markets may be a first necessary step to give people the incentive to put more capital and labour into farming. Indeed a new main road may attract more people to settle, creating the competition for land that gives it value and makes people willing to invest work in it. By the time population densities reach 70-100, new inputs become both feasible and profitable, and the scarce factor becomes land rather than labour. At this point farmer become interested in the return to land, the yield per hectare. He or she will be experimenting with various methods to improve yield and farm income. Livestock will be carefully controlled, to avoid damage to crops, and to generate manure. New ideas for soil improvement and water management will be welcomed, and tested to see how they compare with existing techniques. If they are profitable, these new ideas will be adopted.

TOWARDS SUSTAINABLE MOUNTAIN WATERSHED DEVELOPMENT

Solutions to the challenge of supporting more people on the limited and in some cases degraded natural resources calls for a thorough search for “win-win” solutions in which intervention results in measurable benefits to both humans and nature. Where “win-win” solutions cannot be found, losers may need to be compensated. Some of the actions required are discussed below.

PARTNERSHIPS

Partnerships should be established between governments, NGOs, private sector organisations and communities involved in decision making and management. These partnerships should facilitate multi-sectoral and multi-disciplinary initiatives. Based on this, the participation of stakeholders should be improved while governance is strengthened. Urgent partnerships are required in addressing the following issues:

1. Intergovernmental partnerships to address trans-boundary environmental management issues;
2. Partnership between scientists and resources uses to facilitate efficient generation and dissemination of research results;
3. Partnerships among sectors in order to promote integrated development; and
4. Partnerships in combating poverty, corruption and to promote good governance.

INFORMATION GENERATION AND DISSEMINATION

Monitoring of natural resources and their use, and assessment of the impact of land use change in the highlands on the availability and quality of water in the lowlands are the first steps towards successful water resource management. Another challenging step is to develop management tools that allow prediction of the impacts of future human activities upstream on the availability and use of resources downstream. Dissemination of the information gathered, together with the creation of awareness of water resource issues and the involvement of the different upstream and downstream users in water resource management, are prerequisites for improvement. The main challenges are the search for efficient use of the mountain water resources, equitable distribution of the scarce water, and effective water and land management and policing of water use to secure a stable water supply for the downstream users.

Support education and awareness-building about mountain issues: More support must be given to public education and awareness-building campaigns. Using both environmental and socioeconomic messages, campaigns must target the general public and the political/economic decision makers. Awareness-building must reach audiences living in the rural and urban areas, men and women, adults and children, rich and poor. Decision-makers in developing countries must understand the causes and consequences of natural resources mismanagement, the potential benefits of sustainable use, and the appropriate, alternative actions they can take. Campaigns must be based on sound, quantifiable arguments on the economic and social benefits of wise use of the mountain areas and the high costs of natural resource degradation. It is only through an informed public and informed leadership that the political will

can be found to make the tough policy decisions required (Roper and Roberts, 1999)

STAKEHOLDERS PARTICIPATION

Some past initiatives failed to arrest deforestation because they were conceived without the true participation of all interest groups (communities, companies, local government, and other land users) in their planning and execution. Controlling deforestation must take into account the special interest groups from within the forest sector and the other sectors that share, and at times compete for, the same land base. Furthermore, the formal involvement of natural resource user groups in government decisions on the allocation and use of forests would contribute to reducing corruption in government (Roper and Roberts, 1999) Of particular importance is deciding on a just formula for sharing in the benefits and responsibilities that derive from using forest resources sustainably as an alternative to deforestation (Roper and Roberts, 1999)

MULTI-SECTORAL, MULT-STAKEHOLDER, MULTI-LEVEL APPROACH

The need for a multi-sectoral, multi-stakeholder, multi-level approach is required in the agriculture, forestry and conservation, energy, and water sectors. Win-win situations are possible when agroforestry is used as a tool for soil conservation, when the health sector uses the management of micro-catchments for potable water supplies, when watershed management is used to improve water flows to irrigation systems and when improved firewood supply satisfies energy needs. Supporting the formation and functioning of natural resources user groups would be a positive step to enhancing participation. Natural resources must be managed more holistically, recognizing the interdependence of all sectors (Roper and Roberts, 1999).

IMPROVED INSTITUTIONAL FRAMEWORK

Incentives that encourage deforestation and other destructive land use practices should be reformed and replaced by policies that encourage the sustainable use of natural resources. Reforms to natural resource policies and other policies affecting forest lands should be given the highest priority. Before project-level or community-level interventions can have a meaningful effect, national policies must encourage sustainable management of forests. Forest policies should reflect the environmental importance of the forests as well as their economic value and the appropriate roles of the public and private sectors in implementing the policies. The adoption of national-level criteria and indicators would provide a policy framework for sustainable forest management. Several countries in African have or are in the processes of setting up environmental management agencies to streamline and harmonize natural resources conservation.

There is need to establish effective natural resource accounting within national economic planning which recognizes the true value of forest products and services as well as the costs of liquidating existing natural resource capital.

Land-use policy reforms are needed to secure long-term commitments to sustainable natural resources management. Adequate resource tenure systems must be adopted that provide security of supply for producers while protecting long-term public interests and ensuring a stable environment. In the agricultural sector, small farmers require secure tenure to invest in farm productivity. This will help relieve some of the pressure to deforest. Caution must be exercised when implementing a land titling program to avoid land speculation (Roper and Roberts, 1999).

BETTER SOCIAL AND ECONOMIC VALUATION OF MOUNTAIN RESOURCES

The long-term future of the natural resources and the associated environmental health depend largely on how people perceive the natural resources. If they are considered worthless, mere impediments to the economic growth and prosperity of other sectors; natural resources will surely be degraded in a matter of a few generations. If these resources are to be sustainably utilized, they must be of value to the people who might otherwise destroy them and the benefits derived from them must be distributed fairly.

Traditionally, natural resources have been undervalued. By not collecting natural resources user taxes that reflect the true value of the resource and the cost of managing it, governments have discouraged sustainable management and the long-term investments needed to make more productive. Resource use fees, destruction penalties, and other forms of revenue should, at a minimum, provide the state with sufficient revenues to manage the natural resources and, if possible, generate surplus revenues for the public treasury. Enhancing benefits: Natural resources-derived benefits can be enhanced by: adopting tenure systems that recognize co-management of the resource by the government and local communities; by making more efficient use of the resource (more species and greater recovery per species); by recognizing the important role that mountains play in human survival; by more effectively marketing natural resource products; by capitalizing on the ecotourism potential in the mountain regions; by adopting policies that provide society a fair return from the exploitation of its natural resources; and by ensuring long-term management of the natural resources (Roper and Roberts, 1999)

PROTECTING THE WATER CATCHMENTS

The stability of mountain fresh water flows depends upon maintaining the integrity of watersheds. This calls for conservation of mountain forests as they are particularly important to maintaining a steady supply of fresh water to

downstream areas. The specific action would include (Byers, 1995 and Born and Genskow, 2001):

1. Protection of natural forests and riparian buffer zones due to their significant environmental functions of water recharge and yield, habitat for plants and animals that threatened by forest clearing, reducing erosion, improving the habitat for aquatic life, providing corridors for wildlife, and providing shade, scenic beauty, and recreation possibilities.
2. Appropriate land use to reduce or avoid destabilizing or erosive activities, such as inappropriate mining, logging, road construction, non-sustainable agriculture and over-grazing and introduction of pollution control programmes.
3. Carry out systematic monitoring of climate, hydrology, ecosystems, land use and productivity in order to keep track of changes and detect and act on them before it is too late.
4. Raise awareness of mountain and lowland communities of the full economic and environmental costs of water. Emphasize the role of forests, riparian buffers, and the special case of cloud forests, in water conservation.
5. Identify and implement small-scale alternatives to large water storage systems for water supply, energy production, flood control, and irrigation. Special attention should be given to those activities that increase access by mountain communities to water and its benefits (clean drinking water, water for sanitation, irrigation water, hydroelectricity, and revenues from water use by downstream consumers).
6. Provide a conducive institutional environment through participatory policy formulation, participatory development of a legislative platform and law enforcement and having organizations that are well coordinator, enhance stakeholders participation and focused on improving the welfare of mountain communities.

COMPENSATE THE MOUNTAIN COMMUNITIES FOR THEIR CONSERVATION EFFORTS

It is essential that mechanisms are put in place to compensate mountain people for the benefits their homelands provide to lowland regions. Some of the revenues generated by mountain-based hydoelectric projects, for instance, should flow back to the highland communities - rather than merely enriching the lowland cities that use the power. These fairer economic arrangements will require, in turn, that mountain dwellers have a greater voice in decision-making.

References

1. Bandyopadhyay, J. 1995. *The Mountains and Uplands as Water-Towers for Humanity: Need for a New Perspective in the Context of the 21st Century Compulsions*. International Academy of the Environment. Geneva, Switzerland. 4 pp.
2. Bandyopadhyay, J., Kraemer, D., and Kundzewicz, Z.W. 1997. *Mountain Water Resources-The Need for Their Proper Assessment*. International Academy of the Environment and World Meteorological Organization. Geneva, Switzerland. 15pp.
3. Born S.M., and Genskow K. D., *2001: Towards understanding New Watershed Initiatives*. A report from the Madison Watershed Workshop, held on July 20-21, 2000 in Madison, Wisconsin, University of Wisconsin-Madison, USA.
4. Byers, E. 1995. *Mountain Agenda: Environmentally Sustainable and Equitable Development Opportunities*. Invited paper for the International NGO Consultation on the Mountain Agenda, February 1995, Lima, Peru. The Mountain Institute, Franklin,USA.
5. Gichuki F.N., and Liniger H.P., MacMillan L. Schwilch G., Gikonyo G. 1998b: Scarce water: Exploring resource availability, use and improved management. In: *Resources, actors and policies – towards sustainable regional development in the highland – lowland system of Mount Kenya*. Eastern and Southern Africa Journal, Vol. 8, Special Number, 15-28, Nairobi.
6. Hamilton, L.S. 1996. The role of protected areas in sustainable mountain development, in *Commission on National Parks and Protected Areas of IUCN - The World Conservation Union*.
7. Kapos V., Rhind J., Edwards M., Price M. F., and Ravilious C., 2000: Developing a map of the world's mountain forests. In M.F. Price and N. Butt (eds) *Forests in sustainable mountain development: A state-of-knowledge report for 2000*. CAB International, Wallingford.
8. Liniger (1991), *Water Conservation for Rainfed Farming in the Semi-arid Footzone Northwest of Mt. Kenya: Consequences for the water balance and soil productivity*. Laikipia-Mt. Kenya Papers D-3. Nanyuki (Kenya).
9. Mountain Agenda, 1999: *Mountains of the World: Water Towers for the 21st Century*, Mountain Agenda, Bern, 48 pp.
10. Roper J. and Roberts R. W., 1999: *Deforestation: Tropical Forests in Decline*, CIDA Forestry Advisors Network paper
11. Tiffen M., Mortimore M., and Gichuki F., 1994: *More People, Less Erosion: Environmental Recovery in Kenya*. John Wiley, West Sussex, England

---

Notes to readers

This paper was given at the Africa High Summit Conference, UNEP, Nairobi, 6-10 May 2002.