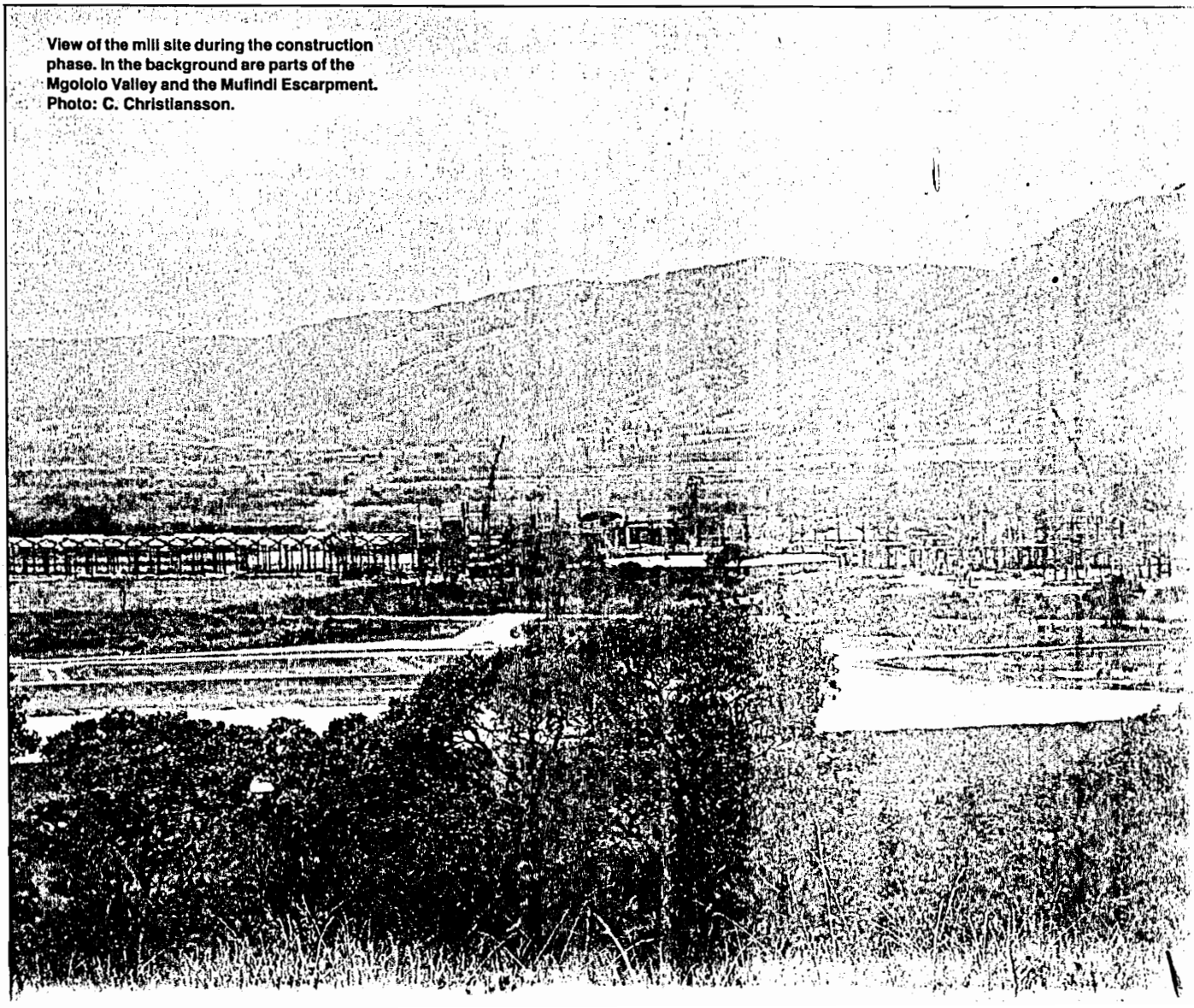
Heavy Industry in a Rural Tropical Ecosystem

BY CARL CHRISTIANSSON AND JOHAN ÅSHUVUD

The establishment of a large integrated pulp and paper mill in the Mufindi District of Tanzania has heavily influenced the local society. Not only has the influx of capital created a modern monetary economy, but immigration is giving rise to a complex set of resource conflicts. However, most of the environmental effects are yet to be seen. When the Southern Paper Mills (SPM) starts producing, there will be emissions into the atmosphere, effluent discharges and solid wastes introduced into a fragile tropical environment. The uncertainty regarding the effects could easily be reduced.



View of the mill site during the construction phase. In the background are parts of the Mgololo Valley and the Mufindi Escarpment. Photo: C. Christiansson.

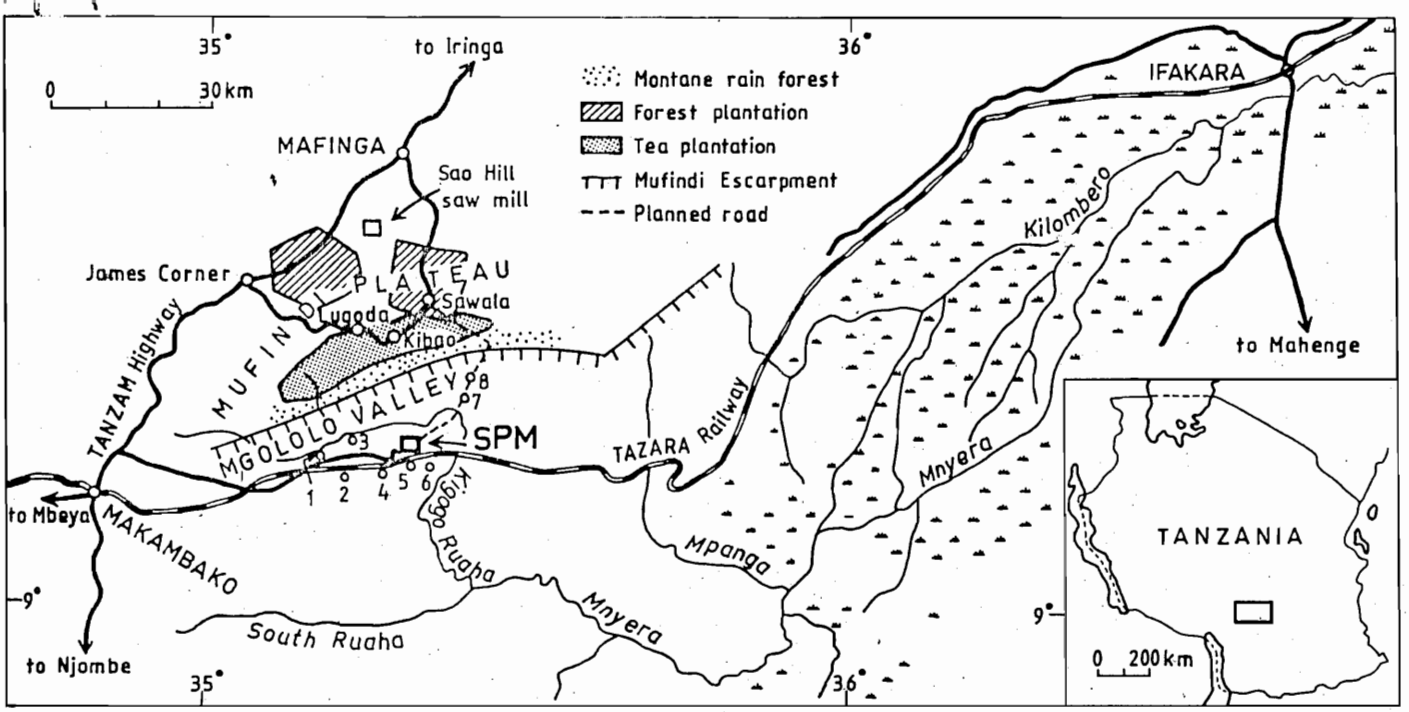
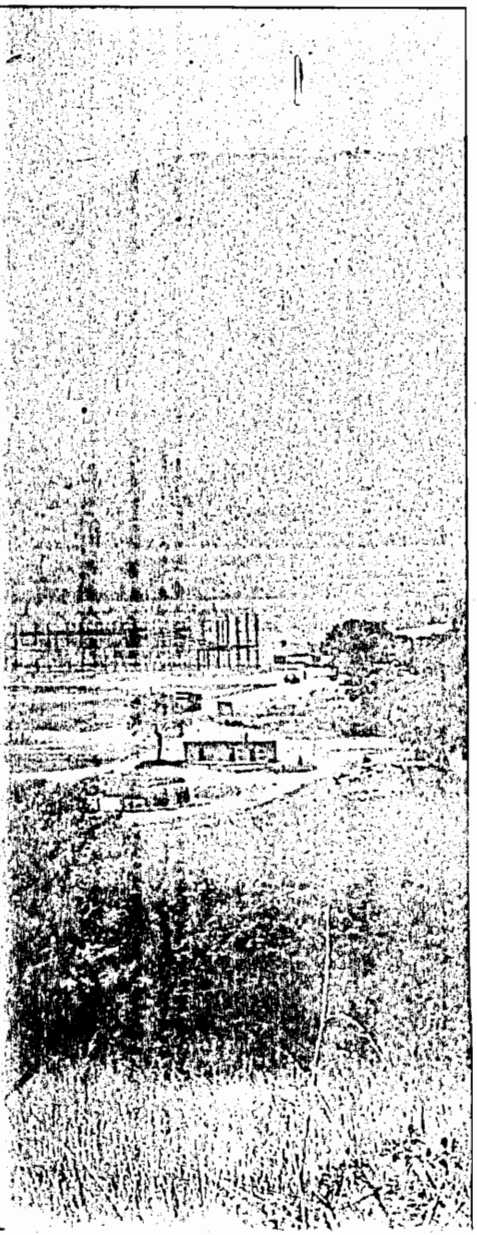


Figure 1. Map of part of the Mufindi District and Kilombero Valley, showing the location of the Southern Paper Mills (SPM). Numbers 1–8 in the Mgololo Valley area indicate villages most likely to be affected by the mill establishment: 1. Isuala, 2. Kiyowela, 3. Magungali, 4. Makuugu, 5. Mabaomi, 6. Lugema, 7. Lugolofu, 8. Kitasengwa.



In January, 1977, the Tanzanian government formally authorized the construction of an integrated pulp and paper mill in the Mufindi District. Since colonial times, the area has had substantial pine plantations, for which no efficient use was found until the first comprehensive feasibility study for pulp and paper production was presented in 1964. The present concept dates from 1974 and forms part of Tanzania's long-term industrial strategy (1). The government expects the project to have effects on many sectors of the national economy and on the development of the rural area surrounding the site. It should be pointed out, however, that the idea was not launched as a rural development project.

The mill will produce groundwood and sulfate pulp to be processed in two paper machines. With an annual capacity of 60,000 tons of industrial and cultural grades, SPM will cover 80 percent of the country's paper needs. One of the paper machines started operating in May this year. The project costs (excluding infrastructure) are estimated at $250 million (2). The principal backers, apart from the Tanzanian government, are the World Bank, the Swedish International Development Authority (SIDA), the *Kreditanstalt für Wiederaufbau*, the Kuwait Fund, the OPEC Special Fund, the Nordic Investment Bank, the European Economic Community and the Commonwealth Development Corporation. Other large-scale commercial enterprises presently operating in the district are the saw mill at Sao Hill, supported by Norwegian aid since the mid-1970s, and several tea plantations established in the 1940s on expropriated German farms.

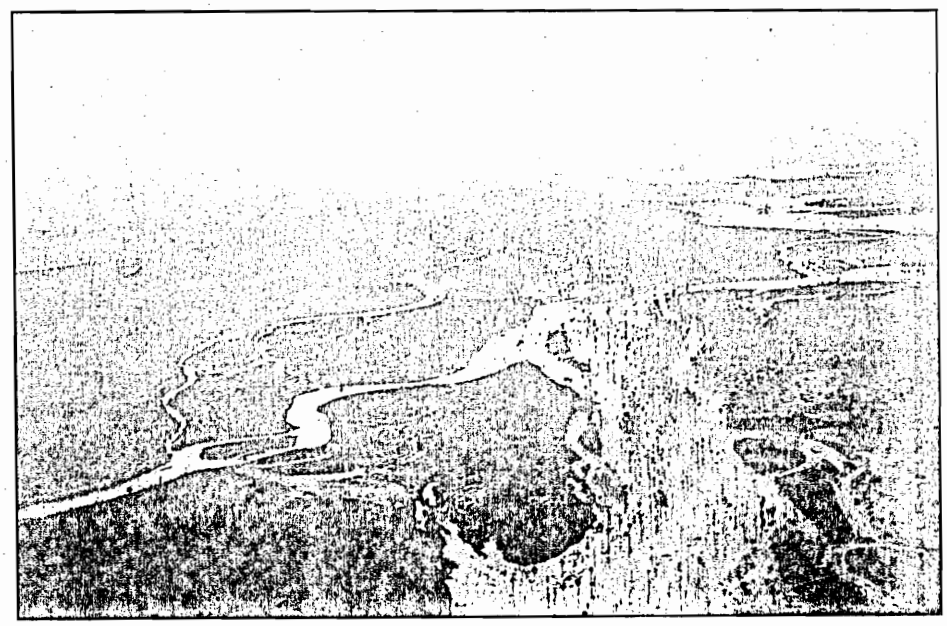
The site selected for the mill complex is situated in Mgololo Valley a few kilometers southeast of the Mufindi Escarpment that runs in a northeast-southwest direction through the district. When the project was authorized the valley was still an isolated rural neighborhood entirely dependent on subsistence farming. More regular contacts with other parts of the country were not established until the Tanzania-Zambia Railway (TAZARA) reached the area in the mid-1970s. At that time very little was known about the natural environment and socio-economic structure of this part of the district.

Three factors seem to have determined the location of the mill: the proximity to the existing pine plantations at Sao Hill, the availability of water for the industrial processes, and the proximity to the national communication network.

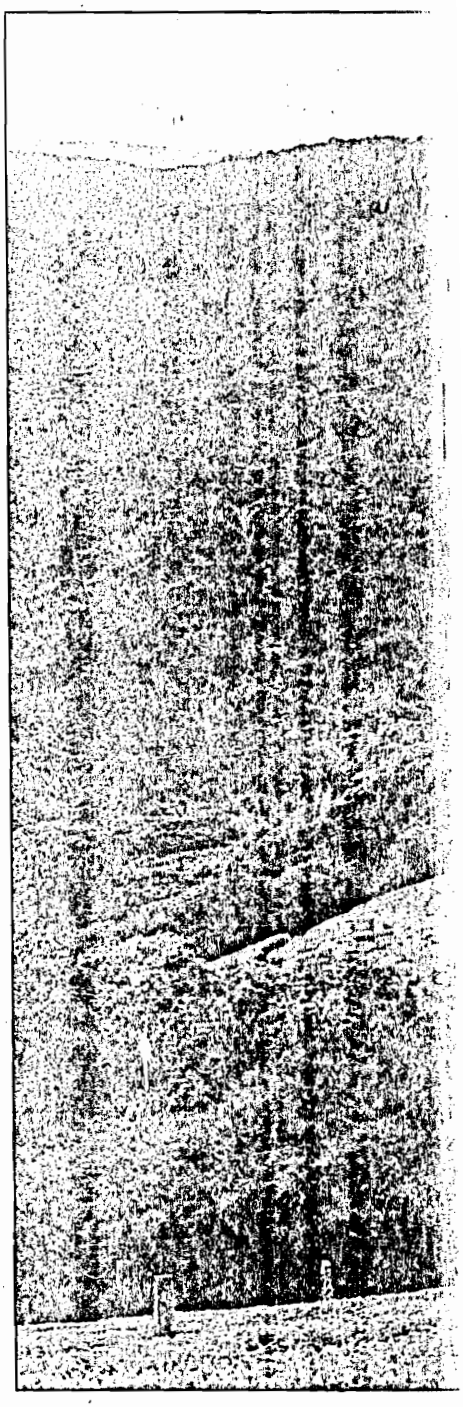
The pulpwood is supplied from the Sao Hill area, 35–50 km from the mill site. Process water is taken from a small stream, Kigogo-Ruaha, flowing through the Mgololo Valley. For transport to the mill of raw materials other than wood, and for transport of paper products from the mill, the TAZARA Railway will be used. The present poor-quality road running through the valley barely admits traffic during the rainy season, but a new road is planned to run from Sawala to the mill site (Figure 1).

THE MUFINDI PLATEAU AND MGOLOLO VALLEY

The area most immediately affected by the mill covers some 500 km^2. Today it has well over 10,000 inhabitants distributed over eight villages, all situated south of the Mufindi Escarpment in the Mgololo Valley. Many other villages in the neighborhood, such as those in the plantation areas on the Mufindi Plateau, will also be more or less affected.



Oblique air photo of the Kilombero flood plain 150–200 km downstream from the mill. The Kilombero Valley is an important spawning and fresh-water fishing area. It has considerable irrigation potential. Photo: C. Christiansson.



Topography and Vegetation

The Mgololo Valley is situated at an altitude of 1,200 meters. It is characterized by poorly drained grassy plains that pass into wooded rolling hills toward the south. Still farther south the woodlands give way to open grasslands, probably a result of earlier frequent forest and bush fires. In this treeless, hilly landscape erosion processes are very active, with gully development and landsliding.

The Mufindi Plateau, with an average altitude of 1,800 meters, slopes gently from the escarpment toward the north.

Near the escarpment, because of the higher rainfall, montane rain forest forms the natural vegetation. However, the total forested area has decreased considerably during the last decades due to the establishment of tea plantations and the expansion of peasant agriculture. The central part of the plateau has long been inhabited. Thus, apart from forest plantations, the original savanna vegetation is now to a large extent replaced by peasant cultivations and forest plantations.

Climate and Drainage

On the Mufindi Plateau there are a number of stations where climate are measured. The Mgololo area, on the other hand, lacks current climate records (3). Except at the highest altitudes, a typical savanna climate characterizes the area, with a wet period from November to April and no, or insignificant, rainfall during the rest of the year. The annual rainfall at the site of the mill was 1,194 mm in 1981. On the upper edge of the escarpment the precipitation is higher, in places over 2,000 mm per year. It then diminishes away from the escarpment so that 40–50 km to the northwest it is only 1,000 mm. The average annual temperature is around 20°C, slightly higher in the Mgololo Valley and lower on the Mufindi Plateau. Particularly during the months of July and August, the weather is cool and misty, with minimum temperatures below 10°C.

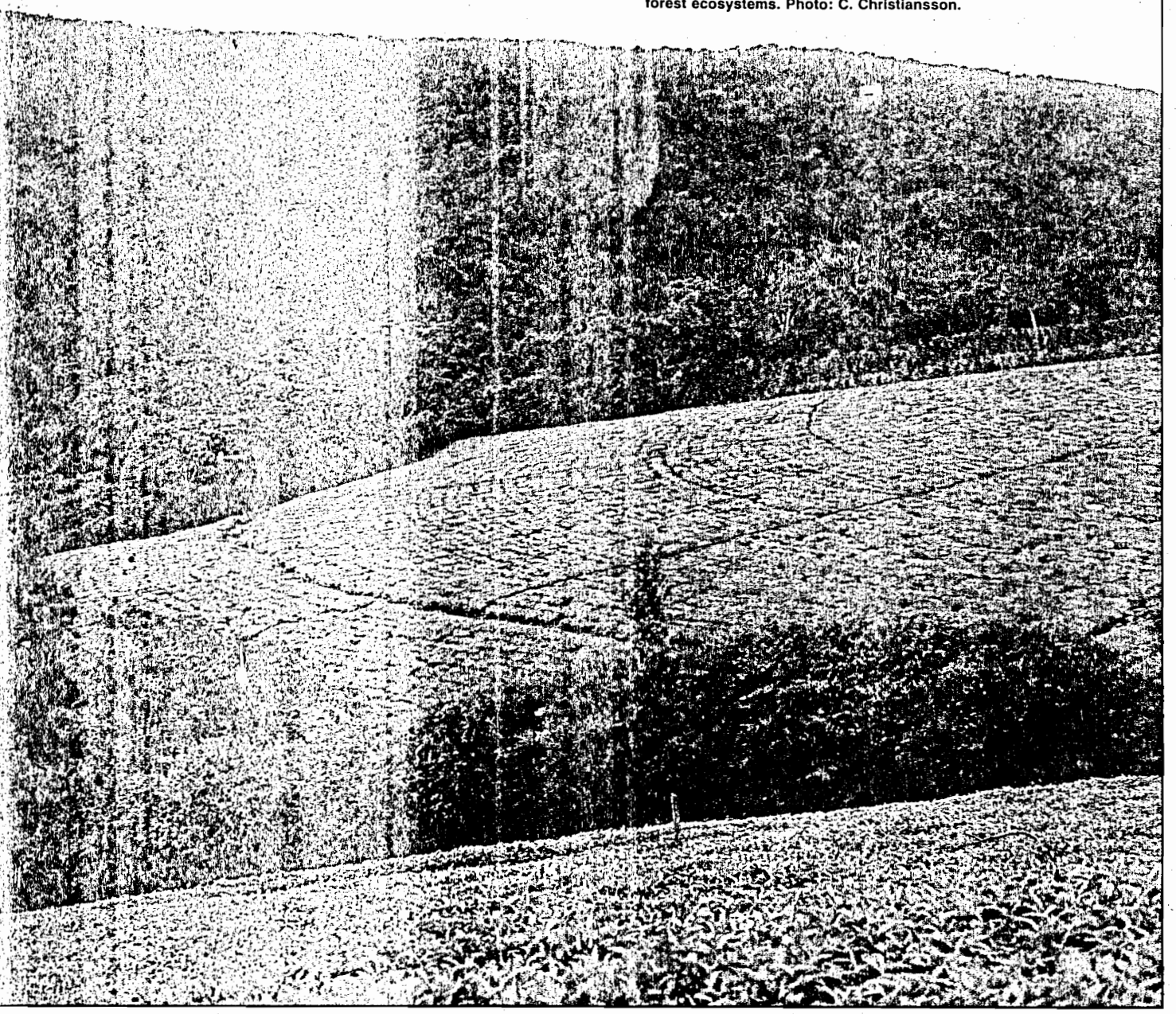
The northern part of the plateau drains toward the northeast, while the southern part and the Mgololo Valley drain southward via the Kigogo-Ruaha River and other small streams flowing down the escarpment. Kigogo-Ruaha is a well-oxygenated, oligotrophic stream hosting a variety of invertebrate and fish species. The stream has a width at the mill site of approximately 10 m and a depth of one to two meters. The average discharge is 10 m^3/sec., but there are considerable variations between seasons. The maximum discharge is estimated to 200 m^3/sec., while the 30-year dry season minimum is 1.3 m^3. Fifty-five km downstream from the mill site, the Kigogo-Ruaha flows into the larger Mnyera River. Via Kilombero and the lower Rufiji, the drainage reaches the Indian Ocean.

Traditional Land Use

On the average between 5 and 15 percent of the total land area of each village is under cultivation. The agriculture practiced is generally of simple subsistence character. The technique applied is rotational fallowing, an intense type of slash-and-burn cultivation with short fallow periods and some use of cattle manure. Each household cultivates on an average of 2.2 to 4.8 hectares, often distributed on several separate fields to maximize the ecological advantages of different areas. The staple crops grown are maize (corn), millet, beans, sweet potatoes and cassava, supplemented by a number of secondary crops (4).

The agricultural potential is low due to the limited content of organic matter. Topsoil pH values vary from 5.1 to 5.7 in the Mgololo Valley, and from 4.5 to 5.5 in the tea plantation areas (5). The local forest resources, which are mainly used as household fuel and as building material, vary from one village to another. Some villages have only one or two percent of their total area under woodland. Common woodland communities consist of *Parinari, Brachystegia, Combretum* and *Uapaca* species, relatively slow-growing and with low wood content. Riverine forest with dense stands of *Syzigium* occurs along streams (6). Game is sparse near settled areas, but towards the south where there are extensive virtually uninhabited areas, buffalo, lion leopard, antelopes and gazelles are found (7).

Tea plantations have partly replaced natural montane rain forests on the Mufindi Plateau. It is now feared that SO_2 emissions from the mill may have considerable impact on both the plantations and the natural forest ecosystems. Photo: C. Christiansson.



THE WOOD RESOURCES

The forest resources that will be utilized in the pulp mill are situated on the plateau above the Mufindi Escarpment. Primarily *Pinus patula* and *Pinus elliottii* and some eucalyptus will be used in the processes, together with waste wood from the Sao Hill sawmill. It has been questioned whether the existing plantation area (14,600 ha in 1982), supplemented by additional plantation programs, will be sufficient as a basis for both the pulp and paper mill and the sawmill. The pulp mill will consume some 287,000 m^3 of wood per annum, and to produce that amount a total plantation area of 19,000 ha is required (8).

Had the mill started operating in 1982 as originally planned, a shortage of pulp wood would have occurred in the early 1990s, necessitating importation of pulp (9). Now that the start of operations is delayed and additional plantations will have reached the recommended felling age, the wood supply situation is improved. There are, however, numerous risks involved in plantation enterprises in tropical areas. Thus, for instance, the results of the 1975–77 plantation activities were very disappointing, with a low rate of seedling survival. The responsible authorities blamed the situation on "unnatural drought, unsuitable planting methods, lack of transport facilities and administrative problems" (10). However, in savanna climates droughts are more often the rule than the exception, and transport and administrative imperfections have burdened the project ever since 1977. A further problem is forest fires that repeatedly devastate considerable plantation areas. Fear has been expressed that competition for the wood resource would arise between the sawmill and the paper mill. The sawmill investment is only two percent that of the pulp and paper mill. Thus the paper production would be given priority, with the consequence that the trees would be felled before they reach the best dimensions for saw logs (11).

The question about a possible shortage of raw material has also been linked to the fact that lack of wood for fuel and building material is an acute problem in large parts

View of the Mgololo Valley at sunrise. Morning mist and smoke from grass fires have accumulated below the escarpment during the night. Later in the day, when the air is warmed, it will rise, bringing with it ash particles and other pollutants.

of Tanzania. Thus, the SPM project is considered questionable because it locks up resources that could have been used in other forestry projects. For the amount spent on the pulp and paper mill project some 5,000 villages could each get a village forest of 100 ha (11), and the need for village forests is acute. Out of 34 million m^3 of wood used in Tanzania in 1973, 33 million went to fuel households.

RESOURCE CONFLICTS AND ENVIRONMENTAL IMPACT

The establishment of the mill strongly influences both the socio-economic structure and the natural environment. New groups of users successively demand shares of resources not yet utilized or already utilized by others. Therefore, it is important to analyze how social and environmental factors interact when new demands are placed on available resources, and which conflicts this process may cause. In the case of Tanzania, there are a number of situations in which primary-resource users encroach on each other's areas of interest with far-reaching consequences. The following are some obvious examples that apply to the SPM project:

– The establishment of a new mill town and the substantial immigration into the area will cause competition for arable land, building material and energy.

– Unavoidable air and water pollutants will affect the natural ecosystem in parts of the area.

– Food requirements have already increased dramatically. Areas now covered by grass, bush or woodland are being cleared for cultivation. If no countermeasures are taken, treeless areas will soon expand around the villages. A comparison can be made with other parts of Tanzania in which land degradation has been observed, not primarily because of difficult physical conditions but as a result of changes in the land-use pattern and land-use methods caused by increasing population pressure (12).

DISPOSAL OF WASTE WATER

There is very limited experience in Tanzania with the treatment of industrial wastes, as practically all industries in the country have thus far emitted wastes and by-products to the surroundings without

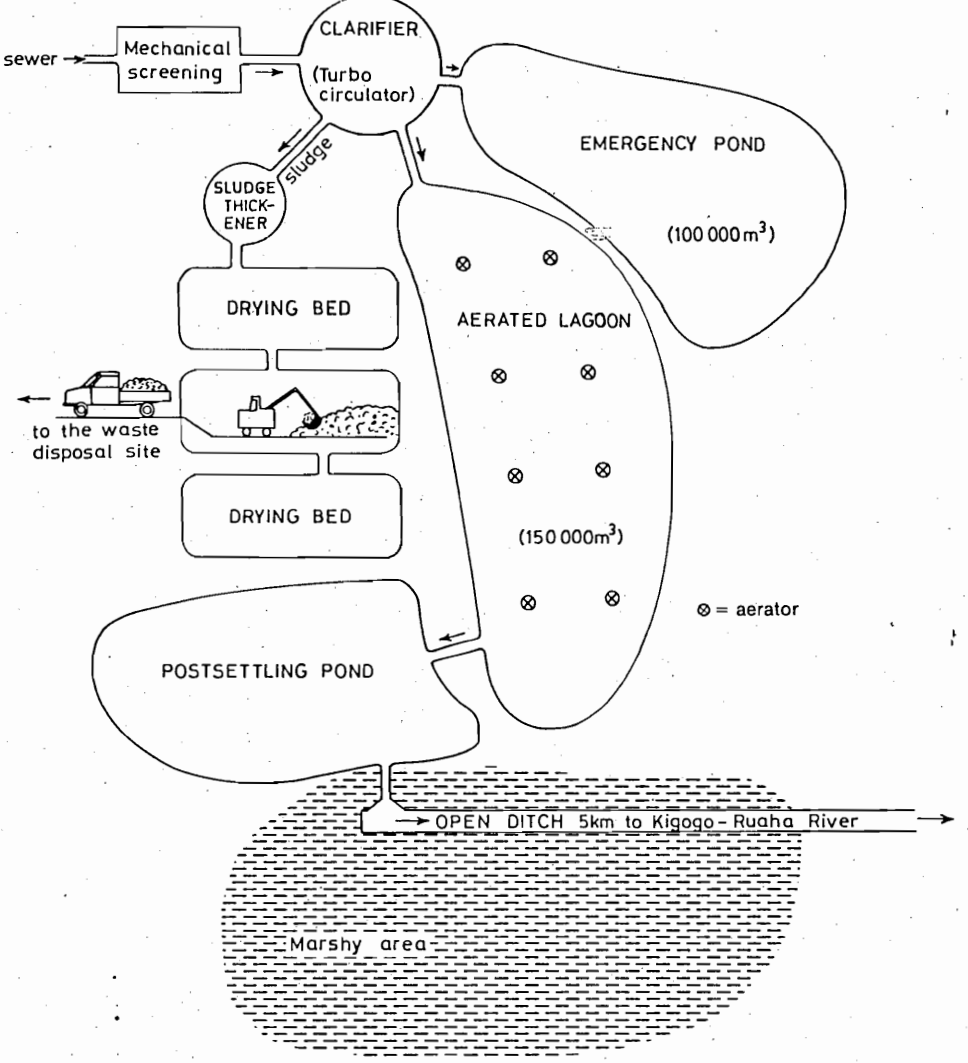


Figure 2. This diagram of an external effluent treatment system tracks the flow of waste from the sewers. After mechanical screening, the effluent reaches the clarifier where sedimentation takes place. The sludge is then led to the sludge thickener, dried in a drying bed, and finally deposited in a waste disposal site. The remaining liquid in the clarifier is led into the aerated lagoon for degradation of organic substances. Three to eight days later it will be let out into the Kigogo-Ruaha (22).

proper treatment.

The Kigogo-Ruaha River and its tributaries will provide water for all industrial processes at SPM and for the new township. The river will also receive effluents from the mill and the town and, even now, supplies the local population with water for domestic purposes.

Relatively few settlements are to be found downstream of the mill along the Kigogo-Ruaha and Mnyera. Farther downstream, in the Rufiji River basin, denser populations are found. One part of the basin, the Kilombero floodplain, supports a commercial fishery with a mean annual catch in the 1970s of 4,660 tons and a potential catch of 25,000 tons (13), just as much as Tanzania catches today in its part of Lake Nyasa.

Effluent Treatment

The mill sewer leads to an external effluent treatment plant (see Figure 2) where sedimentation takes place, followed by degradation of organic substances in an aerated lagoon. The first intention was to construct a pipeline to transport the treated effluent from the mill site to the river. The latest decision is, however, to dig an open ditch instead, the advantages being lower costs and continued oxidation as the effluent flows the five kilometers to the outlet into Kigogo-Ruaha. A clear disadvantage is that the marshy area between the mill and the river might be so flooded in the rainy season that the ditch ceases to function as planned and the effluent spreads in the marshy area instead.

A narrow creek that will be used as a basis for the ditch, presently hosts fish and freshwater arthropods (14). The importance of the surrounding permanent and seasonal marshlands to the life cycles of aquatic organisms in that ecosystem is not known. However, in other parts of the world, such areas have proved essential to the survival of several species.

Nevertheless, individual families do fish when there is free time in order to add Kambare (*Clarias mossambicus*), Relege (*Tilapia* sp) and Mkunga to their diets. This activity takes place mainly during the dry season.

Kigogo-Ruaha River

When the effluent finally reaches the river, a serious potential effect is oxygen depletion. The Swedish Water and Air Pollution

Research Institute (IVL) has in an oxygen-balance calculation (15) showed "oxygen depletion not to be a serious problem" at the intended removal percentage of the aerated lagoon—80–85 percent BOD (biological oxygen demand) reduction. If the treatment is less effective, due to accidental spills or some temporary breakdown in the plant, the entire fish fauna could die out.

The suspended solids discharged into the Kigogo-Ruaha, and the color of the effluent, are expected to restrict light penetration, which might cause decreased algal growth and a reduced fish population. More serious, however, is the toxic content of the effluent. It will contain resin acids and fatty acids, which are both toxic to fish at approximately 1.0 mg/l, and have sublethal effects (i.e., they injure the organism but do not cause immediate death) at approximately 0.05–1.0 mg/l (13). Even more toxic and resistant to biodegradation are the chlorinated resin acids from the bleaching plant. Chlorinated phenolic compounds, products of chlorinated lignin degradation, accumulate rapidly in fish flesh, giving it a taste and odor disliked by most people. At high concentrations the fish would be dangerous to eat.

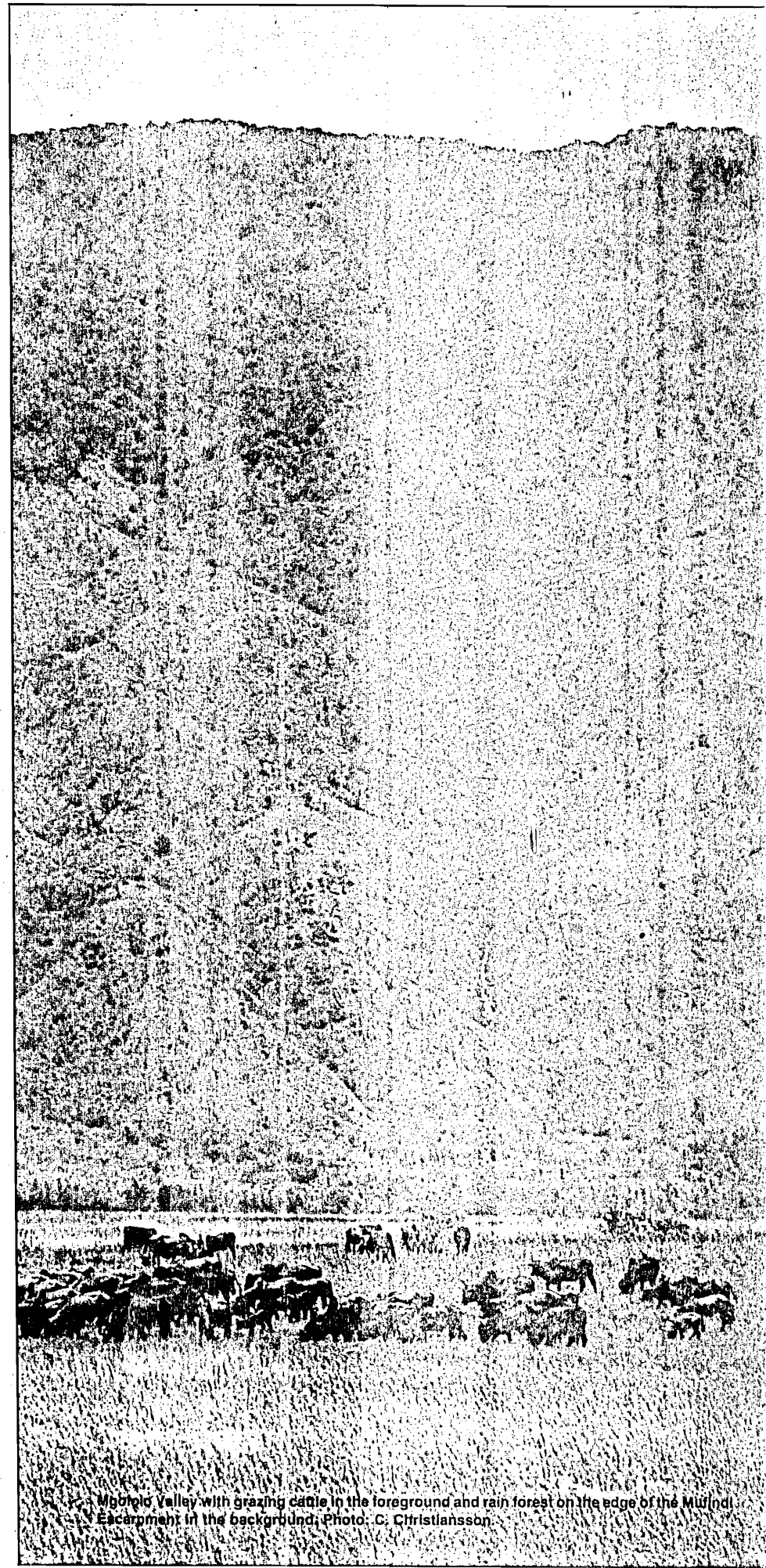
The untreated condensates give rise to organosulfur compounds and hydrogen sulfide (H_2S). It is uncertain whether the organosulfur compounds will all be oxidized before being discharged from the post-settling pond. They will affect the taste of the fish and the water if they reach the river. Before reaching the Kilombero floodplain, however, they will be oxidized.

The likely concentrations of toxicants in the treated effluent are difficult to estimate and little can be said about the possible effects. It should be noted, however, that only at maximum river flow can the desired dilution of 1:30 be achieved or exceeded (16); during the dry season it could be 3–7 times lower.

Possible Effects on Domestic Water Supplies

No noticeable adverse effects are expected on the Kilombero floodplain provided the effluent treatment plant meets the design criteria (e.g., 85 percent BOD reduction). The plain is so far downstream that biodegradation and dilution will have reduced the effects along the way, though toxic organic substances could possibly be noted in tainted fish flesh. Apart from the fact that the aquatic ecosystem of the Kigogo-Ruaha may be brought out of balance, the main concern is how the villages in the vicinity of the mill use the river. Lugema and Makungu (Figure 1) depend entirely on tributaries for drinking water and have no organized fishing.

The inhabitants of the village just beside the mill, Mabaoni, bring their drinking water from a spring close to the outlet of the effluent treatment plant. If the effluent should flow towards the spring instead of along the planned ditch, the effects could be disastrous. Furthermore, the groundwater might contain heavy alloys, bacteria or toxic components from the sludge and ash deposited on land. The soil properties and groundwater movements at the disposal site have not yet been investigated.



Mbarali Valley with grazing cattle in the foreground and rain forest on the edge of the Mufindi Escarpment in the background. Photo: C. Christiansson.

EMISSIONS INTO THE ATMOSPHERE

A major source of emissions, apart from the traditional in-plant sources at an integrated sulfate mill, is the power boiler burning coal, oil and bark. The surrounding ecosystems will be affected in three ways:

a) high ambient concentrations of totally reduced sulfur compounds (TRS), sulfur dioxide (SO_2), dust and possibly nitrogen oxides (NO_x),
b) dry and wet acid deposition,
c) deposition of particulates.

For most of the year the prevailing winds are toward the north-northwest and west-northwest (17). In those directions there is little cultivated land to be found in the immediate vicinity of the mill, but a few kilometers away there is a village, Magunguli, with several hundred households. However, a typical sulfate mill odor will be spread in all directions from the mill. Some officials anticipate protests from the local population while others argue that it will be "the smell of progress" against which nobody will protest.

Southern Paper Mills is planning to run a company farm and the employees will have private lots. Depending on the sensitivity of the crops to the air emissions, the yields might be reduced when the mill starts producing. A general acidification of the soil will undoubtedly occur with time, but how long it will take and how large an area will be affected is not known.

Tea Plantations—an Opportunity Cost?

The most immediate concern about air emissions emanates from the tea plantations some six to nine kilometers north and northwest of the mill, and has been voiced mainly by Brooke Bond Tanzania Ltd. (BBTL), the largest tea grower in the area, with about 2,500 ha of plantation land. Two of the company's most productive plantations are located downwind of the mill site. These plantations are also affected by local atmospheric circulation occurring frequently from March to May and occasionally during the rest of the year (Figure 3) when cold, moist air accumulates in the valley during the night and starts rising along the escarpment as it is warmed up in the morning. If emissions from the mill have been concentrated in the cold air, they will move upwards as the air rises and be deposited with fog or rain on the tea plantations during the course of the day. This rising "morning fog" has been observed for several years, the question is how high a concentration of emissions will be contained in the fog and rain.

The tea growers are worried that SO_2 and TRS might affect the metabolism of the young tea leaves and that the odorous gases might be absorbed by the tea plants. The ultimate factor to consider is, of course, the flavor of the tea. According to the Chairman of BBTL, even a minor change in flavor would render the crop valueless and thereby worsen the already serious strain on Tanzania's balance of payments. A large proportion of the foreign capital earnings from tea export is made by BBTL.

As for acidification, the soil now has a pH value of approximately 5. The ideal

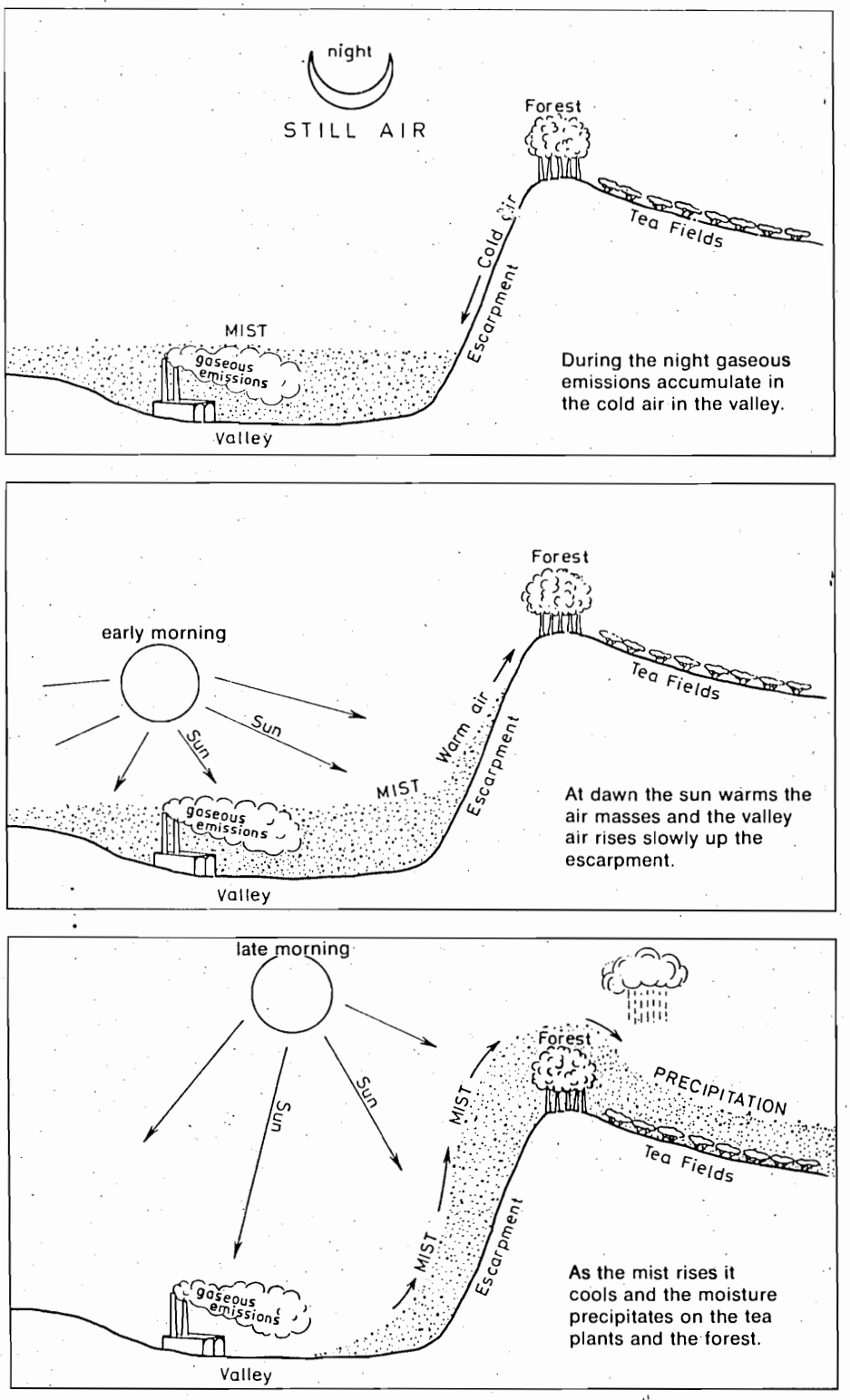
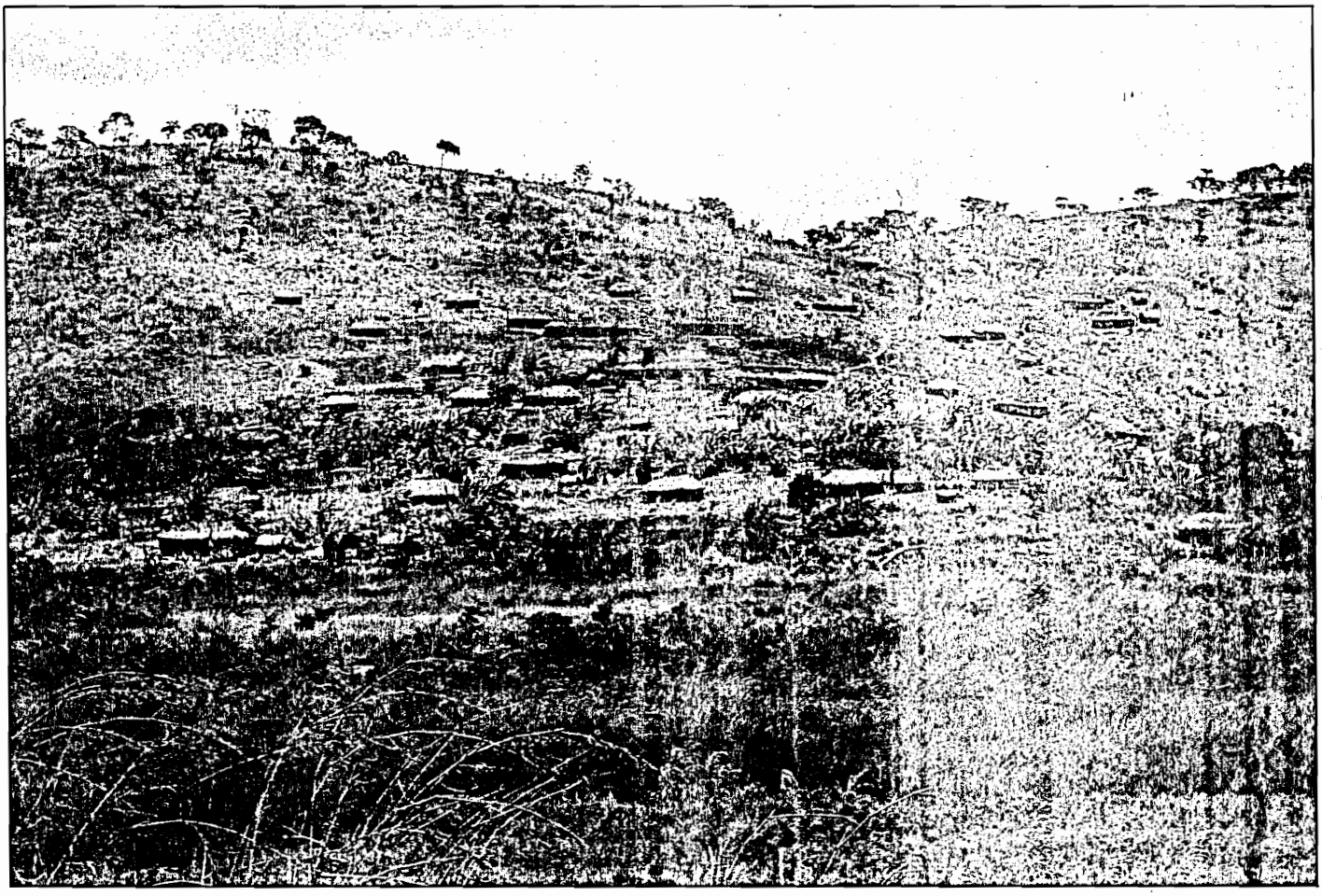


Figure 3. Illustration of the distribution of gaseous emissions from the mill to the rain-forest reserves and tea plantations of the Mufindi Plateau (22).



All villages in the immediate vicinity of the mill site have experienced considerable immigration during the last few years. Settlements and cultivations are spreading to deforested, erosion-prone slopes. Photo C. Christiansson.

value for tea growing is between 4.5 and 5.5 (18), which suggests that a slight acidification of the soil would not affect the tea to any considerable degree.

However, nobody knows what the buffer capacity is in this tropical soil, which has an average pH value just above the lowest acceptable for most crops grown in the area. This makes it probable that it would not take much acid deposition to severely affect the agricultural potential in the tea plantation area.

The Forest Reserve

Between the two above-mentioned tea plantations is a forest reserve, the Kigogo Forest. It is a montane rain forest that regulates the run-off pattern in the area; without it the river flow would fluctuate heavily. If the water level in the Kigogo-Ruaha River should start fluctuating more than usual, the amount of water available for the mill and the township might be seriously reduced.

The forest is part of the Tanganyika-Nyasa mountain-block chain with forests well-known for their diversity and endemism (19). The reserve hosts a spectacular variety of reptiles and amphibians, some of which have been found only there. The biology of these species—eating habits, breeding habits, etc.—is virtually unknown. The bird life is exceptional and the forest is a "type locality" for animals like *Chamaeleo laterispinis* (spiny-sided chameleon), *Melanoseps ater uzungwensis* (Uzungwa limbless skink), *Bufo uzungwensis* (a toad known only from the Uzungwa Mountains, of which the Mufindi scarp forms the southwestern part) and *Cryptomus hottentotus occlusus* (a blesmol), etc. (20).

INDIRECT EFFECTS OF THE MILL

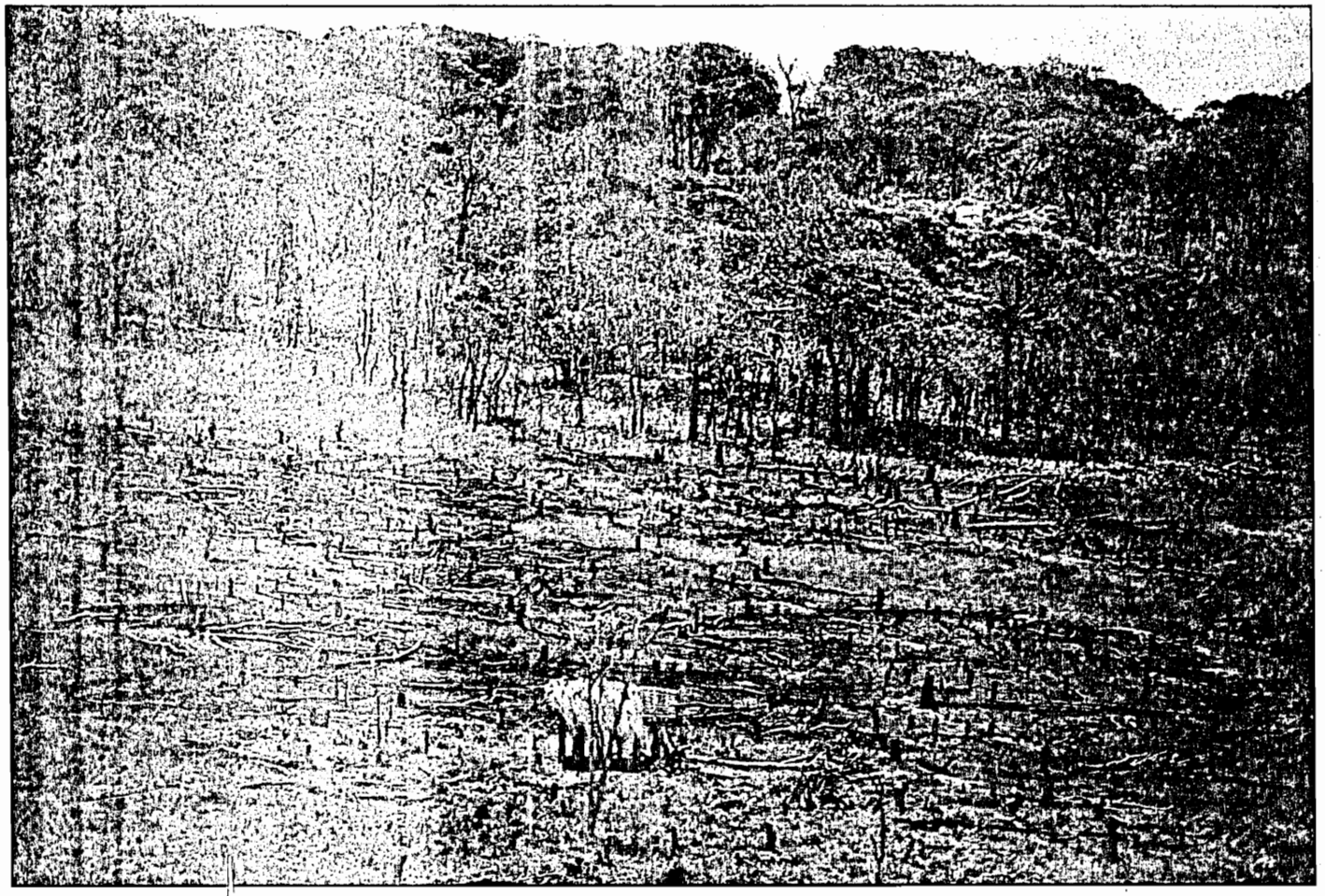
Apart from the direct impact on air, water and soil a number of indirect effects on the environment are likely, and some have already occurred. The immigration into the area is considerable. Lugema village, for instance, which is situated near the mill site, received during a short period in late 1984, 120 applications from households that wanted to become village members (21). And the village had already increased its population markedly during the last few years. Moreover, a completely new village, Mabaoni, has sprung up near the mill site. Large areas that were not cultivated in 1983 are now covered by cleared land and homesteads (22).

Changes in Infrastructure and Socio-Economy

The regional plan for the Iringa region contains no details about land use in the southern part of Mufindi District. Alternatives mentioned in general terms are forest plantations, coffee plantations and ranching (23).

Land belonging to three villages has

Repeated burning of undergrowth in a woodland area kills the woody vegetation, resulting in an open landscape less protected against erosion. Photo: C. Christiansson.



Clearing of savanna woodland for new cultivations near Lugema village. The whole of the Mgololo area is rapidly being deforested as a result of heavy immigration followed by intensified land use.
Photo: C. Christiansson.

Table. Summary of Possible Ecological Effects

Source	Type of change	Initial effect	Ecological effect
Discharges into water	Oxygen depletion	Fauna and flora reduced	Fewer fish, reduced species diversity
	Suspended solids	Increased turbidity	Reduced algal growth and possibly fewer fish
	Toxicity	Bioaccumulation or toxicity	Fewer fish and arthropods, impaired fish taste, risk of toxicity via fish and drinking water
	Color and scum	Decreased light penetration	Reduced algal growth and possibly fewer fish, decreased amenity
	Odor	Odor	Amenity (migration or protests)
Emissions into air	Totally Reduced Sulfur compounds (TRS) (mercaptans & H_2S)	Odor, toxicity, absorption into plant tissue	Damage to plants, agriculture, forest reserves and human amenity
	SO_2	Acidification, absorption into plant tissue	Damage to all vegetation
	Dust (particulates)	Deposition and impaired air quality	Impaired health and damaged vegetation
Disposal of solid wastes	Sludge Ash	Drainage and mud flows at the waste-disposal site, bacteria and heavy alloys in the ground water	Fewer fish and diversity, reduced algal growth and possibly less fish, impaired drinking water
Immigration	Intensification and change of land use	More open landscape, erosion, increased use of fertilizers	Decreased production potential, locals less able to support themselves, less wild life, higher crop yields
	Increased demand for firewood and charcoal	Erosion	Same as above, (except higher yields)
Construction and infrastructure	Occupation of land	More open landscape, erosion, increased use of fertilizers	Decreased production potential, locals less able to support themselves, less wildlife, higher yields
	Sewer and wastes from the township	Fauna and flora reduced, increased turbidity, drainage and mud flows at waste disposal site	Fewer fish, reduced species diversity, reduced algal growth and possibly less fish
	Transportation in the area	Accidents, exhaust fumes	Public health problems and plant-tissue damage

been expropriated to accommodate the mill, the township, the airport, the waste disposal site, new roads, etc. These villages now have less land for their primary activity, agriculture. Furthermore, forest plantations are planned on land that is presently used for cattle grazing and that otherwise would serve as expansion areas for the agricultural sector.

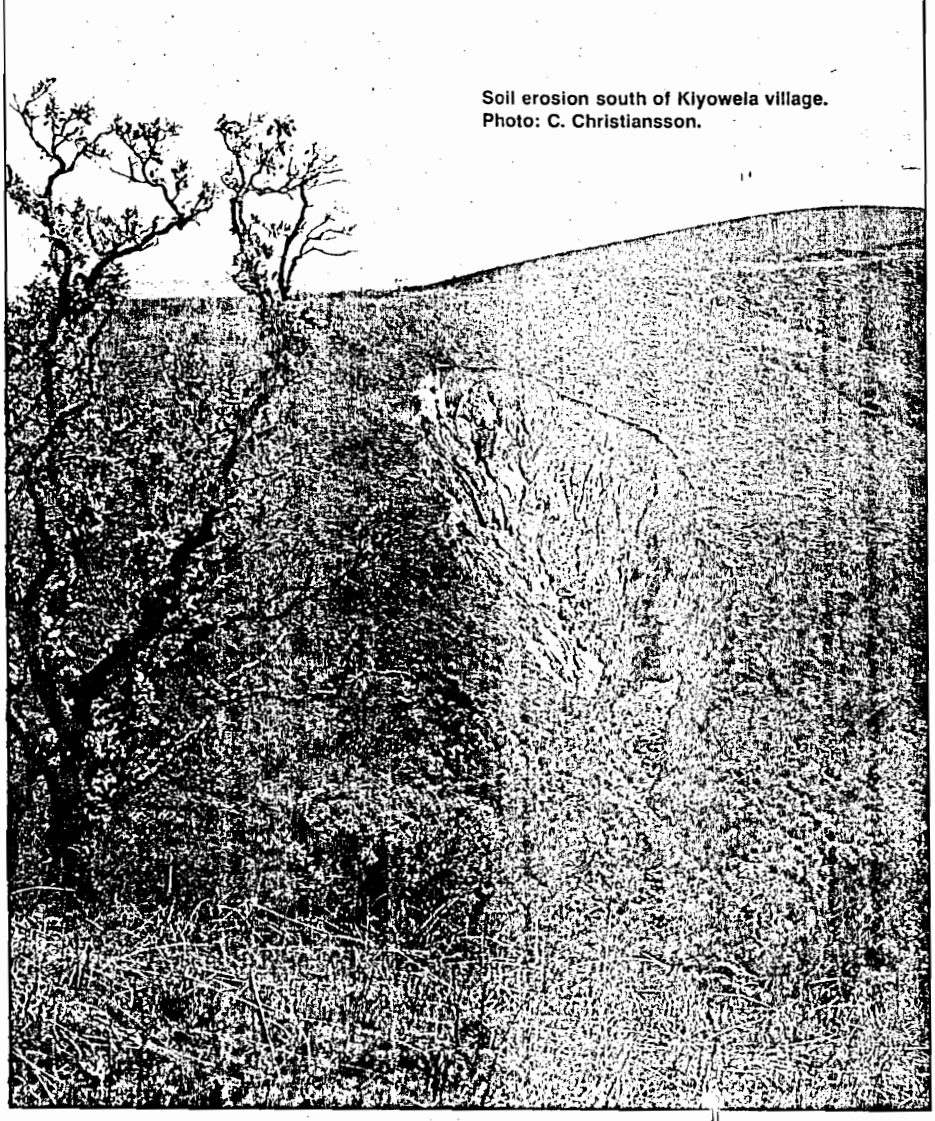
Establishment of the mill town means that town inhabitants will demand land for cultivation. As the most productive land around the town is already used for agricultural purposes, competition will arise between villagers and immigrants.

On the local level many positive effects of the mill establishment can also be expected. Among these are improved communications, improved social and commercial services and creation of new jobs. Furthermore, the project will bring about the introduction of telecommunications and electricity.

But negative effects in addition to those discussed above, and that are not directly related to the bio-physical environment, have begun to appear. One such effect is the increase in the amount of work performed by women, as male labor is removed from the agricultural sector (24).

Intensified Land Utilization

Two of the most serious threats to the environment are the uncontrolled clearing of land to extend cultivation and the uncontrolled grass fires used to improve grazing conditions. Burning is a labor-saving clearing method that has a number of positive effects, but it seriously reduces the content of humus and certain plant nu-



Soil erosion south of Kiyowela village.
Photo: C. Christiansson.

Effects of Industrial Investments in Developing Countries: An Integrated Geographic Research Project

Using the Southern Paper Mills (SPM) as a case study, the purpose of the research program is to contribute to the empirical and theoretical foundation by which to assess the effects of large-scale industrial investments in developing countries. The study is a joint research effort by the Institute of Resource Assessment (IRA) of the University of Dar es Salaam and the Economic Research Institute (ERI) of the Stockholm School of Economics. The project involves participants from the universities of Stockholm, Umeå and Dar es Salaam and the Stockholm School of Economics. The studies are financed by a grant from the Swedish Agency for Research Cooperation with Developing Countries (SAREC).

The research project is conceived as an integrated research program encompassing three interrelated studies. The first of these concerns the description and analysis of the planning and decision processes preceding the implementation of the SPM project. This study not only forms an essential background to the analysis of socio-economic and environmental impact but will also provide valuable insight as to how the organization and design of the "pre-investment function" affect the outcome and effectiveness of industrial project planning.

The second and third central objectives relate to socio-economic and environmental effects of the mill establishment. These include analyses of potential environmental change and the ways in which a number of factors interact in response to the new demands on local resources, the conflicts these processes may cause and the way in which these conflicts might be resolved. The basis for this analysis is, on the one hand, a socio-economic baseline survey encompassing all villages in the vicinity of the mill site and, on the other, an inventory of natural environmental factors and resource conditions in the area likely to be affected.

The studies provide an empirical foundation on which to construct a number of "scenarios" describing possible future development paths and identifying potential problems and areas of conflict. These scenarios may be used as a planning instrument for the SPM project, i.e., a support for future decisions concerning changes in technical design and administrative policy as well as for long-term community planning and environmental management in the area. The results are also meant to be used to assess effects of similar industrial projects in other developing countries.

trients in the topsoil.

The selection of land for cultivation is based on farmer assessment of the actual state of the natural vegetation. Areas with tall trees with wide crowns and dense canopies are considered the most fertile. The clearing of this land means that practically all trees in the selected area are cut or burned down without any environmental consideration. Only trees with edible fruits such as *Parinari curatellifolia* (Msaula) and *Uapaca kirkiana* (Mkusu) are left (6).

Clearing implies increased erosion risks. The result of unregulated burning in a savanna environment is development of a more open countryside. In the treeless, hilly areas east and south of the mill site active erosion is obvious. Water infiltrates on the upper parts of the hills, seeps through the soil and again emerges on the surface farther down the slope. When tree roots no longer bind the soil efficiently seepage affects the stability of the soil (on the hillsides) and it tends to slump or slide down the slope. The erosion sear on the photo on page 132 covers several thousand m^2 and is the effect of a combination of slide and channel erosion processes. This suggests that land degradation quickly can reach serious proportions.

The pressure on forest resources is further increased by the growing demand for fuelwood in the expanding village. The production and sale of charcoal has also become a profitable business for the inhabitants. Other expanding activities are brick production and the brewing of local beer, placing additional demands on fuelwood resources (25).

UNCERTAINTY AND THE VALUE OF PRESERVATION

A large industrial project of this kind is expected to benefit the entire nation by, for example, improving the balance of trade and increasing technical know-how. Before the project got underway, costs and benefits were discussed at length, but the feasibility study did not take up any potential ecological or socio-economic effects. Uncertainty regarding such external effects did not, however, delay the authorization of the project.

In 1978 an integrated research project was initiated by the Institute of Resource Assessment (IRA) at the University of Dar es Salaam and the Economic Research Institute (EFI) at the Stockholm School of Economics to contribute to the empirical and theoretical foundation with which to assess the effects of large-scale industrial investments in developing countries (Box). The SPM project was chosen as a case study, and the results are expected to serve as useful instruments in the planning process at the district level (26).

Incorporation of External Effects in the Decision Process

Whether the external effects are explicitly incorporated in the decision process, i.e., in monetary terms, or assessed in some multidimensional impact analysis, the effects must at least have been identified and quantified. The indirect effects are related to the establishment of the project as such, and can therefore be registered today. The direct effects from emissions and discharges will not be seen until the mill starts producing pulp and paper.

It is important that the threatened ecosystems be studied before the foreign industrial substances are introduced to the environment. So-called base lines must be established in order to facilitate meaningful repeatable scientific research. This could provide a unique opportunity to amass data for future application to other industrial projects located in tropical ecosystems, as well as gather factual information concerning the SPM project. Southern Paper Mills needs good scientific material to protect itself from accusations of destroying tea plants, polluting drinking water, etc., and Brooke Bond Tanzania Ltd. will need substantial evidence if it is to blame declining productivity or changes in tea taste on emissions from the mills.

The potential conflict between growing tea and producing pulp and paper is an example of how present user values might have to be weighed against one another. A more fundamental problem is that most of the effects mentioned in this article are of a different kind, representing the value of future options. The project was initiated by national authorities and financed by foreign-aid organizations and international loans, but an entirely different group of people will have their lives revolutionized and their environment changed.

The typical inhabitant of, say, Lugema Village may, in a few years, have seen his family go from an established, relatively secure existence as subsistence farmers to a situation in which it is dependent on the demand for local labor, beer and charcoal in a deteriorating environment. Tanzania's development towards national self-reliance has its price, and that price appears to be reduced individual self-reliance and fewer options for the future.

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