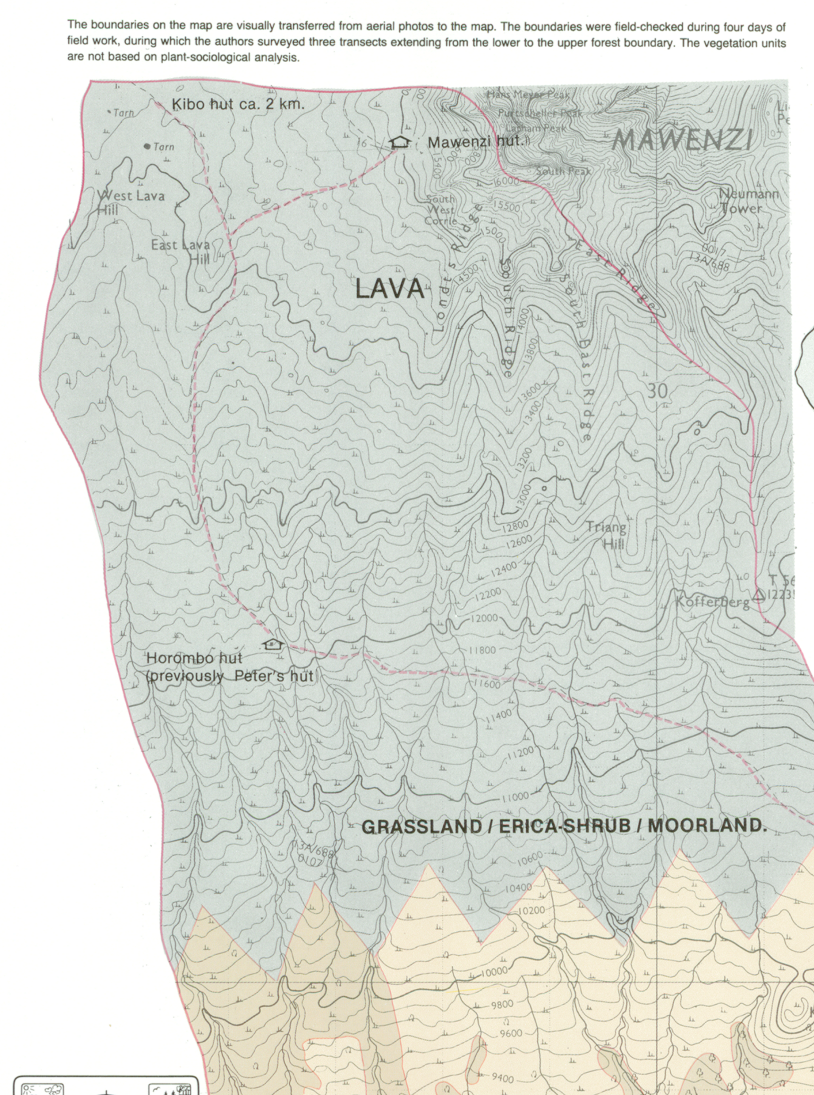
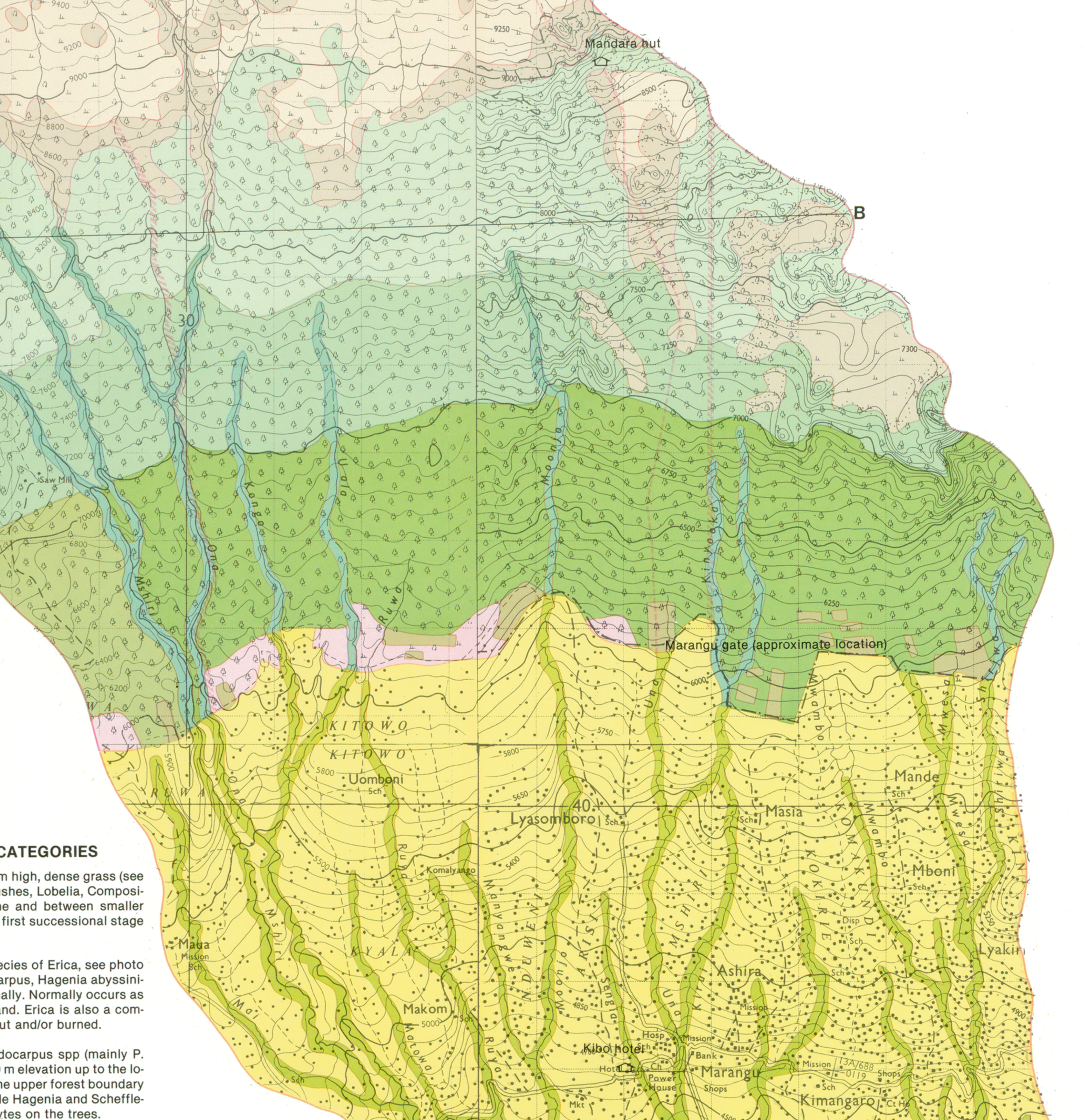
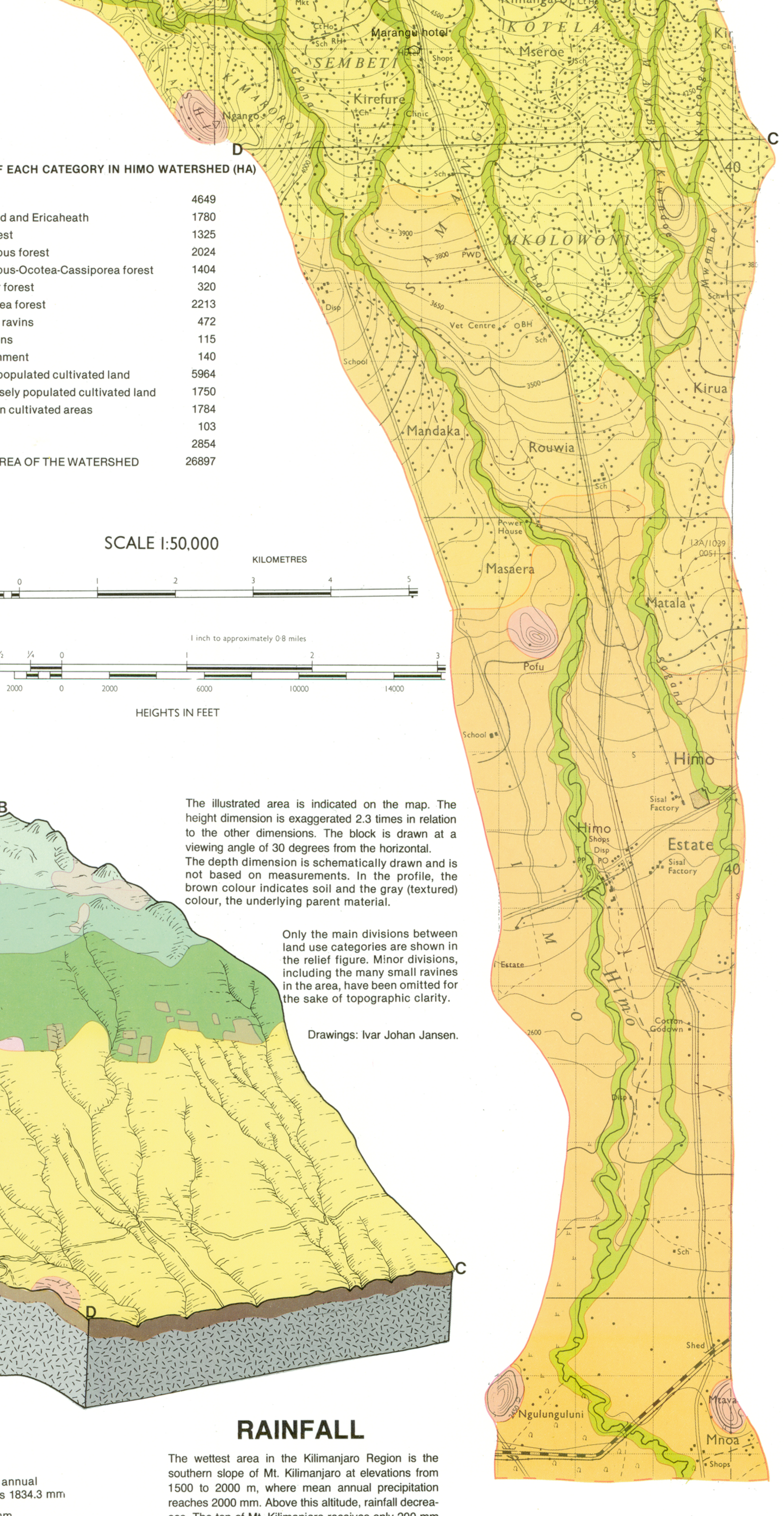
VEGETATION AND LAND USE
HIMO WATERSHED
KILIMANJARO REGION, TANZANIA

SCALE 1 : 50 000

PRODUCED BY THE INSTITUTE FOR ENVIRONMENTAL ANALYSIS, BØ, NORWAY
Mapping and reproduction by Tore Corneliussen, John Hermansen, Jphnny Holsten and Hans Venvik.

The map was produced as part of a Norwegian Agency for International Development (NORAD) project entitled «Preparatory study for actions limiting destruction of the remaining natural forest on the hill and mountainsides in Tanzania.» The map is part of the final project report from the Institute for Environmental Analysis to NORAD entitled «Catchment forestry in Tanzania.» The map demonstrates how aerial photo interpretation and field inventory can be used for planning and management of natural forest and human-impacted areas within watersheds.

The boundaries on the map are visually transferred from aerial photos to the map. The boundaries were field-checked during four days of field work, during which the authors surveyed three transects extending from the lower to the upper forest boundary. The vegetation units are not based on plant-ecological analysis.

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KILIMANJARO FOREST RESERVE -KILIMANJARO NATIONAL PARK

Kilimanjaro Forest Reserve includes essentially the entire forest belt around Mount Kilimanjaro. It was established in 1921, and is now a part of the Kilimanjaro Catchment Forest Project. The area of the reserve is ca. 1080 km². Six «corridors» have been established in the reserve that are representative of the natural conditions around the base of mountain. Use of these corridors is strictly regulated so that the areas may serve as reference points for natural vegetation and ecology. One of the corridors, Marangu, lies in Himo watershed, and is marked on the map. The most popular tourist route up the mountain (Marangu trail) goes through this corridor up to Kibo Peak. The other corridors are Mashati, Rongai, Shira, Geraragua and Nrwaa.
Kilimanjaro National Park was established in 1974. It consists of the area lying above the forest boundary. Tourist traffic in the national park is organized at Marangu Gate. There are three huts on the trail from Marangu Gate to Kibo Peak, the highest point in Africa (5985 m). These are Mandara hut (ca. 2700 m), Horombo hut (ca.4000 m) and Kibo hut (ca.5100 m).

DESCRIPTION OF LAND USE/ VEGETATION CATEGORIES

Grassland and Erica heath. Approximately 1 m high, dense grass (see photo 1). Significant amounts of low Erica bushes, Lobelia, Compositeѕ, etc. Occurs above the Erica forest zone and between smaller stands of Erica forest. Grassland is often the first successional stage after fire.

Erica forest. Forest dominated by various species of Erica, see photo 1. Typically has a single-layer canopy. Podocarpus, Hagenia abyssinica, and other tree species may be present locally. Normally occurs as the highest forest type, bordering on grassland. Erica is also a common successional tree on areas previously cut and/or burned.

Podocarpus forest. Forest dominated by Podocarpus spp (mainly P. milanjianus). Occurs in a belt from about 2600 m elevation up to the lower boundary of Erica forest. May also form the upper forest boundary to grassland. Other significant species include Hagenia and Schefflera spp. Large amounts of mosses and epiphytes on the trees.

Podocarpus-Ocotea-Cassiporea forest. Forms a transition zone between Podocarpus forest and Cassiporea/Ocotea forest. Dominated by species of Podocarpus, Ocotea, and Cassiporea.

Camphor forest. Dominated by Ocotea usambarensis. Other species include Macaranga, Croton, Albizia, Syzygia, Schefflera, Ilex, Ficus. Camphor may also occur as pure stands. Few large, mature trees due to cutting. Regeneration may lead to a patchwork of stands of varying age, see photo 3. Divided into management compartments.

Cassiporea forest. Dominated by Cassiporea malosana. Many species in common with camphor forest. Diverse and well-developed canopy. Occurs in the eastern part of the lower forest zone.

Forested ravines. Heavy growth of bush, including tree ferns and Lobelia. Locally well-developed forest with several canopy layers. More open vegetation along steep slopes. See photo 2.

Plantations. Plantations of exotic tree species. Mostly eucalyptus, cypress, and pine. Some black wattle stands have been cut and are lying in fallow.

Encroachment. Illegal tree-cutting and gathering of fodder in the forest reserves. This impoverishes the tree and bush canopy layers and hinders forest regeneration. See photo 4.

Densely populated cultivated land. Highly productive conditions. Zero grazing. Intensive cultivation of bananas, maize, coffee, and beans in small holdings (shambas). Intercropping. Well-developed irrigation systems from rivers and streams. See photo 5.

Less densely populated cultivated land. Less productive natural conditions. Essentially no grazing. Fewer irrigation canals than the previous category.

Ravines in cultivated areas. Consists mostly of highly impacted forest subject to fuelwood cutting and fodder-gathering. Erosion along ravines and riverbeds. On the plains, the rivers have cut channels. Reduced forest cover leads to heavy erosion on the riverbanks. See photo 6.

Hills. Many of the hills are deforested due to fuelwood cutting and grazing, and are very susceptible to erosion. See photo 7.

Plains. Unforested area, often susceptible to erosion. Less fertile soil. Often heavily grazed. See photo 8.

Marangu trail (approxomate location)
Corridor boundary (approximate)

AREA OF EACH CATEGORY IN HIMO WATERSHED (HA)

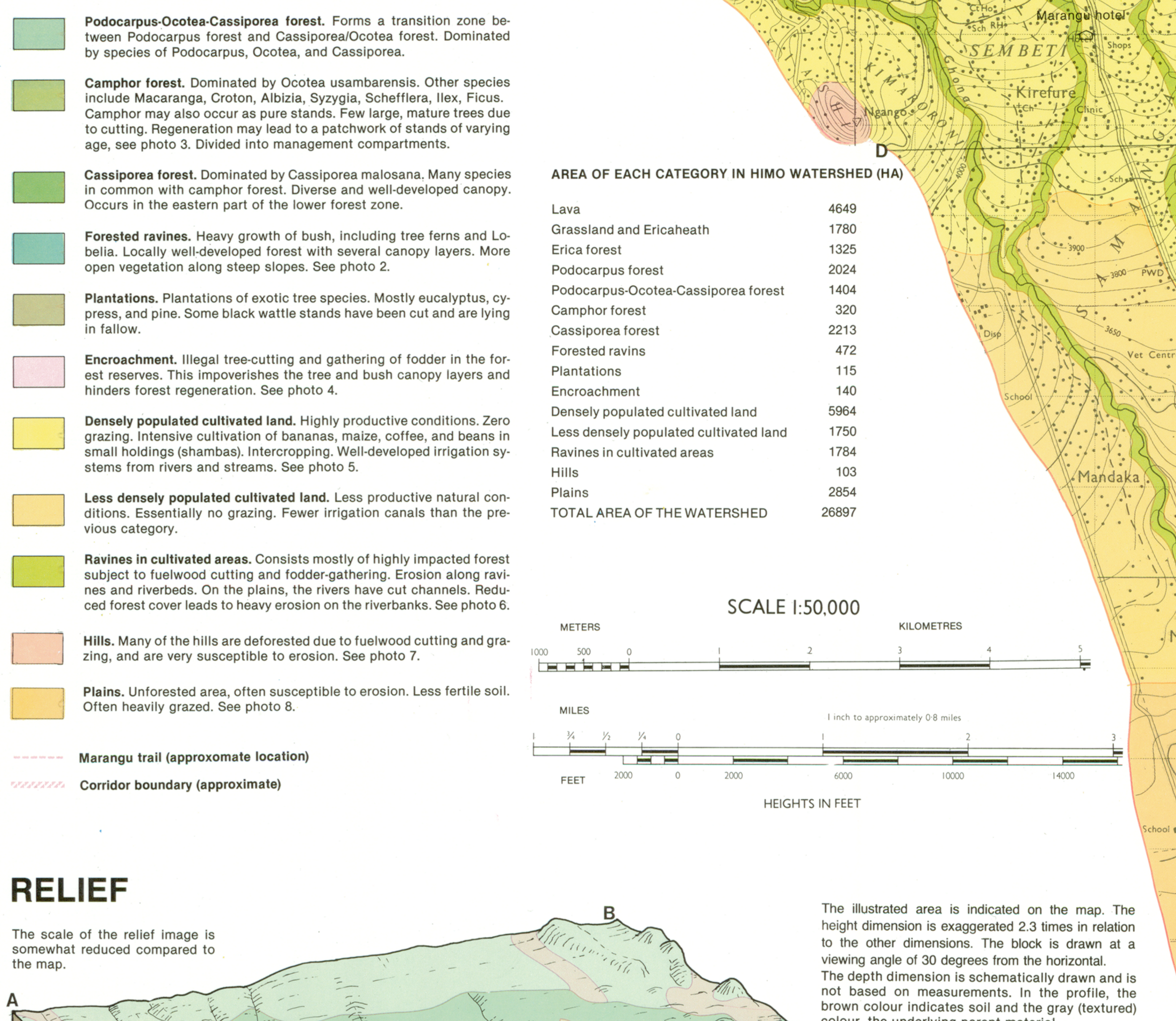
Lava	4649
Grassland and Ericaheath	1780
Erica forest	1325
Podocarpus forest	2024
Podocarpus-Ocotea-Cassiporea forest	1404
Camphor forest	320
Cassiporea forest	2213
Forested ravins	472
Plantations	115
Encroachment	140
Densely populated cultivated land	5964
Less densely populated cultivated land	1750
Ravines in cultivated areas	1784
Hills	103
Plains	2854
TOTAL AREA OF THE WATERSHED	26897

SCALE 1:50,000

METERS 1000 500 0 — KILOMETRES 1 2 3 4 5
MILES 1 ¾ ½ ¼ 0 — 1 2 3 — 1 inch to approximately 0·8 miles
FEET 2000 0 2000 6000 10000 14000
HEIGHTS IN FEET

RELIEF

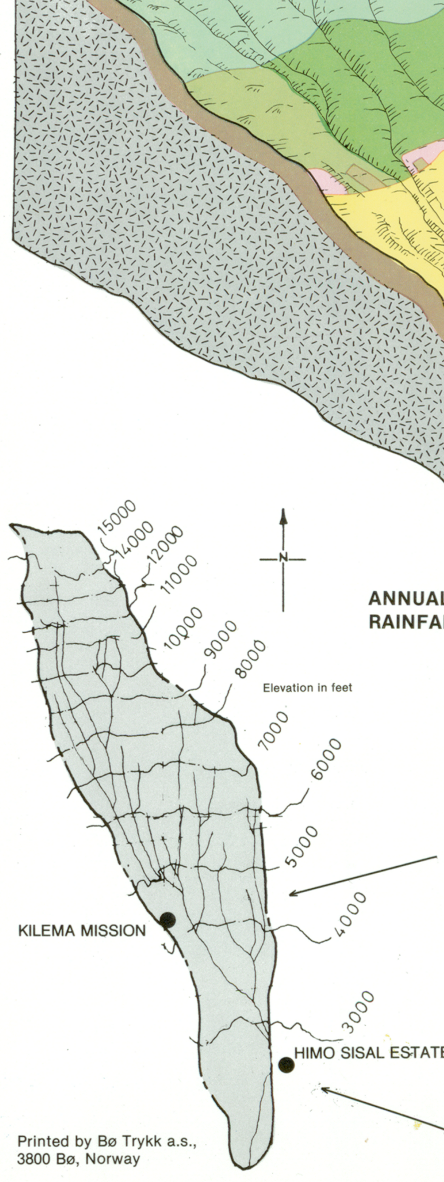
The scale of the relief image is somewhat reduced compared to the map.



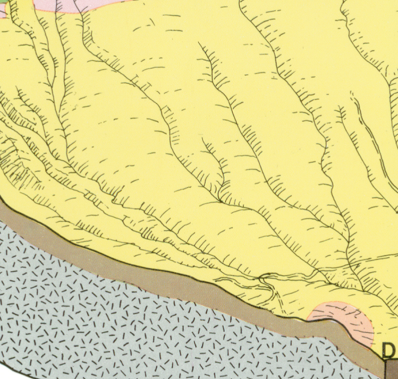
The illustrated area is indicated on the map. The height dimension is exaggerated 2.3 times in relation to the other dimensions. The block is drawn at a viewing angle of 30 degrees from the horizontal.
The depth dimension is schematically drawn and is not based on measurements. In the profile, the brown colour indicates soil and the gray (textured) colour, the underlying parent material.

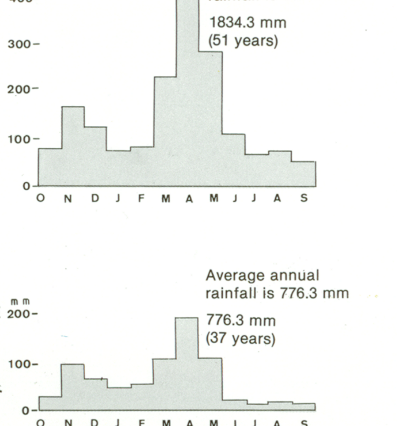
Only the main divisions between land use categories are shown in the relief figure. Minor divisions, including the many small ravines in the area, have been omitted for the sake of topographic clarity.

Drawings: Ivar Johan Jansen.



ANNUAL DISTRIBUTION OF RAINFALL AT TWO STATIONS





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CATCHMENT FORESTRY

Catchment or catchment area means the land area from which water flows to a given watersource. Water quality and water balance are often analyzed for a catchment area.

Watershed management is the wise use of soil, climate and vegetation within a given catchment area in order to achieve maximum precipitation and minimum runoff. Watershed management deals with distribution of water in time and space, water quality and soil water storage.

Catchment forestry is the management of forest resources to enhance the beneficial uses of water resources generated within the catchment. It is a basic component of watershed management. In a wide sense every forest may be called a catchment forest since all forests play a role in the water balance of some catchment area. Slightly less than one percent (900.000 km²) of the total land area in Tanzania is covered by closed, high, indigenous tropical forests. These occur at intermediate to high elevations, are commonly referred to as catchment forest in Tanzania. The forest on Mt. Kilimanjaro is an example of this kind of forest.

Catchment Forest Project - Kilimanjaro Region is one of four projects that have been established to maintain and manage important catchment forests properly.

OBJECTIVES OF CATCHMENT FORESTRY

The catchment forest serves three main functions:

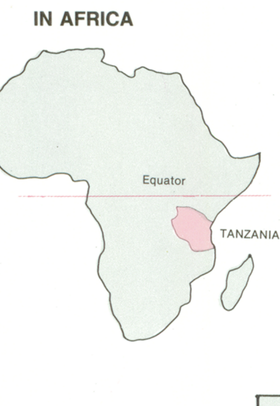
A. Water conservation. The catchment forests are important to regulate runoff, prevent soil erosion, store water and assure a good water supply to human populations at the base of the watershed.

B. Gene-pool conservation. Tropical moist forests are diverse and contain many endemics; conserving these can prevent extinction of plant and animal species.

C. Production of timber from indigenous species and other forest products (e.g. medicinal plants) for local consumption.

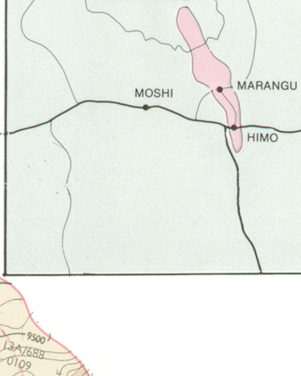
LOCATION

IN AFRICA



IN TANZANIA

IN THE KILIMANJARO AREA

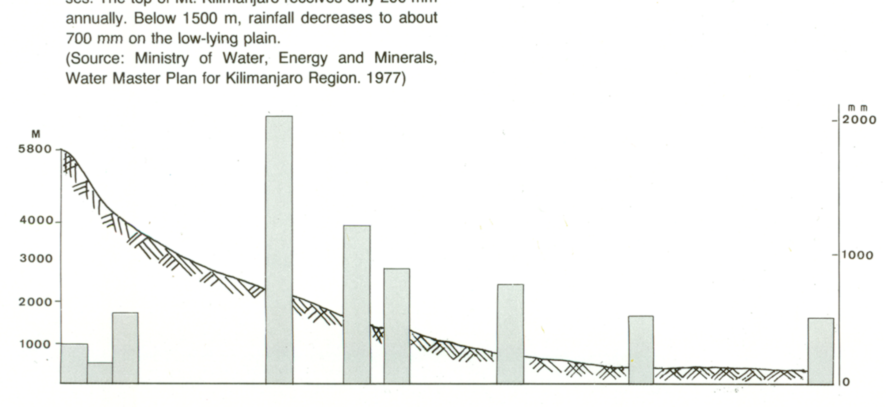


HIMO

Himo watershed lies 3° S and 39° E in Moshi District in Kilimanjaro Region. The catchment spans an elevation gradient of ca. 4500 m. The highest point is Mawenzi Peak (previously Hans Meyer Peak) at 5148 m. The underlying rock is volcanic lava, which has been shown to be up to 13-15 million years old. The soils are derived from lava and volcanic ash.
Areas below about 1800 m are mostly cultivated. Mountain rain forest occurs from about 1800-3000m. The alpine zone above this consists of heath shrub and grassland. These grasslands become shorter with increasing elevation, and give way to lava desert at about 4300 m. Few plants survive the hard conditions in the desert, where annual rainfall is less than 200 mm and the mean temperature is below 0°C.
The flora around Mount Kilimanjaro is not especially rich, but contains many endemic species. Many of the more common genera and species are also quite widely distributed in other temperate and tropical areas.
The water from the rivers in the Himo watershed are vital to agriculture on the eastern, lower slopes of Mount Kilimanjaro. The water flows through this zone in a number of irrigation systems, and then continues in the Ruvu and Pangani rivers to their endpoint at the Nyumba ya Mungu dam.

RAINFALL

The wettest area in the Kilimanjaro Region is the southern slope of Mt. Kilimanjaro at elevations from 1500 to 2000 m, where mean annual precipitation reaches 2000 mm. Above this altitude, rainfall decreases. The top of Mt. Kilimanjaro receives only 200 mm annually. Below 1500 m, rainfall decreases to about 700 *mm* on the low-lying plain.
(Source: Ministry of Water, Energy and Minerals, Water Master Plan for Kilimanjaro Region. 1977)

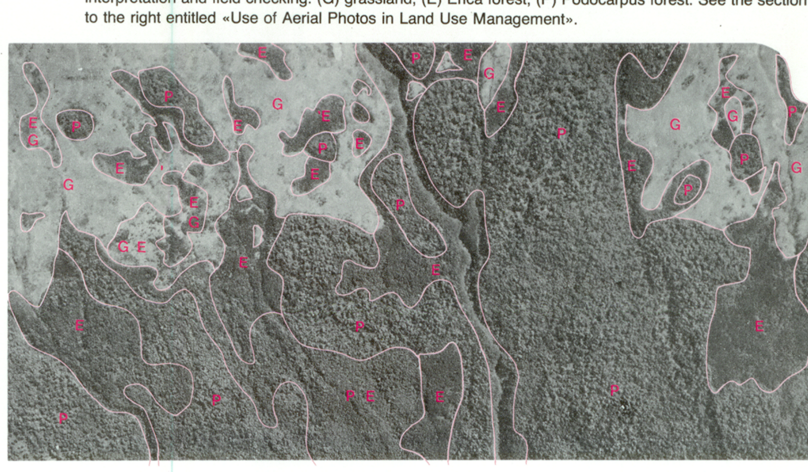


SAMPLE OF AERIAL PHOTOS FROM THE AREA

Scale 1 : 30 000

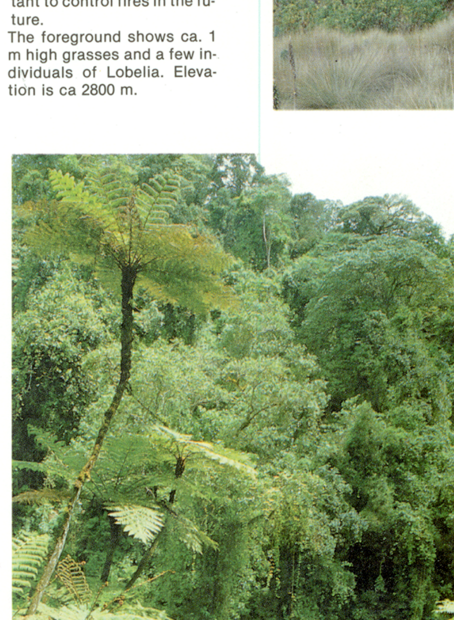
The photo shows an area at the upper forest boundary in Himo watershed.

The boundaries between the vegetation units are drawn (in red lines) based on a combination of photo interpretation and field checking. (G) grassland, (E) Erica forest, (P) Podocarpus forest. See the section to the right entitled «Use of Aerial Photos in Land Use Management».



ILLUSTRATIONS OF CURRENT CONDITIONS

1. Upper forest boundary. The photo shows the upper boundary of Erica forest against grassland at about 3000 m. The grassland is a product of fire and would, if allowed to undergo succession in the absence of fire, probably develop into Erica forest.
Fires are most often set by people while hunting and collecting honey. Reduced area and diversity of forests due to fire greatly reduces the watershed's ability to capture water and control runoff. It is therefore important to control fires in the future.
The foreground shows ca. 1 m high grasses and a few individuals of Lobelia. Elevation is ca 2800 m.

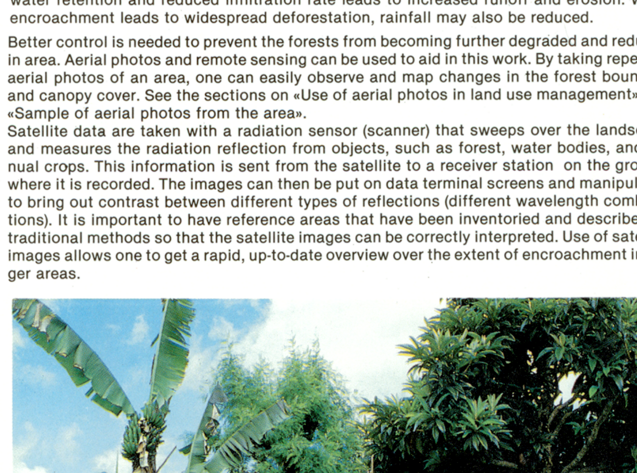


2. Mature natural forest. The photo is taken in a ravine and shows a dense forest with several canopy layers. This is a stable, diverse plant community. The precipitation that falls on this forest will be retained so that runoff is greatly reduced. This contributes to the w ,ershed's value as a catchment. Tree ferns are growing in the foreground. The background is camphor forest with heavy growth of lianas. Thick undergrowth makes it difficult to walk through the forest.

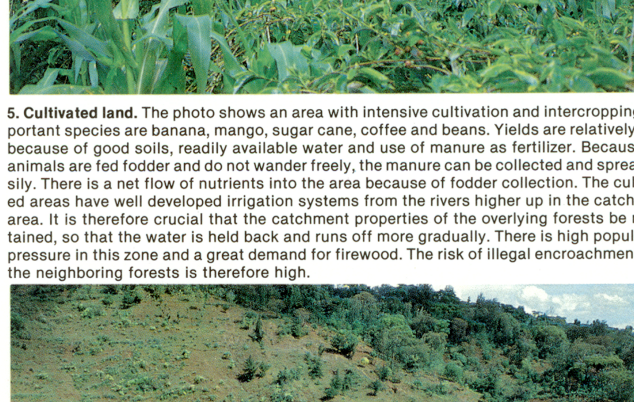
3. Camphor forest regeneration. Many of the forests in the watershed have been cut. Certain valuable species such as camphor have been highly exploited. The photo shows attempts to achieve faster regeneration of camphor. Two of the methods used are management of stump sprouts and scraping the bark from roots (slashing) to increase sprouting. Regeneration of forests that are diverse and productive is important in order to maintain the watershed's catchment value.

4. Encroachment. The forests bordering on cultivated land have often been encroached upon. This is normally the first step in permanent conversion of forest to cultivated land. Encroachment includes all kinds of illegal use of the forest: cutting fuelwood, logging for private use or illegal sale, grazing or fodder collection, cultivation, and use of fire in beehunting or gamehunting. These activities come on top of the impacts of legal forest activities (licensed logging, fuelwood collection etc.) and wild animals. Elephants and buffalos, for example, graze on small branches and bark in some forests and this can to a great deal of damage to young trees.
Encroachment reduced the forest's area, diversity and regenerative ability.
This, in turn, has serious consequences for the water balance within a catchment. Reduced water retention and reduced infiltration rate leads to increased runoff and erosion. When encroachment leads to widespread deforestation, rainfall may also be reduced.

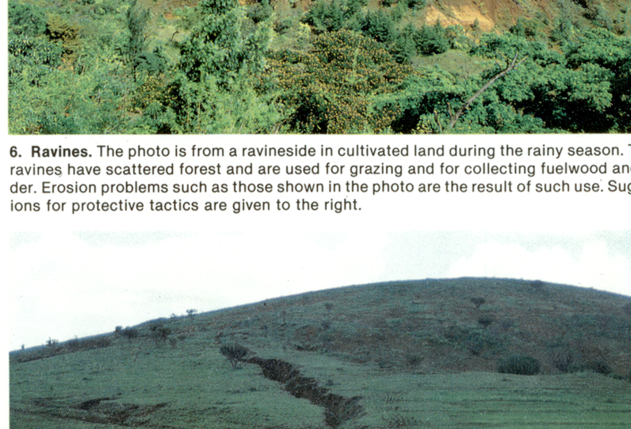
Better control is needed to prevent the forests from becoming further degraded and reduced in area. Aerial photos and remote sensing can be used to aid in this work. By taking repeated aerial photos of an area, one can easily observe and map changes in the forest boundary and canopy cover. See the sections on «Use of aerial photos in land use management» and «Sample of aerial photos from the area».
Satellite data are taken with a radiation sensor (scanner) that sweeps over the landscape and measures the radiation reflection from objects, such as forest, water bodies, and annual crops. This information is sent from the satellite to a receiver station on the ground, where it is recorded. The images can then be put on data terminal screens and manipulated to bring out contrast between different types of reflections (different wavelength combinations). It is important to have reference areas that have been inventoried and described by traditional methods so that the satellite images can be correctly interpreted. Use of satellite images allows one to get a rapid, up-to-date overview over the extent of encroachment in larger areas.



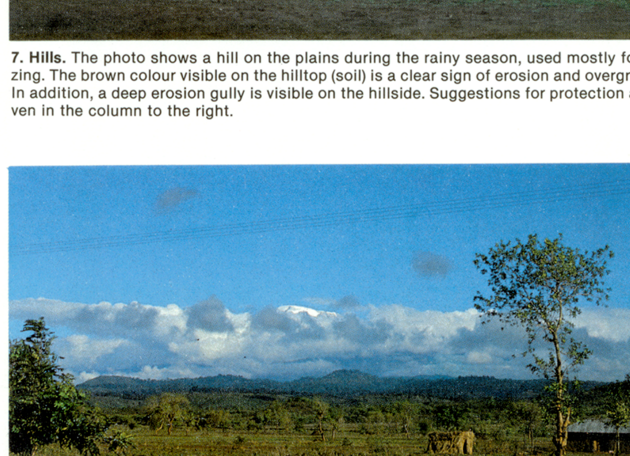
5. Cultivated land. The photo shows an area with intensive cultivation and intercropping. Important species are banana, mango, sugar cane, coffee and beans. Yields are relatively high because of good soils, readily available water and use of manure as fertilizer. Because the animals are fed fodder and do not wander freely, the manure can be collected and spread easily. There is a net flow of nutrients into the area because of fodder collection. The cultivated areas have well developed irrigation systems from the rivers higher up in the catchment area. It is therefore crucial that the catchment properties of the overlying forests be maintained, so that the water is held back and runs off more gradually. There is high population pressure in this zone and a great demand for firewood. The risk of illegal encroachment into the neighboring forests is therefore high.



6. Ravines. The photo is from a ravineside in cultivated land during the rainy season. These ravines have scattered forest and are used for grazing and for collecting fuelwood and fodder. Erosion problems such as those shown in the photo are the result of such use. Suggestions for protective tactics are given to the right.



7. Hills. The photo shows a hill on the plains during the rainy season, used mostly for grazing. The brown colour visible on the hilltop (soil) is a clear sign of erosion and overgrazing. In addition, a deep erosion gully is visible on the hillside. Suggestions for protection are given in the column to the right.



8. Plains land. The photo shows cultivation on the surrounding plains during the rainy season. The area is used mostly for grazing and annual cropping. Government-owned estates are also present. Productivity is relatively low due to poor soil nutrient status. Rainfall is significantly lower here than on the higher slopes. Proposals for protection are given to the right. Above the clouds is Kibo Peak visible.

LAND USE MANAGEMENT IN HIMO WATERSHED

USE OF AERIAL PHOTOS IN LAND USE MANAGEMENT

Reliable information about prevailing *land use* practice and *natural resources* is necessary in order to establish a good *management plan* for a watershed. One must describe the natural elements such as *plant communities, forests, hydrology, soils, geologic parent material,* and *topography.* In addition, the extent and impact of human activities such as *cultivation, housebuilding, grazing, erosion, forest cutting, burning,* and *technical installations* should be mapped and evaluated. Inventory of the watershed according to a suitable *classification system* is the source of this information. The inventory results should be presented on a *base topographic map* so that they are readily available to planners. It is important that the map give a correct overall impression and accurately portray the actual conditions. To make the map easy to read, the various classification units may be portrayed using suitable colours and patterns.

Aerial photos are a useful aid to inventory work. Objects on the ground reflect radiation as characteristic gray tones, or colours when colour film is used. Aerial photos convey considerable detail, and many types of objects can be identified. A great advantage of aerial photography is the possibility of *three-dimensional (stereoscopic)* analysis of the landscape to detect height and elevational differences. This method can give much information on topography, drainage patterns, and vegetation height. The stereo effect also aids in orientation in the field. In addition it allows more accurate mapping of boundaries of, for example, geologic forms and vegetation types. The amount of information a planner can extract from aerial photos depends on many factors, such as degree of detail in the terrain, photo quality, photo scale, and the mapper's interpretive skill.

Inventory normally consists of a combination of photo analysis and field checking (ground truthing). An experienced inventory-taker with good photo interpretation skills who knows the area can also map information from photo interpretation alone, without much field checking. This is especially true for simple, uniform areas. In most landscapes, however, one must check the interpretation by sampling in the field. In difficult areas, extensive field work may be necessary. The amount of field checking needed depends on the area's complexity and the degree of precision required.

Many details in aerial photos can be recognized without particular training in photo interpretation (for example, water, roads, and buildings). Other details, such as vegetation types or annual crops, can be difficult to distinguish from one another and identify. Soil types are also difficult to distinguish in aerial photos, and are often identified on the basis of indirect criteria. Other examples of difficult photo interpretation are overgrazed areas with potential erosion problems, and forest areas damaged by air pollution. These problems require both experience in photo interpretation and extensive field checking.

Photo interpretation is based on certain *basic elements* used to identify objects. Consideration of one or more of these elements allows positive identification. The most important basic elements are:

Form. Shapes of objects are used directly to identify houses, rivers, roads, tree crowns, and geologic form and structures. Landscape forms can also give indirect information on soil types and geologic processes.

Size. The relative size of objects can give information that aids in identification. Tree height, for example, is often used to determine forest type and age. In this map, height was one criterion used to distinguish between Erica and Podocarpus forests. Stereocopy can also be used to determine slope and the size and elevation changes of, for example, ravines and hilltops.

Shadow. Shadows are easier to identify when their shadows are visible. The shape of tree crowns, for example, are clearer and species identification easier when shadows are present. Photos taken at midday in the tropics characteristically have few shadows due to the high angle of the sun. Too many shadows can obscure other details in the photo.

Gray tones and colours. This is the most important basic element in photo interpretation. Variations in gray tones in the photo are a function of light reflection by the objects in the photo. Varying reflectivity among objects and between objects and their background shows up as gray tone variation in the photo. The inventory-taker must learn to recognize these variations. Grassland has high reflectivity and therefore appears very light gray in tone, while the frequently adjoining Erica forest is gray or dark. Broadleaf forests are often much lighter in tone than, for example, planted pine forest. Maize fields are typically lighter in colour than areas planted with bananas. Moisture conditions can be evaluated, since moist soil is darker in tone than dry soil. Badly eroded areas will appear lighter in tone than the surrounding vegetation.

Pattern. On cultivated land, a pattern of small fields and banana plantations gives a typical patchy pattern identifiable as cultivation. A sisal field can be identified in a large-scale photo by the characteristic pattern of the individual sisal plants. Drainage system patterns can give information on the soil type. Geology can also be interpreted to some extent on the basis of pattern.

Texture. Over larger, essentially uniform areas, one will often get the impression of an even or uneven (smooth or rough) texture. This can be used to identify various elements. Thick Erica forest, for example, is clearly discernable from more open Podocarpus forest with rounded crowns. Young forest has an even texture, while older forest has a coarser, uneven texture due to thinning.

Location. Knowledge of where objects are located in the terrain often allows one to identify or exclude objects. A camphor forest, for example, can be excluded bordering alpine grassland. In that location, Erica forest is much more likely to occur.

A sample of an inventoried aerial photo is shown at the top of the column to the left. The photo covers part of the upper forest boundary in Himo watershed. There are three main vegetation types: grassland (G), Erica forest (E), and Podocarpus forest (P). The areas were identified by a combination of photo interpretation and field checking. The aerial photos were mounted for stereoscopic viewing during the field work, and boundaries were drawn directly on the photos.

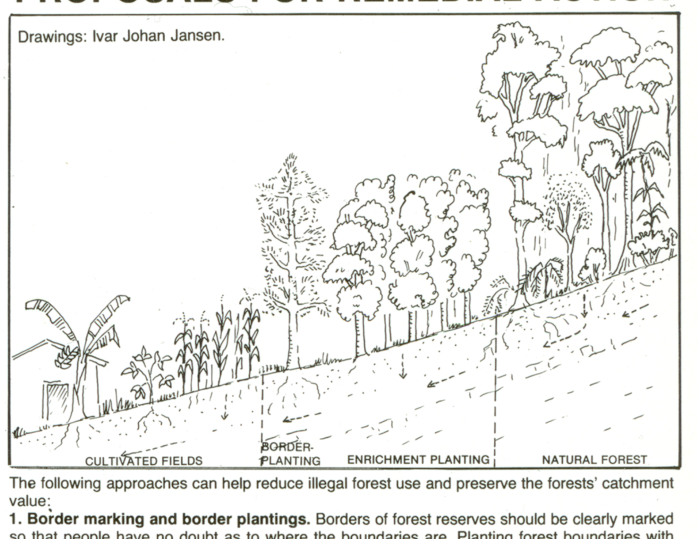
Photo interpretation of the vegetation types in the area was based on the following basic elements:

Grassland. Light gray tone. Even texture, but with some small black spots due to intrusion of Erica. Relatively low vegetation height. No characteristic form. Located along the upper forest boundary.
Erica forest. Dark to gray tone. Even, fine texture. Relatively low vegetation height. Located primarily along the upper forest boundary, along streams, and in burnt areas.
Podocarpus forest. Light to gray tone. Relatively coarse texture. Taller than Erica forest. Located near the upper forest boundary but below the Erica forest.

By observing which gray tones correspond with which objects, one can construct an *interpretation key* to be used within an area. One must be careful, however, about transferring the interpretation of gray tones to another area or another set of photos. The same object may have different gray tones in different sets of photos. Transferring the interpretation of gray tones and colours to new areas is also difficult because new species may be present. This is particularly true for tropical vegetation that is typically diverse and contains many endemics (species occuring only in a particular area).

The most commonly used films at present are *black and white.* These films respond to the same wavelengths as the human eye. It has now become more common to use *colour film* and *infrared film.* Infrared film is sensitive to wavelengths outside of the range of the human eye. With these photos it is possible to extract a good deal more information about certain objects. One disadvantage of these photos is their relatively high cost.

PROPOSALS FOR REMEDIAL ACTION



The following approaches can help reduce illegal forest use and preserve the forests' catchment value:

1. Border marking and border plantings. Borders of forest reserves should be clearly marked so that people have no doubt as to where the boundaries are. Planting forest boundaries with exotic tree species creates a conspicuous zone that acts as a barrier against intrusion.

2. Fuelwood production. There is often a very high concentration of people in the transition zone between cultivated land and the forest reserve who have a great demand for fuelwood. Ideally fuelwood should be produced in open spaces in the cultivated zone, or in plantations on the plains. In areas where transport distances are too long for these strategies, a temporary solution could be to plant a 10 - 50 m zone of fastgrowing exotic tree species inside the reserve. Fuelwood could then be collected from this zone instead of from the natural forest. The rates of harvest should be based on foresters' recommendations.

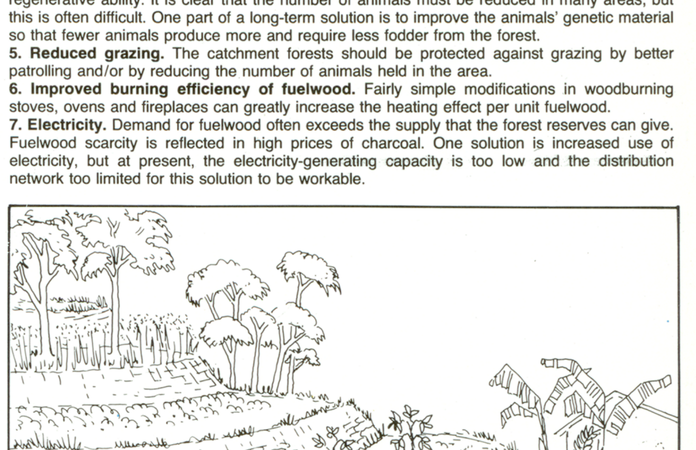
3. Better patrolling. To more effectively patrol the forest boundaries, the guards need improved working conditions and access to transport.

4. Reduced fodder collection. Collection of fodder in the forest reserves reduces the forest's regenerative ability. It is clear that the number of animals must be reduced in many areas, but this is often difficult. One part of a long-term solution is to improve the animals' genetic material so that fewer animals produce more and require less fodder from the forest.

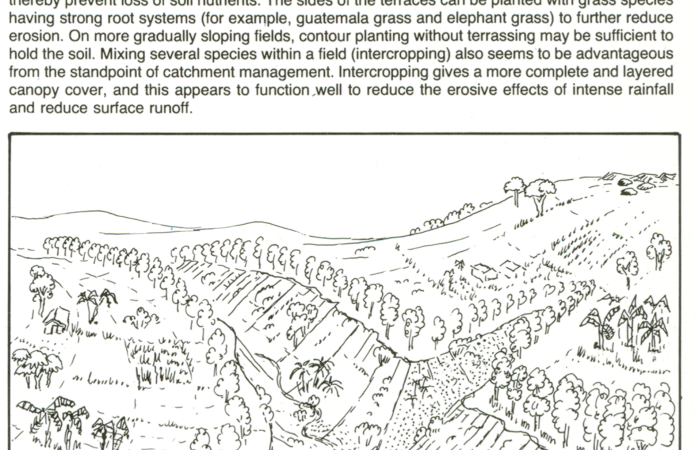
5. Reduced grazing. The catchment forests should be protected against grazing by better patrolling and/or by reducing the number of animals held in the area.

6. Improved burning efficiency of fuelwood. Fairly simple modifications in woodburning stoves, ovens and fireplaces can greatly increase the heating effect per unit fuelwood.

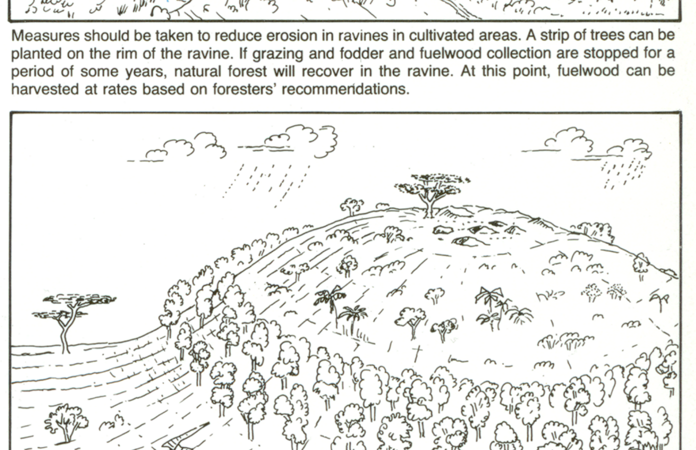
7. Electricity. Demand for fuelwood often exceeds the supply that the forest reserves can give. Fuelwood scarcity is reflected in high prices of charcoal. One solution is increased use of electricity, but at present, the electricity-generating capacity is too low and the distribution network too limited for this solution to be workable.



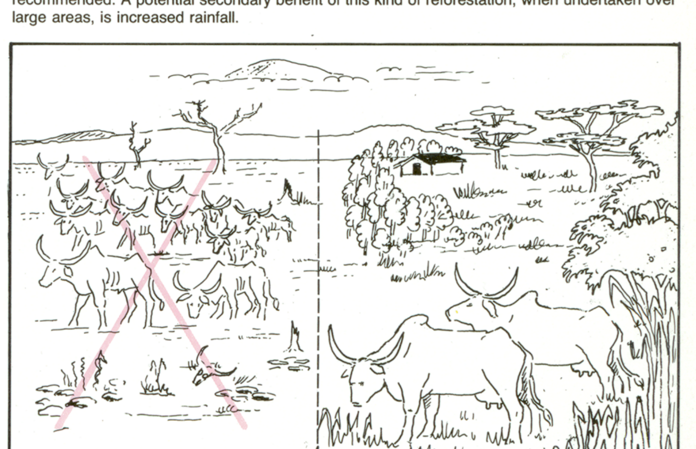
Cultivated fields usually have an incomplete cover of vegetation. Erosion can be considerable during heavy tropical rainstorms. Terrassing can reduce erosion by holding the soil in place, and thereby prevent loss of soil nutrients. The sides of the terraces can be planted with grass species having strong root systems (for example, guatemala grass and elephant grass) to further reduce erosion. On more gradually sloping fields, contour planting without terrassing may be sufficient to hold the soil. Mixing several species within a field (intercropping) also seems to be advantageous from the standpoint of catchment management. Intercropping gives a more complete and layered canopy cover, and this appears to function well to reduce the erosive effects of intense rainfall and reduce surface runoff.



Measures should be taken to reduce erosion in ravines in cultivated areas. A strip of trees can be planted on the rim of the ravine. If grazing and fodder and fuelwood collection are stopped for a period of some years, natural forest will recover in the ravine. At this point, fuelwood can be harvested at rates based on foresters' recommendations.



Deforestation on hilly areas rapidly leads to erosion scars. Afforestation in these areas will both stop erosion and help supply the population with fuelwood. To reforest these areas, a border planting around the base of the hill with natural forest regeneration on the hilltop is recommended. A potential secondary benefit of this kind of reforestation, when undertaken over large areas, is increased rainfall.



The plains areas are highly overgrazed (left side of illustration). The number of cattle should be greatly reduced to limit erosion, reduce the press on the vegetation, and improve the quality of vegetation for grazing. Introduction of improved genetic material in the cattle herds can also help achieve these goals. Reforestation is also recommended in some areas. The righthand side of the drawing illustrates these measures.