3 Importance of Biodiversity

Humanity depends upon components of biodiversity for all of its food and much of its medicine and industrial products. Residents in the Eastern Arc Mountains use many native plant and animal species for medicines, food, building materials, and household items. These forests also contain many other species, particularly microorganisms, which could yield important new products and medicines. However, few species here have yet been carefully screened for medicinal or other commercial properties. It is quite likely that many of the lesser-studied organisms in the Eastern Arc Mountains may prove ultimately to be among the more important economically.

3.1 Medicinal Plants

In the Eastern Arc Mountains, wild plants are the primary if not the only source of medicine for many people. In most villages, the individuals most knowledgeable about the medicinal value of wild plants are traditional healers. It is estimated that Tanzania has 30,000–40,000 traditional healers, compared to 600 Western-trained doctors, who practice primarily in the cities (Hedberg et al. 1982). Traditional healers in Tanzania use many plants and plant parts in their remedies.

In a survey of five villages in the East Usambara Mountains, Ruffo et al. (1989b) found that traditional doctors used 185 plant species to treat 63 different diseases and conditions. Some of the more commonly treated conditions included asthma, convulsions, impotence, infertility, and stomach ailments. They also noted that of these 185 plant species 34 % were forest species. The families of plants that contain the highest numbers of species with medicinal properties are Moraceae, Euphorbiaceae, Rubiaceae, Meliaceae, Rutaceae, and Sapindaceae.

In the West Usambara Mountains, Flueret (1980) recorded that traditional healers in one village used 93 species of medicinal plants to treat 22 major ailments including gastro-intestinal disorders and parasites, pain, sores, coughs, and eye infections. During the early 1980s, a team of Swedish and

Table 3.1. Plants with traditional medicinal uses occurring in the Usambara Mountains. Nomenclature follows Iversen (1991a). (Hedberg et al. 1982, 1983a,b)

Species	Treated diseases and symptoms
ACANTHACEAE	
Justicia englerana	Nausea, swollen liver and spleen
AMARANTHACEAE	
Achyranthes aspera	Diseases of the spleen, stomach ache
ANACARDIACEAE	
Ozoroa insignis	Bilharzia
Rhus natalensis	"Drive out the devil"
Rhus vulgaris	Painful menstruation
Sorindeia madagascariensis	Mental illness
ANNONACEAE	
Annona senegalensis	Abdominal pain, snake bites, abscesses
Monanthotaxis fornicata	Mental diseases
Uvaria acuminata	Mental diseases, convulsions in children
Uvaria leptocladon	Epileptic-like attacks
Uvaria lucida	Constipation, stomach pain, mental disease
APOCYNACEAE	
Diplorhynchus condylocarpon	Rectal prolapse
Voacanga africana	Kidney ailments, frequent menstruation and urination
ASCLEPIADACEAE	
Parquetina nigrescens	Dysmenorrhea
BERBERIDACEAE	
Berberis holstii	Jaundice
BIGNONIACEAE	
Kigelia africana	Male sterility, aphrodisiac, excessive menstrual bleeding
Markhamia obtusifolia	Tachycardia
BOMBACAEAE	
Adansonia digitata	Vaginal bleeding
BORAGINACEAE	
Ehretia amoena	Fungus infections, diarrhea, abdominal pain
Tichodesma zeylanicum	Coughing
BURSERACEAE	
Commiphora africana	Stomach problems
Commiphora pteleifolia	Abdominal pain, excessive menstruation
CAPPARIDACEAE	
Boscia salicifolia	Antidote for poisoning, tuberculosis
Capparis erythrocarpus	Child convulsive fever
Maerua angolensis	Miscarriage
Maerua triphylla	Antidote for poisoning
CELASTRACEAE	
Maytenus heterophylla	Dysmenorrhea

Table 3.1 (*continued*)

Species	Treated diseases and symptoms
COMBRETACEAE	
Combretum collinum	Excessive menstrual bleeding, rectal prolapse
Combretum exalatum	Excessive menstrual bleeding, "drive out the devil"
Combretum molle	Diarrhea, abdominal pain
Combretum pentagonum	Hernia
Combretum xanthothyrsum	Mental illness
Combretum zeyheri	Diarrhea, vomiting
Pteleopsis myrtifolia	Sterility, infertility
Terminalia kilimandscharica	Asthma, cough, back and loin pain
COMPOSITAE	
Conyza pyrrhopappa	Convulsions in children, chest infections
Dichrocephala integrifolia	Bloody diarrhea, stomach ulcers
Microglossa pyrifolia	Epilepsy
Pluchea dioscorides	Sterility, impotence
Psiadia punctulata	Epilepsy
Vernonia colorata	Leg, arm, chest swellings
Vernonia hildebrandtii	Mental diseases
Vernonia lasiopus	Produce lactation, purify milk of lactating women
Vernonia usambarensis	Excessive menstruation
CUCURBITACEAE	
Momordica calantha	Asthma, headache, stomach ache
EBENACEAE	
Euclea divinorum	Stomach pains, constipation
EUPHORBIACEAE	
Acalpyha fruticosa	Skin diseases
Bridelia cathartica	Protruding rectum
Clutia abyssinica	Dizziness
Croton polytrichus	Impotence, "drive out the devil"
Croton pseudopulchellus	"Drive out the devil"
Euphoriba heterochroma	Tuberculosis, coughing
Macaranga capensis	Mental illness
Margaritaria discoidea	Miscarriage
Phyllanthus reticulatus	Venereal diseases, diarrhea
Spirostachys africana	Induce diarrhea and vomiting, stop severe diarrhea, intestinal parasites
Suregada zanzibariensis	Infectious skin disease
Synadenium glaucescens	Severe cough
FLACOURTIACEAE	
Trimeria grandiflora	Body and mouth sores
LABIATAE	
Hoslundia opposita	"Drive out the devil", stomach pain, excessive menstrual bleeding, vomiting, diarrhea, polio, convulsions in children, stomach pains, swelling of genitals
Hyptis suaveolens	Convulsions in children
Plectranthus assurgens	Cheek and face swelling

Table 3.1 (*continued*)

Species	Treated diseases and symptoms
LEGUMINOSAE CAESALPINIOIDEAE	
Tamarindus indica	Vomiting
LEGUMINOSAE MIMOSOIDEAE	
Acacia polyacantha	Asthma
Albizia anthelmintica	Sterility
Albizia glaberrima	Bilharzia
Albizia versicolor	Sinusitis
Dichrostachys cinerea	Emetic, snake bite
LEGUMINOSAE PAPILIONOIDEAE	
Abrus precatorius	Asthma, aphrodisiac, impotence
Cajanus cajan	Stomach ache
Crotalaria zansibarica	Otitis
Dalbergia melanoxylon	Abdominal pain, hernia
Dolichos trilobus	Cataracts
Lonchocarpus bussei	Infertility, palpitation, bilharzia, quicken labor
LOGANIACEAE	
Strychnos spinosa	Stomach pains
MALVACEAE	
Hibiscus micranthus	Snake bite, convulsive fever in children
Sida rhombifolia	Miscarriage
MENISPERMACEAE	
Cissampelos pareira	Diarrhea, miscarriage
MYRICACEAE	
Myrica salicifolia	Cheek and face swelling, coughing
PASSIFLORACEAE	
Adenia gummifera	Sterility
POLYGALACEAE	
Securidaca longepedunculata	Gonorrhea, palpitations
POLYGONACEAE	
Rumex usambarensis	Bilharzia
RHAMNACEAE	
Scutia myrtina	Gonorrhea, bilharzia
Ziziphus mucronata	Asthma
RUBIACEAE	
Crossopteryx febrifuga	Constipation, asthma
Vangueria infausta	Genital swelling
RUTACEAE	
Vepris eugeniifolia	Kidney disorders

Table 3.1 (*continued*)

Species	Treated diseases and symptoms
SAPINDACEAE	
Allophyllus rubifolius	Chest and rib swelling
Deinbollia borbonica	Headache, constipation, gonorrhea, stomach ache, vomiting, mental illness, dysenteric diarrhea, rapid heart beat, nervousness
SAPOTACEAE	
Pachystela msolo	Lactagogue
SIMAROUBACEAE	
Harrisonia abyssinica	Hernia, stomach pain, swelling in male genitals
SOLANACEAE	
Solanum incanum	Vomiting, diarrhea
STERCULIACEAE	
Dombeya shupangae	Amenorrhea
Sterculia appendiculata	Bloody stools, rectal prolapse
Waltheria indica	Infected wounds, convulsions in children
UMBELLIFERAE	
Steganotaenia araliacea	Abdominal pains plus constipation
VERBENACEAE	
Lantana camara	Stomach ache and vomiting in children, skin rashes and itching
Lantana viburnoides	Infertility
Premma chrysoclada	"Drive out the devil", snake bite, mental illness
Vitex payos	Infertility
VITACEAE	
Cyphostemma adenocaule	Stomach pain, excessive menstrual bleeding, migraine headaches, mental disease, wounds
Rhoicissus revoilii	Miscarriage

Tanzanian researchers (Hedberg et al. 1982, 1983a,b) described more than 150 species of medicinal plants that grow in northeastern Tanzania and are used by traditional healers. Nearly 100 of these species are found in the Usambara Mountains (Table 3.1).

Although within Tanzanian villages, traditional healers are the individuals with the most extensive knowledge about medicinal plants, many villagers actively collect and grow their own medical plants. Flueret (1980) found in one village in the West Usambara Mountains that nearly one half of the households use one or more herbal medicines on a daily basis. She also noted that villagers regularly cultivate medicinal plants around their houses. In the East Usambara Mountains, Woodcock (1995) found that more than one half of the households in the ten villages she surveyed grew medicinal plants around their homes.

The exact number of plants that traditional healers and residents in the Eastern Arc Mountains use as medicines is unknown. However, based upon

descriptions of plant use (Flueret 1980) and the number of recorded plant species (n=2960; Iversen 1991a) in the Usambara Mountains, the number may be as high as one quarter to one third of all indigenous plant species. Flueret (1980) reported that Cory collected over 1000 species of medicinal and toxic plants in the West Usambara Mountains during the 1930s. She also reported that Williams (1963) included within a dictionary of Shambaa (the ethnic group residing in the Usambara Mountains) 1600 plant names, of which a majority are reported to have medicinal value.

A number of plants that grow in the Eastern Arc Mountains have been screened as sources for new drugs. The following plants, three of which are used by traditional healers, are known to contain useful pharmaceutical compounds (Kokwaro 1976; Vickery and Vickery 1979; FAO 1986):

Achyranthes aspera (Amaranthaceae) has a pantropical distribution and occurs throughout the Eastern Arc Mountains. This species reportedly contains a cardiac stimulant, and extracts of this plant are fungicidal.

Artemisia afra (Compositae) is restricted to montane regions of eastern and southern Africa and contains a chemical compound useful in the treatment of intestinal parasites.

Datura metal and *D. stramonium* (Solanaceae) are found throughout most of Africa and the Eastern Arc forests. These species contain a number of alkaloids useful in the production of atropine, which is used to dilate pupils and is important in eye surgery. Atropine is also used as an antispasmodic, a sedative, to treat diarrhea and as an antidote to organophosphorus compound poisoning.

Maesa lanceolata (Myrsinaceae) is a tree found throughout the Eastern Arc Mountains. This plant contains an antibiotic, and is used locally to prevent cholera and to treat intestinal parasites.

Milicia excelsa (Moraceae) is a tree that occurs throughout the Eastern Arc Mountains. A fungicide has been extracted from its wood.

Ocimum suave (Labiatae) occurs throughout sub-Saharan Africa in primarily savannah habitat. It is found in lowland regions of many of the Eastern Arc Mountains. Chemical compounds derived from this plant have disinfectant and insecticidal properties. In addition, a chemical constituent of this plant has been used by dentists as an oral analgesic and topical anesthetic, and as an alternative to clove oil.

Rauvolfia caffra (Apocynaceae) has a geographic distribution encompassing much of eastern, central, and southern Africa between 500 and 2100 m. An alkaloid extracted from the plant has been used to treat hypertension and

schizophrenia. In addition, it is thought to contain an alkaloid useful in treating malaria.

Solanum incanum (Solanaceae), a shrubby perennial, is widely distributed in sub-Saharan Africa and in the Eastern Arc Mountains. Native groups use the plant to treat snake bites, jiggers, ringworms, and syphilis. This plant is also thought to contain a powerful anti-fungal compound.

3.2 Food Plants

Wild plants and mushrooms comprise an integral and significant proportion of the diets of many people living in the Eastern Arc Mountains. Flueret (1979a,b) studied the diets of residents in three villages in the West Usambara Mountains during the mid-1970s. She found that the single most common accompaniment to the staple high carbohydrate diet of maize and cassava is green leafy plants – which are referred to in Swahili as *michicha*. Villagers eat

Table 3.2. Green leafy plants eaten by local people in six villages in the East and West Usambara Mountains. (Flueret 1979b; Woodcock 1995)

Species	Shambaa name
ACANTHACEAE	
Justicia heterocarpa	*Ungobo, ungoto*
AMARANTHACEAE	
Amaranthus spp.	*Bwache, mchicha*
BASELLACEAE	
Basella alba	*Ndelema*
CHENOPODIACEAE	
Chenopodium opulifolium	*Shekazeu*
Chenopodium sp.	*Mshughukumba, mshumbuu*
COMPOSITAE	
Bidens pilosa	*Mbwembwe*
Compositae (unknown sp.)	*Komba*
Sonchus luxurians	*Msunga*
Sonchus oleraceus	*Kwake, pwake*
CUCURBITACEAE	
Momordica foetida	*Ushwe*
SOLANACEAE	
Solanum nigrum	*Mnavu*
Solanum sp.	*Zinge*

both cultivated vegetables and wild leafy plants (Table 3.2) as *michicha*. Of the 2248 meals that she observed, wild leafy plants were eaten in 25 % of these meals. The genera of wild plants eaten in the West Usambara are known from other studies in Africa to contain significant amounts of carotene, calcium, iron, and protein and, thus, Flueret (1979a) was able to demonstrate that wild plants are important sources of nutrients for residents in the West Usambara. Fieldwork in the East Usambara Mountains has also documented that villagers eat wild green leafy plants, and not surprisingly, residents here eat the same species of plants as are eaten in the West Usambara Mountains (Woodcock 1995). Härkönen and Vainio-Mattila (1998) have identified 73 plant species, representing 26 families, that are eaten as *michicha* by residents in the East and West Usambara Mountains (Fig. 3.1).

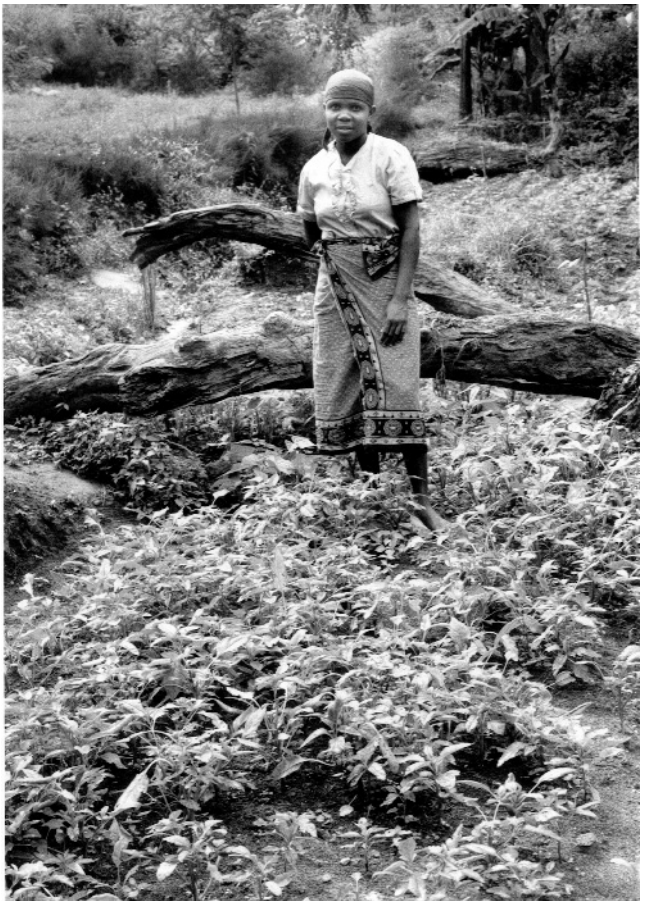

Fig. 3.1. Many residents in the Eastern Arc Mountains raise wild leafy plants. These plants are important sources of nutrients

Table 3.3. Plants whose fruits are eaten by residents in the Eastern Arc Mountains. (Flueret 1979b; FAO 1983; Ruffo 1989)

Species	Vernacular
ANACARDIACEAE	
Sorindeia madagascariensis	*Mpiripiri* (Swahili), *mkwingwina* (Shambaa)
ANNONACEAE	
Annona sengalensis	*Mchekwa* (Swahili)
APOCYNACEAE	
Landolphia kirkii	*Ugoroto* (Shambaa)
Saba comorensis	*Mbungo* (Swahili), *mbungo* (Shambaa)
BOMBACACEAE	
Adansonia digitata	*Mbuyu* (Shambaa)
CHRYSOBALANACEAE	
Maranthes goetzeniana	*Ng'anga* (Shambaa)
Parinari excelsa	*Muula* (Shambaa), *mbura* (Swahili)
COMBRETACEAE	
Terminalia sp.	*Kungu* (Shambaa)
FLACOURTIACEAE	
Flacortia indica	*Mchongoma* (Swahili)
ICACINACEAE	
Alsodeiopsis schumannii	*Mnozambeya* (Shambaa)
LOGANIACEAE	
Strychnos cocculoides	*Mtonga* (Swahili)
Strychnos spinosa	*Tonga* (Shambaa)
MORACEAE	
Ficus sp.	*Kuyu* (Shambaa)
Myrianthus arboreus	*Konde* (Shambaa)
Myrianthus holstii	*Mkonde* (Shambaa)
MYRTACEAE	
Syzygium cordatum	*Mshihwi* (Shambaa)
Syzyium guineense	*Mzuari* (Swahili), *mshihwi* (Shambaa)
Syzygium jambos	*Zambarau* (Shambaa)
OLEACEAE	
Ximenia caffra	*Mtundwa* (Hehe)
RHAMNACEAE	
Berchemia discolor	*Mnago* (Swahili)
ROSACEAE	
Rubus apetatus	*Mashawa* (Shambaa)
Rubus spp.	*Mshaa* (Shambaa)
RUBIACEAE	
Vangueria infausta	*Mviru* (Shambaa)
Vangueria linearisepala	*Mviru* (Swahili)
Vangueria madagascariensis	*Mviru* (Shambaa)

Table 3.3 (*continued)*

Species	Vernacular
APOTACEAE	
Manilkara obovata	*Mumbulu* (Gogo)
Pachystela msolo	*Msambia* (Shambaa), *msavia* (Swahili)
STERCULIACEAE	
Cola scheffleri	*Msamaka* (Shambaa)
VERBENACEAE	
Vitex doniana	*Mfuu* (Swahili)
Vitex ferruginea	*Mtalali* (Swahili)
Vitex payos	*Mfuu* (Swahili)
PALMAE	
Phoenix reclinata	*Kindu* (Shambaa)

Wild green leafy plants are also economically important to many villagers and particularly women. In the Usambaras, young unmarried women, elderly widows, and divorcees almost exclusively sell wild eatable plants (Flueret 1979a; Woodcock 1995). For these individuals, wild plants provide an important source of income for purchasing other food and household items.

Residents in the Eastern Arc Mountains extensively collect mushrooms, which are considered a delicacy (Flueret 1979a; Kiwasila and Odgaard 1992; Härkönen et al. 1995; Härkönen and Vainio-Mattila 1998). In the early 1990s, a team of Finnish and Tanzanian scientists conducted a survey of the distribution and use of mushrooms in Tanzania (Härkönen et al. 1993a,b,c, 1994, 1995, Saarimäki et al. 1994). This team identified eight species of mushroom, *Armillaria mellea, Auricularia delicata*, *Pleurotus djamor, Polyporus moluccensis, Termitomyces aurantiacus*, *T. eurrhizus*, *T. letestui,* and *T. microcarpus*, which ethnic groups in the Eastern Arc Mountains regularly collect and eat (Härkönen et al. 1995). As part of this study, researchers analyzed the nutritional content of some of the more commonly eaten mushrooms in Tanzania (*Cantharellus* spp., *Lactarius* spp., *Termitomyces* spp.) and found that wild mushrooms are highly nutritious. Protein and other nitrogenous substances, potassium, and magnesium content of these three species ranged by dry weight from 24.6–49.0 %, 1.6–5.0 %, and 0.07–0.17 %, respectively (Härkönen et al. 1995).

Villagers also widely gather wild fruit. The fruits from over 30 indigenous plant species, representing 19 families of plant, are known to be eaten by residents in the Eastern Arc Mountains (Table 3.3).

3.3 Cooking Fats

Villagers in the Eastern Arc Mountains regularly extract cooking fat from the fruits of native trees. *Allanblackia stuhlmannii* (Guttiferae) and *Trichilia roka* (Meliaceae) are two of the most important species (FAO 1983). *Allanblackia stuhlmannii* (Fig. 3.2) is found in the Usambara, Nguru, and Uluguru Mountains, while *Trichilia roka* grows throughout most of the Eastern Arc Mountains.

Fruits of *Allanblackia* can weigh up to 7 kg and contain over 70 % extractable fat (Glendon 1946). During the German colonial era, a proposal was made, although not implemented, to establish *Allanblackia* plantations and commercialize the production of cooking fat, light-weight oils, and soap (Iversen 1991a). In recent years, the General Agricultural Products Export Company (GAPEX) in Tanga, Tanzania, has purchased *Allanblackia stuhlmannii* fruits from villagers and extracted the oil. At present, there is sufficient regional demand for this cooking fat that GAPEX exports it regionally (Ruffo 1989).

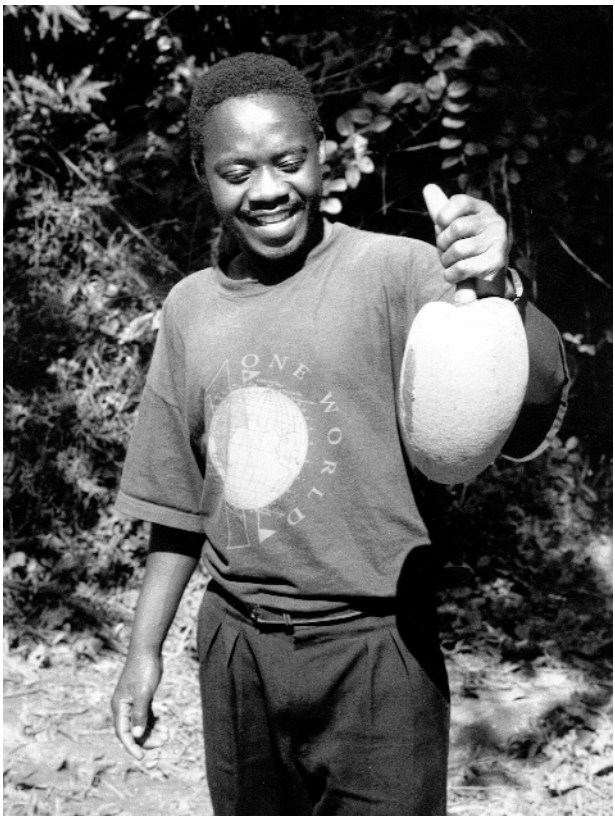

Fig. 3.2. Residents in the Eastern Arc Mountains extract cooking fat from the fruit of *Allanblackia stuhlmanni*. The fruits of this native tree can weigh up to 7 kg

The fat content of *Trichilia* fruits is very similar to that of *Allanblackia* and ranges from approximately 58–68 % (FAO 1983). These fruits have been used to produce not only cooking fats but also soap and cosmetics. The Tanzanian government is encouraging the planting of *Trichilia roka* as a source of oil for the manufacturing of cooking fats and soap (FAO 1983).

3.4 Honey Production

Honey production is an important rural industry and a source of foreign exchange for Tanzania. In 1988, Tanzania exported honey and beeswax valued at US$800,000 [Tanzania Forestry Action Plan (TFAP) 1989] which was equivalent to 0.2 % of the total US$299 million agricultural exports for that year (World Bank 1998). Honey is also an important item in the diets of many ethnic groups in the Eastern Arc Mountains and is used in many areas to make local beer or *pombe* (Fig. 3.3). In the Udzungwa Mountains, honey is frequently used as a medicine for coughs and burns (Kiwasila and Odgaard 1992). In the West Usambara Mountains, the Wambugu (an ethnic group residing in the central plateau region) use honey as a medium of exchange with the Maasai living in lowland areas (Conte 1996). Ruffo (1989) has identified more than 40 species of plants that are important sources of nectar and pollen for bees in the East Usambara Mountains. However, given the large number of flowering plants in the Eastern Arc forests, many more species could undoubtedly be added to this list.

3.5 Wildlife as Food

Wild meat is an important source of protein for many villagers in the Eastern Arc Mountains. Among the animals that residents frequently hunt are duikers *Cephalophus* spp., suni *Neotragus moschatus*, bushbuck *Tragelaphus scriptus*, buffalo *Syncerus caffer*, bushpig *Potamochoerus porcus*, black and white colobus *Colobus abyssinicus*, blue monkey *Cercopithecus mitis*, tree hyrax *Dendrohyrax validus*, giant pouched rat *Cricetomys gambianus*, fish, and birds. Villagers normally hunt large mammals using dogs, snares, or digging pits, while they capture large rodents, fish, and birds using traps, poisons, and natural latexes (Fig. 3.4).

In the East Usambara Mountains, Woodcock (1995) found in nine of the ten villages she surveyed that two groups of three to ten men would hunt on average once or twice per week. In eastern Kenya, FitzGibbon et al. (1995a) estimated that 63 % of the 2660 households residing immediately adjacent to

Fig. 3.3. Local people place beehives in trees within or adjacent to forests in the Eastern Arc Mountains. Beehives are constructed frequently from hollowed logs. Honey is an important portion of the diet of many people in the Eastern Arc Mountains and is used also as a medicine for coughs and burns

Fig. 3.4. Wild meat is an important source of protein for many people in the Eastern Arc Mountains. One of the most frequently hunted large mammals in the Eastern Arc forests is the Bushpig *Potamochoerus porcus*. Bushpigs are normally captured with snares or dogs

the Arabuko-Sokoke Forest regularly hunted and trapped, while 33 % of the 334 households living 2 km from the forest did so. In total, they estimated that over 1277 people hunted or trapped annually in the Arabuko-Sokoke Forest.

Unfortunately, because of intensive hunting pressures, many species are becoming increasingly scarce in the Eastern Arc forests. In portions of the West Usambara Mountains, many streams and rivers are now devoid of fish because of the extensive use of poisons to capture fish (Flueret 1980). However, the decline in population of many hunted animals is probably not a recent phenomenon. Colonial reports from the beginning of this century mentioned that forest antelopes and bush pigs were becoming scarce in the Usambaras as a result of hunting (Iversen 1991b).

3.6 Building Materials

Residents in the Eastern Arc Mountains are highly dependent upon natural forests for building materials. The second most frequent use of plants in the East Usambara Mountains, after those collected for medicinal purposes, are for building materials (Fig. 3.5).

Most houses in the Eastern Arc Mountains are built from materials acquired from nearby forests. In the East Usambara Mountains, villagers regularly use more than 20 tree species as building poles because of their resistance to termites and decay (Ruffo 1989). In the Lushoto District in the West Usambara, the preferred building pole is not a tree but the tree fern, *Cyathea* spp.

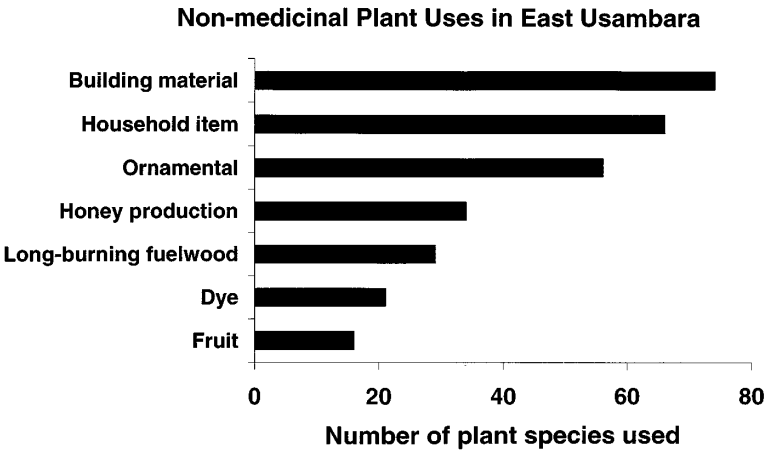

Fig. 3.5. Comparison of the number of identified plant species commonly used for non-medicinal uses by local people in the East Usambara Mountains. (Ruffo 1989)

(Cyatheaceae). Villagers prefer this plant because it is also resistant to termites and decay (Flueret 1980). In the Udzungwa Scarp Forest Reserve in the Udzungwa Mountains, 110 species of trees have been identified that are commonly used by residents for building materials (Zilihona et al. 1998; Fig. 3.6)

Historically, the Eastern Arc forests have been the most important source of hardwoods in Tanzania. *Albizia* (Leguminosae), *Allanblackia* (Guttiferae), *Beilschmiedia* (Lauraceae), *Cephalosphaera* (Myristicaceae), *Khaya* (Meliaceae), *Macaranga* (Euphorbiaceae), *Milicia* (Urticaceae), *Newtonia* (Compositae), *Ocotea* (Lauraceae), *Parinari* (Chrysobalanaceae), *Podocarpus* (Coniferae), and *Terminalia* (Combretaceae) are among the more highly valued timber genera that grow here (Willan 1965; Ruffo 1989; Mbuya et al. 1994). Unfortunately, because of the small size of the Eastern Arc forests, it is highly unlikely that these forests will be able to continue to provide most of Tanzania's hardwood needs as they have in the past.

An increasingly important role of the Eastern Arc forests is to serve as a seed bank or genetic reservoir from which disease-resistant and fast-growing native species can be selected for use in establishing hardwood plantations. The National Tree Seed Program in Tanzania collects seeds of indigenous tree

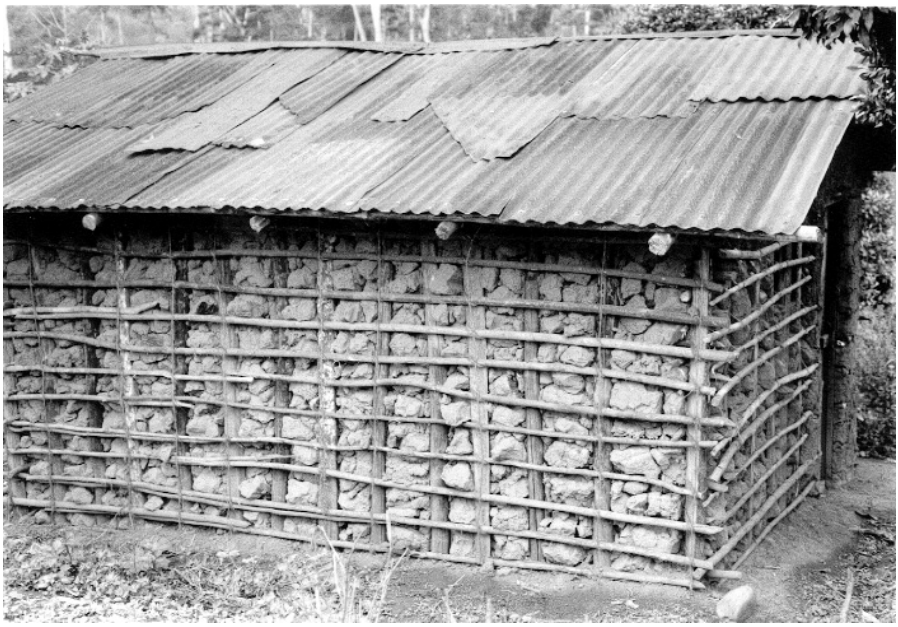

Fig. 3.6. Most houses in the Eastern Arc Mountains are constructed by plastering mud on a wooden framework. Villagers prefer to construct the wooden frame for their houses from termite-resistant trees gathered from adjacent forests

species from the Eastern Arc Mountains and propagates them. Between 1992 and 1997, the National Tree Seed Program collected more than 2500 kg of seeds of indigenous species (Ruffo 1997).

3.7 Household Items

Most of the common household items used by people in the Eastern Arc Mountains are constructed from plant materials collected from the adjacent forests. Examples include stools, chairs, baskets, bed frames, sugarcane presses, mortars and pestles, pipe stems, wooden spoons, beehives, baskets, bows and arrows, twine, and rope. Ruffo (1989) has identified more than 60 species of plant used by villagers in the East Usambara Mountains to construct common household items (Figs. 3.7, 3.8).

Fig. 3.7. The gears and handle of this sugarcane press in the East Usambara Mountains are constructed from native trees

Fig. 3.8. Local residents in the Eastern Arc Mountains gather vines, which are used for twine and rope

3.8 Long-Burning Fuels

Villagers in the Eastern Arc Mountains prefer certain tree species as fuelwood because they are long-burning. In the East Usambara Mountains, 29 species are known to be actively collected by residents because of this property (Ruffo 1989). With increasing emphasis now being placed in Tanzania upon using indigenous tree species in village woodlots and reforestation projects, the suitability of these long-burning tree species should be evaluated. Unfortun-

ately, most long-burning species tend to have dense wood and thus are generally slow-growing which reduces their attractiveness for use in woodlots.

3.9 Dyes

In the Eastern Arc Mountains, residents frequently use dyes for body paints and for coloring houses, household items, cloth and fibers. Dyes are normally extracted by boiling the bark, roots, or fruits of a plant in water and are fixed using lemon juice and salt (Ruffo 1989). In the East Usambara, over 20 species of plants have been identified as sources for dyes (Table 3.4; Ruffo 1989).

Table 3.4. Plants used by villagers in the East Usambara Mountains for dyes. (Ruffo 1989)

Species	Shambaa name
ANACARDIACEA	
Lannea welwitschii	*Mumbu*
ANNONACEAE	
Enantia kummeriae	*Muaka*
BALSAMINACEAE	
Impatiens sodenii	*Jamto*
CHRYSOBALANACEAE	
Maranthes goetzeniana	*Ng'anga*
COMPOSITAE	
Newtonia buchananii	*Mnyasa*
EUPHORBIACEAE	
Bridelia micrantha	*Mwiza*
GUTTIFERAE	
Allanblackia stuhlmannii	*Msambu*
Garcinia spp.	*Mndee-mzize*
Harungana madagascariensis	*Mkuntu*
Symphonia globulifera	*Mziwaziwa*
LEGUMINOSAE PAPILIONOIDEAE	
Pterocarpus mildbraedii	*Hampa*
Pterocarpus tinctorius	*Mkula*
MUSACEAE	
Ensete edule	*Tambwe*
MYRISTICACEAE	
Cephalosphaera usambarensis	*Mtambara*
MYRTACEAE	
Syzygium cordatum	*Mshihwi*
Syzygium guineense	*Mshihwi*

Table 3.4 (*continued*)

Species	Shambaa name
RUBIACEAE	
Morinda asteroscepa	*Mromberombe*
Rubia cordifolia	*Ukakaka*
RUTACEAE	
Toddalia asiatica	*Mdongonyezi*
URTICACEAE	
Milicia excelsa	*Mvule*

3.10 Ornamentals

The Usambara Mountains are probably best known internationally as the source of the African violet, which is grown widely as an ornamental in Europe and North America. The African violet is not a true violet; rather it belongs to the family of Gesneriaceae. The Eastern Arc forests contain 18 of the 21 described species of African violets.

Fig. 3.9. The Eastern Arc forests contain 18 of the 21 known species of African violet *Saintpaulia*

The worldwide cultivation of African violets is estimated to be worth over US $100 million annually, and the basis for this industry is the collection of *Saintpaulia ionantha* acquired in 1891 from the East Usambara Mountains and Tanga (Baatvik 1993; Fig. 3.9).

African violets have specialized habitats and show very high levels of endemism. Nearly all African violets in the Eastern Arc forests grow on steep, well-shaded rock faces (Johansson 1978), and over half of all species are known only from a single location (Johansson 1978; Baatvik 1993). The East Usambara Mountains have the highest diversity of African violet species in the Eastern Arc Mountains (Johansson 1978; Eastwood et al. 1998).

A recent molecular phylogeny of African violets suggests the high diversity of African violets in the East Usambara Mountains may be a result of recent, possibly Pleistocene, species radiation (Möller and Cronk 1997). This analysis also suggests that the Uluguru Mountains may be the origin of *Saintpaulia* and that it subsequently colonized the other Eastern Arc Mountains species. Given the restricted distribution of most African violet species in the Eastern Arc Mountains and the fragmented nature of their habitat, Eastwood et al. (1998) have recently classified eight species of *Saintpaulia* as critically endangered

Table 3.5. Species of African violet *Saintpaulia* found in the Eastern Arc Mountains and their globally threatened status. (After Eastwood et al. 1998; additional source Baatvik 1993)

Species	Eastern Arc location	IUCN threatened status
S. ionantha	Udzungwa	Critically endangered
S. goetzeana	Uluguru, Nguru	Data deficient
S. pusilla	Uluguru, Nguru, Ukaguru	Data deficient
S. grotei	East Usambara	Data deficient
S. diplotricha	East Usambara	Vulnerable
S. orbicularis	West Usambara	Data deficient
S. magungensis	East Usambara, West Usambara	Critically endangered
S. shumensis	West Usambara	Data deficient
S. confusa	East Usambara, West Usambara, Nguru	Vulnerable
S. difficilis	East Usambara	Vulnerable
S. grandifolia	West Usambara	Critically endangered
S. inconspicua	Uluguru	Data deficient
S. intermedia	East Usambara	Critically endangered
S. nitida	Nguru	Data deficient
S. pendula	East Usambara	Data deficient
S. teitensis	Taita Hills	Critically endangered
S. veluntina	East Usambara, West Usambara	Critically endangered
S. brevipilosa	Nguru	Data deficient
S. intermedia	East Usambara	Critically endangered
S. velutina	East Usambara, West Usambara	Critically endangered

Fig. 3.10. The busy lizzy *Impatiens* spp. is globally an important horticultural plant growing in the Eastern Arc forests. The Uluguru Mountains are particularly rich in *Impatiens*. (Grey-Wilson 1982)

and three species as vulnerable (Table 3.5) using the 1996 IUCN Red List Criteria (see Table 2.5; Chap. 2).

Several other internationally important horticultural plants are also found in the Eastern Arc Mountains. These include the African primrose *Streptocarpus* (Gesneriaceae) and the busy lizzy *Impatiens* (Balsaminaceae). The Usambaras have nine species of African primrose and 12 species of busy lizzy (Iversen 1991a; Fig. 3.10).

Although villagers do not grow *Saintpaulia* as a house plant, they do grow other plants as ornamentals. In the East Usambara, local people frequently plant *Cordia africana (*Boraginaceae), *Dracaena steudneri* (Liliaceae), *Ensete ventricosum* (Scitamineae), *Millettia dura* (Leguminosae), *Morinda asteroscepa* (Rubiaceae), and *Plectranthus barbatus* (Labiatae) as ornamentals (Ruffo 1989). In the Udzungwa Mountains, local people also plant *Impatiens* as ornamentals (Shangali et al. 1998).

3.11 Cash Crops

Coffee is the largest export crop for Tanzania (Bukuku 1993). In 1989, coffee exports were valued at US $166 million in current prices (Bukuku 1993) and accounted for 54.1 % of the total US $299 million agricultural exports for that year (World Bank 1998). Globally, coffee is the single largest agricultural commodity in the world. The world's trade in coffee is in the billions of dollars and is surpassed in value only by petroleum (Myers 1984). Of the approximately 40 species of wild coffee, *Coffea* spp. (Rubiaceae), 16 species grow in Tanzanian forests, and 13 species are endemic to the forests and woodlands of eastern Tanzania and southeast Kenya (Bridson and Verdcourt 1988; Lovett 1988; Wrigley 1988; Lovett et al. 1997). Because less effort has been expended to upgrade the productivity and disease resistance of existing cultivars than for other important commercial crops (Prescott-Allen and Prescott-Allen 1983), the potential economic importance of the non-cultivated coffee species growing in the Eastern Arc forests is extremely high.

In many of the Eastern Arc Mountains, coffee is an important cash crop. In the Pares, coffee is the largest cash crop, and is commonly intercropped with bananas. At the beginning of the last century, coffee was the single largest cash crop in the Usambaras. However, due to problems of disease and low soil fertility (Milne 1937), coffee was eventually replaced by tea in many areas (Hamilton and Mwasha 1989a). In recent years, local farmers in the Usambaras have started to plant coffee again in order to diversify their plantings and provide a buffer against adverse fluctuations in the price of other cash crops.

3.12 Additional Indirect Benefits of Conserving Biodiversity

The Eastern Arc forests are also important to Tanzania because of the many indirect services and benefits that these forests provide. These include water and soil conservation, climate regulation, tourism, and education and research.

3.12.1 Water and Soil Conservation

The Eastern Arc forests are among the most important catchment forests in Tanzania and are the primary source of water for all of the major cities in east central and northeastern Tanzania. The four largest river basins in east-central and northeastern Tanzania, the Pangani, Wami, Rufiji, and Ruvu, receive a significant proportion of their water from the Eastern Arc Mountains (Fig. 3.11). Based upon 1988 national census data, approximately one quarter of

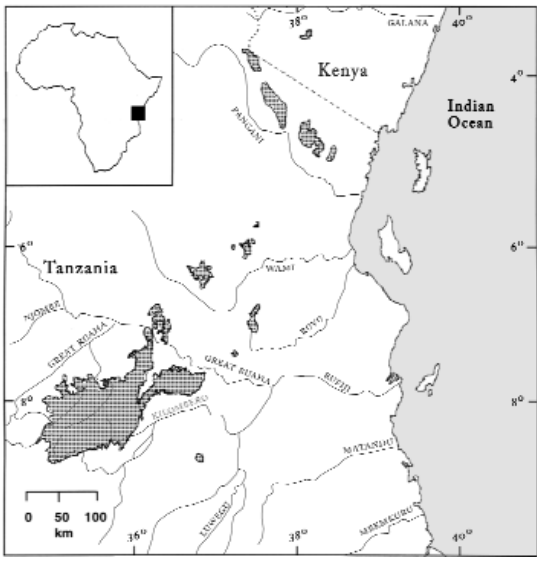

Fig. 3.11. Location of the major river systems in eastern Tanzania and Kenya

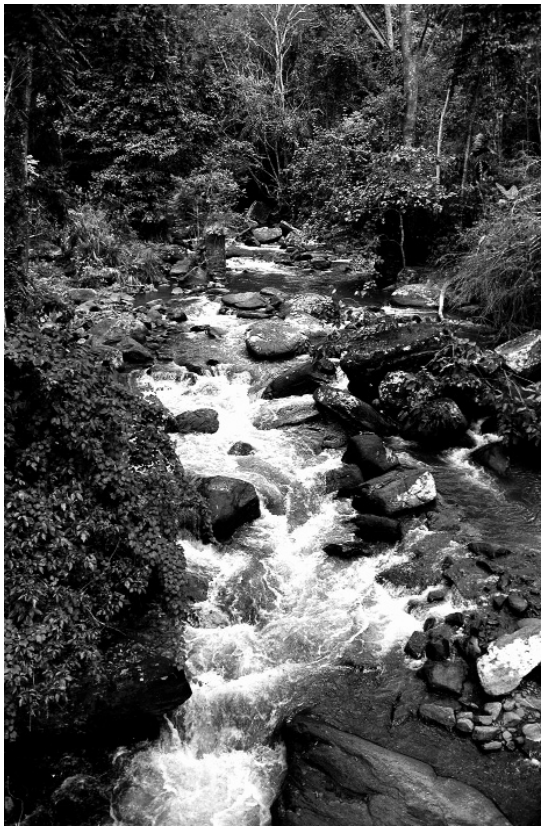

Fig. 3.12. The rivers and streams that flow from the Eastern Arc Mountains provide the drinking water for one quarter of Tanzania's population

Tanzania's population is dependent upon water from these four river basins. The largest cities and towns that draw their water from these four river basins are Bagamoyo, Dar es Salaam, Iringa, Ifakara, Korogwe, Lushoto, Morogoro, Muheza, Mlalo, Same, and Tanga (Fig. 3.12).

The Eastern Arc Mountains, along with the highland areas around Bukoba, Tukuyu, Mbamba Bay, and Mount Kilimanjaro, receive annually the highest amounts of precipitation in Tanzania (Fig. 2.6; Chap. 2). Central to collecting, storing, and discharging the precipitation that falls on the Eastern Arc Mountains are the forests. In the hydrological cycle, forest cover is critical in diminishing the impact of falling raindrops, absorbing and releasing water (Fig. 3.13), enhancing the infiltration of water into the soil surface, and reducing overland flow. The combined result of these functions is that forests play an important role in reducing soil erosion and flooding and maintaining water quality.

The Eastern Arc forests are the catchment forests for all of the major hydroelectric facilities in Tanzania, and thus play a critical role in reducing siltation rates of reservoirs and extending the life span of these expensive capital investments. Currently, 546 MW or 77 % of Tanzania's 707 MW total

Fig. 3.13. Ephiphytic moss shown on the trunk of this tree is important in intercepting rainfall

electrical generating capacity comes from hydroelectric facilities that have catchment areas encompassing the Eastern Arc Mountains (Table 3.6).

While the Eastern Arc forests play a critical role as water catchment basins, forest cover is less important in maintaining dry season discharge than is often

Table 3.6. Hydroelectric facilities in Tanzania and their available generating capacity, river basin, and mountain catchment. (Matondo and Rutashobya 1995; Luhanga, unpubl.; J. Høiseth, pers. comm.)

Hydroelectric facility	Available generating capacity (MW)	River basin	Mountain catchment
Nyumba ya Mungu	8	Pangani	Mount Meru, Mount Kilimanjaro
Hale	17	Pangani	Mount Meru, Mount Kilimanjaro, North and South Pare, West Usambara
Pangani Falls	68	Pangani	Mount Meru, Mount Kilimanjaro, North and South Pare, West Usambara
Mtera	80	Rufiji	Udzungwa
Kidatu	200	Rufiji	Udzungwa
Kihansi	180	Rufiji	Udzungwa
Tosamaganga	1	Rufiji	Udzungwa
Total	554		

Table 3.7. Comparison of the annual water balance in a forested catchment basin with two cultivated catchment basins in the Udzungwa Mountains for 1993–1994. (After Lørup and Hansen 1997)

Water balance component	Forested catchment basin (mm/year)	Cultivated catchment basin 1 (mm/year)	Cultivated catchment basin 2 (mm/year)
Rainfall	1257	1232	1131
Total runoff	290	455	414
Soil moisture storage	–3	4	11
Groundwater storage	10	27	10
Actual evapotranspiration	960	746	696
Potential evapotranspiration	978	914	914

claimed. Lørup and Hansen (1997) found that the dry season (June–November) runoff in 1993–1994 in two cultivated catchment basins in the Udzungwa Mountains was nearly twice as high (90 mm/year) as that recorded in a paired-forested catchment basin (55 mm/year). They also found, on an annual basis, that runoff was 30–36 % higher in the cultivated catchment basins than in the paired-forested basin (Table 3.7). They attributed these patterns to higher evapotranspiration from the forested catchment basin.

3.12.2 Climate Regulation

On a regional and global scale, the Eastern Arc forests help to store and sequester carbon. Undisturbed and selectively logged tropical evergreen forests contain on average the highest amount of carbon per hectare of any major forest type and, therefore, reducing the loss of tropical forests worldwide is one means of reducing carbon dioxide emissions (Brown et al. 1996). Of particular importance in sequestering carbon are old-growth forests because they contain proportionally more carbon as soil black carbon, which turns over very slowly (Schulze et al. 2000). Globally, tropical Africa has the ability to store as well as sequester the third largest quantity of carbon after tropical America and tropical Asia (Brown et al. 1996). However, terrestrial ecosystems such as the Eastern Arc forests are not permanent sinks for carbon and can only temporally – on a time scale of decades to centuries – offset fossil fuel emissions since terrestrial carbon sinks are part of an active biological cycle (Schulze and Heimann 1998; Steffan et al. 1998).

3.12.3 Ecotourism

Tourism is the largest source of foreign exchange for Tanzania, and between 1992 and 1993 it accounted for 14.5 % of the gross domestic product (Sharma et al. 1994). In 1995, Tanzania earned US $205 million from tourism (Kitima 1995). Currently, Tanzania ranks seventh among all African nations in the amount of income generated by tourism (Kitima 1996). The rapid growth of the tourist industry in Tanzania mirrors similar patterns of growth throughout much of Africa. Between 1950 and 1990, Africa experienced the highest rate of growth in tourism of any continent (Cater and Lowman 1994). The most rapidly growing sector of the tourist industry worldwide is ecotourism, defined broadly as nature-based tourism (Cater and Lowman 1994).

Ecotourism is the backbone of Tanzania's tourist industry and the Eastern Arc Mountains are potentially an important site. An increasing number of tourists visit the Eastern Arc forests to hike, photograph, and view the many rare and endemic plant and animal species (Fig. 3.14).

Fig. 3.14. The information center of the Amani Nature Reserve in the East Usambara Mountains. An increasing number of tourists visit the Eastern Arc forests

Nearly all proponents of ecotourism agree that nature-based tourist operations in developing countries should be ecologically responsible and culturally sensitive. In addition, it is argued that nature-based tourism in developing countries should be based locally- and should seek to employ residents so as to provide direct benefits to local communities and help link conservation with economic development. In an effort to develop supportive relationships with local communities, protected area authorities encourage villagers living adjacent to Udzungwa National Park and the Amani Nature Reserve to work as guides and porters to tourists visiting these protected areas.

Although many regions worldwide have benefited economically from ecotourism, it is not without problems. In Tanzania, some of the most adverse impacts of ecotourism can be seen on Mount Kilimanjaro. Along the Marangu trail on Mount Kilimanjaro, heavy tourist use has led to extensive littering, graffiti on hut walls, improper sewage disposal, trampling of alpine vegetation, trail erosion, and depletion of vegetation (Newmark and Nguye 1991). Although it is unlikely that visitation levels in any of the Eastern Arc protected areas will ever approach that of Mount Kilimanjaro, many of the problems associated with ecotourism on Mount Kilimanjaro could occur in the Eastern Arc Mountains, if tourist activities and facilities are not carefully planned and managed.

3.12.4 Education and Research

The Eastern Arc Mountains have been compared to the Galápagos Islands in importance for the study of evolution. The University of Dar es Salaam, Sokoine University of Agriculture, Tanzania Forestry Research Institute, and the College of African Wildlife Management, Mweka, are located in close proximity to these mountains, and thus faculty members and students from these institutions can easily conduct field trips, projects, and studies here. These mountains have also attracted many foreign scientists over the years, and several international field courses in tropical ecology use the Eastern Arc Mountains as a field site.

3.13 Economic Valuation of Forest Products

Timber and non-timber forest products are important components of Tanzania's economy. The *Tanzania Forestry Action Plan* (1989) estimated that the total value to the nation of forestry-based activities in 1988 was approximately US $184 million. This report valued wood and wood products (fuelwood, charcoal, building poles, pulp, paper, joinery, furniture, etc.) in 1988 at US $91.3 million and non-timber products (honey, beeswax, wildlife-based activities, fruit, medicinal plants, fodder) at US $92.6 million. This document also noted that this analysis underestimated the true economic value of the forestry sector because (1) much of the forest output in Tanzania goes towards subsistence consumption; (2) a significant proportion of forest products are traded informally; and (3) it is difficult to estimate the value of many forest outputs and ecological services such as erosion control, watershed management, and pollination.

Given the importance particularly of non-timber forest products to local communities in the tropics, there has been an increasing number of studies that have examined the economic value of these products. Godoy et al. (1993) reviewed 24 studies in Latin America, Asia, and Africa that examined the economic value of non-timber forest products. They found that the median value of non-forest products across these studies was US $50 per hectare per year. Assuming this value is generally reflective of the true value of non-timber forest products in the Eastern Arc Mountains, then the total annual value of non-forest products in the Eastern Arc Mountains may be as high as US $28.5 million.

In many places in the world, forest land in addition to forest products represent a significant proportion of a household's potential income. Economic analysis around Mantadia National Park in Madagascar has valued

forest land and products at US $100 per household per year (Kramer et al. 1995). In Madagascar, the annual per capita income is about US $250, and thus forest land and products represent a significant proportion of the potential income for people living adjacent to these forests (Kramer et al. 1995). Given the similarity in social and economic conditions between Madagascar, Tanzania, and Kenya, forest land and products almost certainly represent a significant proportion of the potential income for residents in the Eastern Arc Mountains.

The economic value of ecosystem services provided by tropical forests is also extremely high. Among the more valuable ecosystem services that tropical forests provide, as discussed above, are climate, disturbance, and water regulation, water supply, erosion control, soil formation, nutrient cycling, waste treatment, food production, raw materials, genetic resources, and recreation. Society, however, rarely values ecological services because they are not included in the market system. Costanza et al. (1997) estimated the non-market annual value of 17 ecosystem services in 16 biomes using willingness-to-pay models. These models assume that people have perfect knowledge about their connection to ecosystem services, which in reality they do not, and therefore these models most likely underestimate the true value of ecosystem services (Costanza et al. 1997). Costanza et al. (1997) estimated the annual non-market value of ecosystem services of a hectare of tropical forest to human welfare was approximately US $2007, which implies that the annual non-market value of ecosystem services provided by the Eastern Arc forests may be as high as US $1.14 billion ($10^9$).

3.14 International Convention on Biological Diversity and Biological Diversity Prospecting Agreements

Tanzania and Kenya are among the biologically richest nations in Africa. As a result of the international Convention on Biological Diversity, negotiated by nations attending the Earth Summit in Rio de Janeiro in June 1992, and several recent international agreements, Tanzania and Kenya are in a better position now than in the past to benefit economically from their biological wealth. It is estimated that the current annual value of genetic resources worldwide may be as high as US $50–100 billion (Reid et al. 1993; Rogers 1993).

The objectives of the Convention of Biological Diversity are "the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources.". This objective is to be accomplished by "including appropriate access to genetic resources and by appropriate transfer of relevant technologies" (Gollin 1993).

To date, 176 countries including Tanzania and Kenya have ratified the international Convention on Biological Diversity. However, in order for developing countries to truly benefit from this convention, nations will need to pass legislation and establish regulations to boost a country's negotiating position and encourage further investments in conservation (Reid et al. 1993). In addition, nations will need to ensure that local communities, who are ultimately responsible for the conservation of wildland resources, receive benefits for conserving biodiversity (Reid et al. 1993). In many African countries, legal issues such as who owns indigenous knowledge that is possessed by traditional healers still needs to be addressed (Makhubu 1998).

Over the last 15 years, a number of public and private medical and pharmaceutical institutions in developed countries have signed agreements on biodiversity prospecting with developing countries. An example is the agreement between the US-based pharmaceutical company Merck & Co. Ltd. and the Costa Rican National Biodiversity Institute (INBio), a private, non-profit organization. Under this agreement, INBio will provide chemical extracts from plants, insects, and microorganisms collected in Costa Rica's wildlands. In exchange, Merck has agreed to pay US $1.1 million and royalties on any resulting commercial products. Similarly, the UK-based Biotics Ltd., a firm serving as a broker between pharmaceutical companies and source country suppliers, agreed to share future royalties with source country suppliers (Reid et al. 1993). Yet, whether these types of commercial agreements between developing countries and pharmaceutical firms will increase in the future is unclear.

The most immediate benefit that Tanzania and Kenya have received as a result of signing the Convention on Biological Diversity is access to the Global Environment Facility (GEF) funds. The GEF was created by the international community in the early 1990s to provide financial support to address global environmental problems. The US $1.3 billion fund is the world's largest environmental fund. The primary purpose of the fund is to allow developing countries to contribute to the improvement in the global environment. GEF funding targets four broad areas of global interest: international waters, biodiversity, climate change, and protection of the earth's ozone layer (Sjöberg 1994). Criteria for a country's eligibility for GEF funding for biodiversity include being a signatory to the international Convention on Biological Diversity and having a per capita income of US $4000 or less (Sjöberg 1994). Since 1991, GEF has provided more than US $27.5 million dollars to Tanzania and Kenya for biodiversity oriented projects [United Nations Development Programme (UNDP) 2000; World Bank 2000].