Australian National University

"THE ATZERA PROJECT"

ECOLOGICAL MANAGEMENT OF THE ATZERA RANGE ADJOINING LAE, PAPUA NEW GUINEA : AN INITIAL PROPOSAL

by

DR. J.A. HARRIS*

CENTRE FOR RESOURCE AND ENVIRONMENTAL STUDIES

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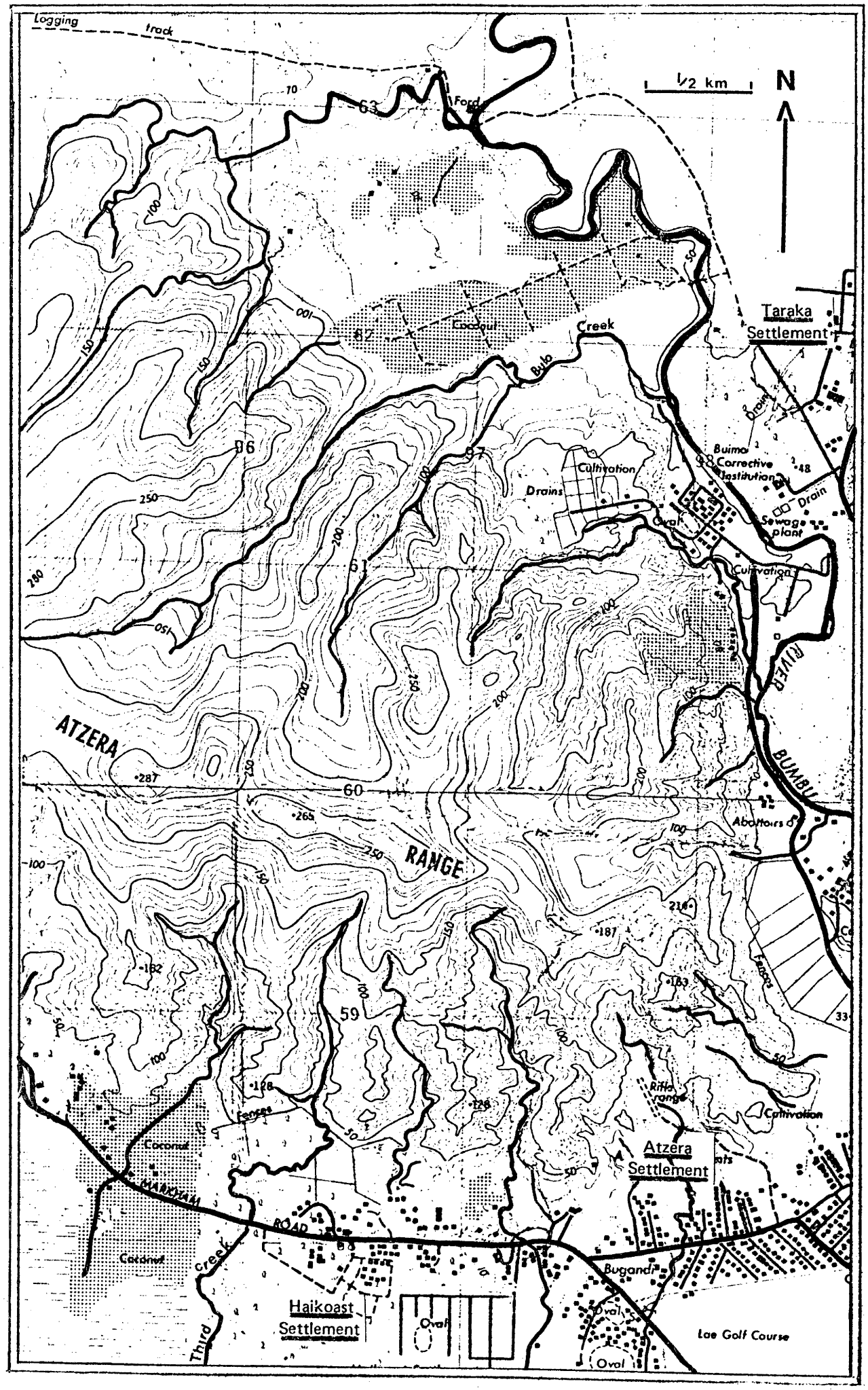

Figure I. Atzera Range study area adjoining Lae. Major settlements Haikoast, Atzera and Taraka are underlined in red. Watercourses shown in blue. Contour interval 10m.

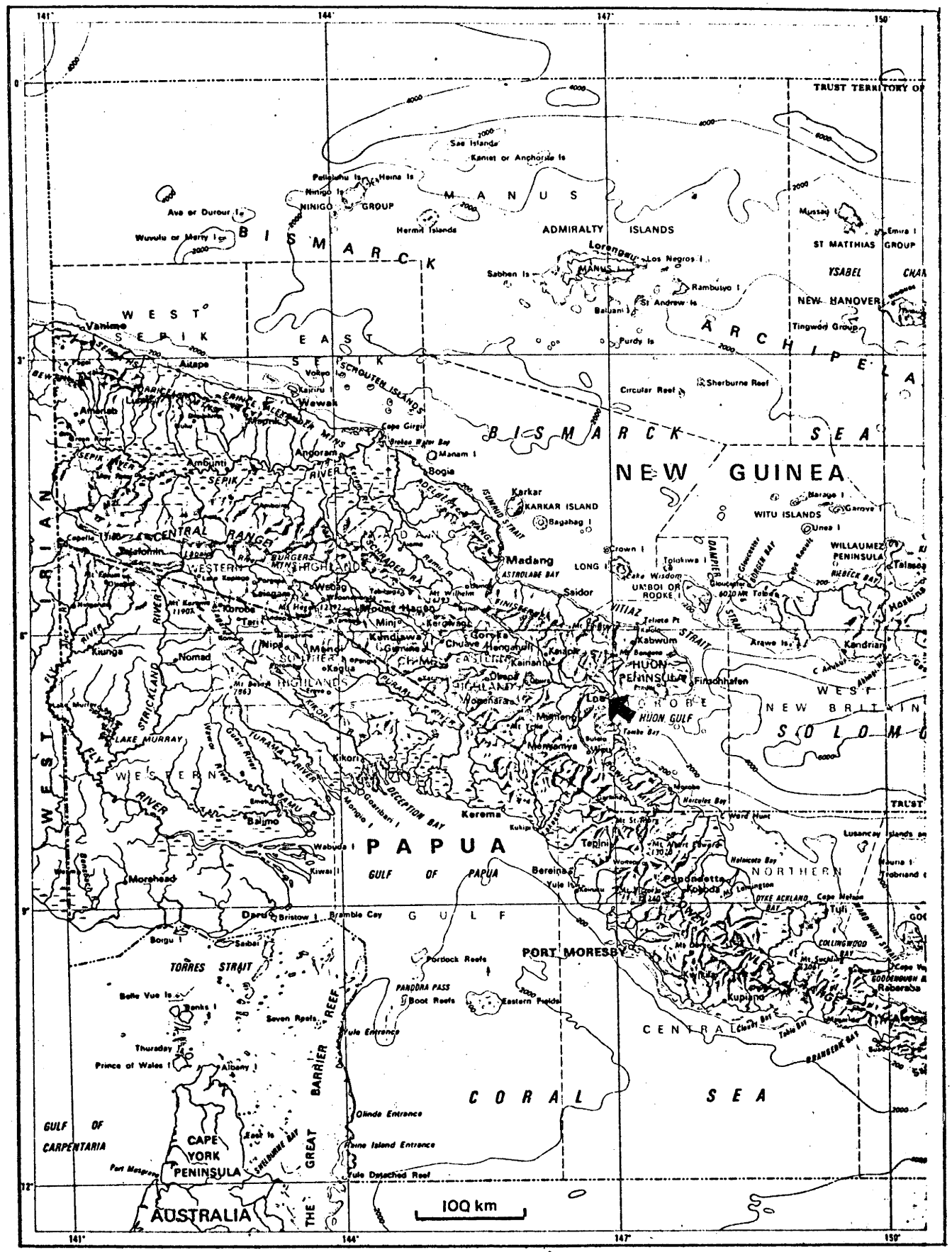

Figure 2. PAPUA NEW GUINEA Locality of study area shown in red

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1. INTRODUCTION

This is the report of a project[1] made as part of the Papua New Guinea Human Ecology Programme (PNGHEP) of research that is focussed on the city of Lae and its hinterland. This Programme is funded by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) and the United Nations Environment Programme (UNEP) as part of the Man and the Biosphere Project Area 11 "Integrated Ecological Studies on Human Settlements" (UNESCO, 1976).

The PNGHEP is a broad integrated programme of research comprising four main projects, each covering problems of development from an ecological viewpoint. These projects cover (1) energy use patterns, (2) food habits and beliefs, (3) social relationships and (4) consumer behaviour of people living in the city of Lae compared with those living in villages within the Morobe Province. The aim of research in this Programme is to improve understanding in selected problem areas of national importance to demonstrate the utility of a holistic ecological approach which necessarily involves the integration of both social and biological factors in problem solving.

It is intended that this report on "The Atzera Project" should serve both to improve understanding of human impact on the Atzera Range adjoining Lae and to serve as a practical

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1 The research on "The Atzera Project" was carried out while the author was a Visiting Fellow with the Human Ecology Group, Centre for Resource and Environmental Studies of the Australian National University from February - June 1978 and includes intensive field work in Papua New Guinea from 1 - 17 May.

management plan for approximately 600 ha of this range of hills that is zoned within the Lae city boundary.[1] The city council of Lae wishes to assist the Papua New Guinea government by developing an integrated management plan for this area : the study area. Figures 1 and 2 show the site location of this area and a map of its topography and relationship to Lae.

Situated on the Huon Gulf close to the Markham River, Lae has a hot and humid climate with little seasonal variation. Annual average rainfall is 456 cm, with a peak in July and August. Relative humidity usually is about 80%. Average monthly temperatures vary from 24.8 - 27.4°C with an overall mean of 26.3°C and a daily range of approximately 5.5°C (Commonwealth Bureau of Meteorology, 1970).

The study area is a small section of an extensive system of steeply sloping and dissected range of hills called the Atzera Range which rises immediately behind the city of Lae (Fig.3) and extends about 13 km to the north-west in between the large Markham and Bumbu Rivers. The Atzera Range reaches a height of 300 metres and is the source of numerous streams that drain into the Bumbu and Markham rivers and associated swamps. The Bumbu River itself flows through the city of Lae.

Lae is the second largest urban centre and foremost industrial town of Papua New Guinea. The population is estimated to be 45,000 made up of 41,000 nationals and 4,000 expatriates.

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1 In 1900 the German government claimed 4743 ha of the Lae area between the Markham and Bumbu Rivers from the coastline inland for 7 miles (11 km) (Willis, 1974). In 1914 there was a change of administration when Lae was occupied by Australian troops. The League of Nations subsequently gave Australia a mandate for the administration of this area in 1920 but this was interrupted during the Japanese invasion in 1942 and subsequent military administrations during the Second World War. In 1946, when civilian administration resumed, the Lae area became part of a United Nations Trust Territory administered by Australia. On 1 December 1973, Papua New Guinea was granted self-government and on 16 September 1975, PNG adopted its own Constitution and became a fully independent state. Currently, the study area is zoned for recreation. The Lands Department carried out test drilling in the higher slopes of the area and found the soil too unstable for housing and permanent settlement (Young, pers. comm.).

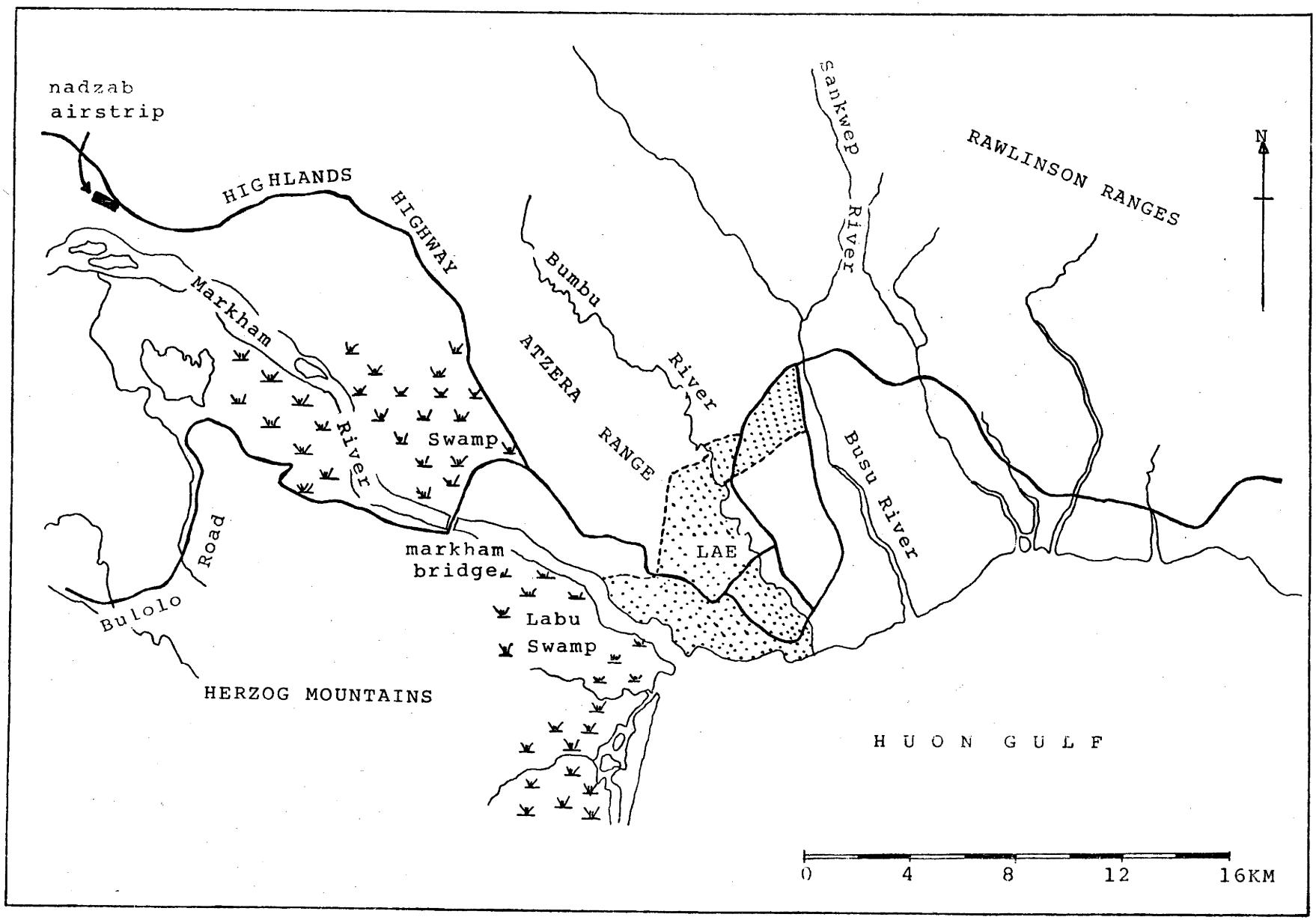

Figure 3. The Atzera Range extends for about 13km to the north-west of Lae in between the Markham and Bumbu Rivers.

The city's population growth rate is a very high 5% per annum, mostly due to the migration of Highlanders, who have easy access to Lae along the Highlands Highway. The self-help settlements of Atzera (Boundary Road), Haikoast (Two Mile and Three Mile) and Taraka (Fig. 1), contain a large proportion of this migrant population (about 20,000). These people have easy access to the study area. Many of the families living in these settlements, and elsewhere on the outskirts of the city, have to (or choose to) garden, and gather firewood in the hills overlooking their homes (Fig. 4), or further in the forests. These activities are necessary to provide numerous individuals and families with subsistence food, a little cash from food sales at the local market and their firewood (the most commonly used domestic fuel). It is these people who are having an increasing impact on the local ecosystems of the Atzera Range.

Unemployment is high in the population, therefore, people who cannot get a job look for land on which to garden. In most parts of Lae, however, land suitable for gardening is government owned or belongs to the traditional people still living in the villages around the city. It is rarely available for migrant settlers. The only land easily accessible to these people occurs in the Atzera Range adjoining their settlements shown in Figure 1, but this land is showing signs of serious deforestation and soil erosion (Fig. 4). Not only is there a shortage of land for these people but their cultivation of this land is not suited to their new social and environmental conditions. In general, gardening is usually more haphazard and over-intensive around the settlements. Most of these gardeners have some form of employment, but have few communal ties with each other and the sanctions and customs that would have traditionally protected a person's garden are not very effective. Therefore, thefts and damage to gardens often occurs.

Jeffries[1] states that women of the Fore language group who

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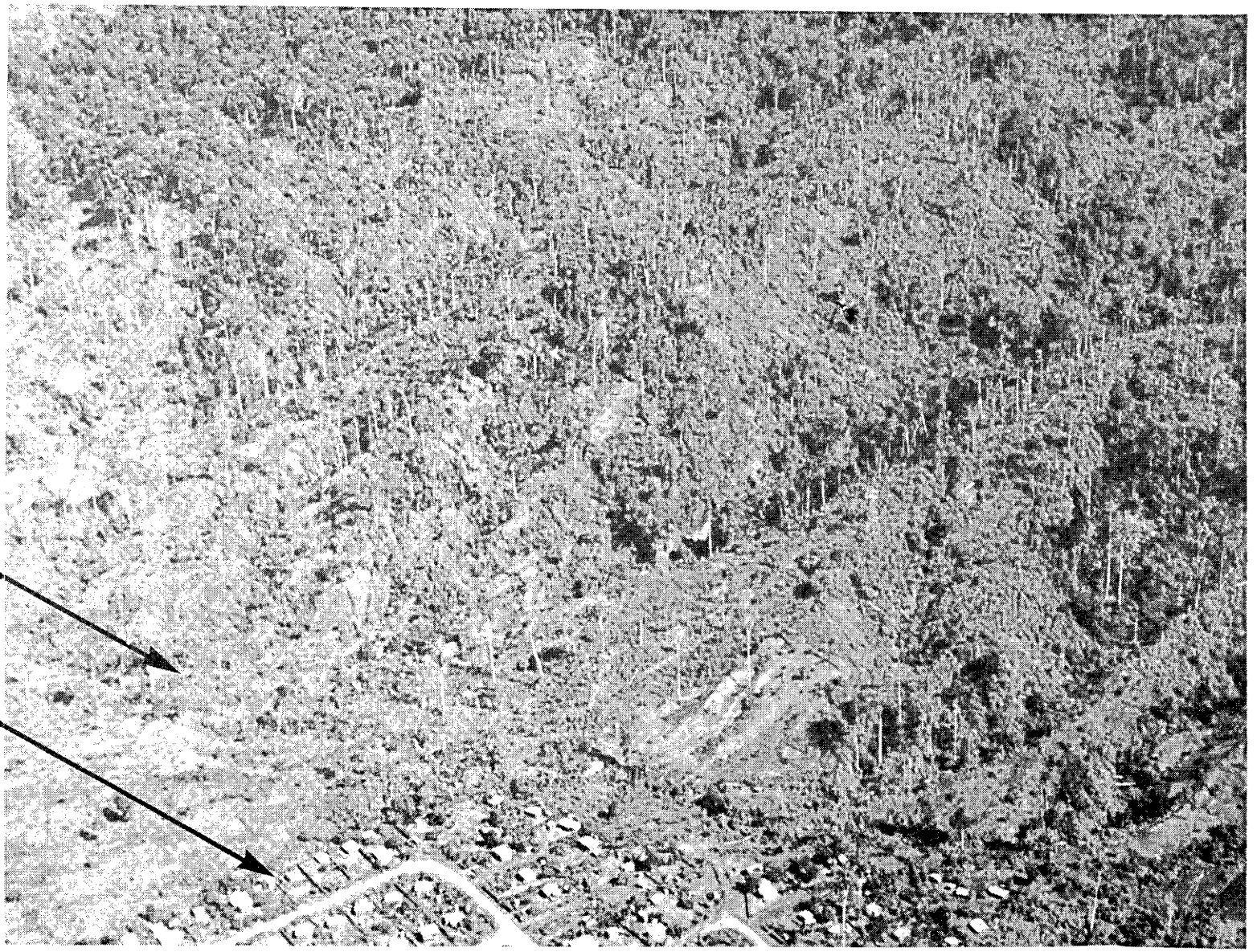
1 D. Jeffries is carrying out research into the food habits and beliefs of Fore people in their villages and Lae as part of the PNGHEP.

Figure 4. Atzera Range rising behind Taraka Settlement. The scarcity of large trees on coastal plains and foothills is due to intensive gardening; soil erosion is also evident. Extensive gardening is occurring further in the hills.



have migrated to Lae are likely to feel particularly insecure in town, with their men away at work for most of the day, and their older relatives still in the village. They are therefore less likely to walk long distances to gardens in unfamiliar forests where dangers may exist in the form of strangers and unfriendly "spirits" or "devils". Nevertheless, further in the hills away from the settlements less intensive bush gardens are common. Their cultivation is carried out less haphazardly with more traditional forms of shifting cultivation being used. Usually women and whole families are involved on a regular daily basis. The men of these families are probably unemployed.

There is no evidence of traditional tree crops being planted and husbanded anywhere in the study area. Annual food crops are universally grown with the longest living crop being bananas. This aspect of gardening probably is a true indication of gardeners knowing that there is no security of tenure for their gardens. In addition, the rapid decline in soil fertility, expressed in Pidgin as the loss of *gris*, is widely recognised as a problem and leads to more rapid shifting of bush gardens.

At the time of preparing this report the environmental consequences of these human activities are extensive deforestation and soil erosion. This situation is significant enough but when superimposed on a history of the study area since the turn of the century (see Willis, 1974) a greater realisation is gained of the extent of the on-going human disturbances to the lowland tropical rainforests that once covered this area : forests that for thousands of years sustained traditional hunting and gathering activities.[1] Disturbances such as the logging of commercial plant species as well as the cutting of timber during the Second World War have occurred and even the presence of bulldozers on at

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1 Traditional gardening was not practised in the Atzera Range adjoining Lae owing to ample coastal flatlands. (Holzkneckt, pers. comm.).

least one spur immediately behind the Haikoast Settlement.[1] Intensive hunting in the study area is another activity reflected now in the paucity of wildlife, (although hunting still occurs it is more successful in the remoter parts of the Atzera Range). The ecological implications of these cumulative human impacts is that the study area is regressing to kunai grasslands and, in many places, eroded landscapes[2] with no durable vegetation (Fig. 4). As a further consequence, both the quality and abundance of local resources are declining.

No one can be sure what the long-term consequences of such trends are for the future health and sustainability of human populations in the locality because of wider and larger events such as regional and national population changes (e.g. currently 47% of the total population of PNG is under 16) and, in general, the processes of cultural adaptation that are occurring in Papua New Guinea (e.g. Howlett, 1973; Sack, 1974) and the Pacific Region as a whole (Brookfield, 1973). Even on the scale of this study it is uncertain whether the expanding accelerating tidal wave of human impact along with its environmental consequences so clearly reflected by the Atzera Range, as if it were a finely polished mirror, can be stopped. It is certain, however, that if nothing is done these processes of degradation will continue. On the other hand, even if all human activities in the study area ceased, there is no guarantee that the existing forests could be self-regenerating without their faunal components. It is against this wider socio-ecological perspective that this report should be viewed.[3]

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1 New Guinea Industries logged upstream of the third river (Fig. 1) during 1949/50 and again in 1960 (Niall, pers. comm.).

2 There were landslips and erosion events in the early 1950s, well before the first squatters came to Lae in 1958/59 which resulted in the intensive use of the study area for shifting agricultural and hunting activities (Niall, pers. comm.).

3 There was a considerable degree of difference in the opinions of people interviewed with respect to these wider issues and how they could effect the practicability of implementing a management plan for the study area. Some people, for example, consider intensive broad-acre agriculture on coastal flatlands as the practical solution.

The study area is only a small, yet integral, part of a total human ecological system comprising the whole Atzera Range along with its surrounding aquatic and terrestrial ecosystems and dependent human populations. More especially, this initial proposal must be considered as part of the PNGHEP and harmoniously related to the future development of the city of Lae. For the rest of this report, I will be dealing only with the specific information available during the research period with respect to its primary aim.

The primary aim of this initial proposal is to produce an ecological plan for the management of the natural resources of the Atzera Range adjoining Lae that will enable the "urban-rural mix" of people living in Lae to develop more healthy sustainable ways of living. It is a plan based on principles of ecological science and includes traditional ecological knowledge and customs. I have incorporated as many traditional aspects of the management of natural resources as practical not only because of their validity but also with the aim of sustaining a continuum of ecological relationships between people and the local ecosystems. It is hoped that these aspects of the plan will make it more readily acceptable to the people currently gardening in the hills. In addition, I have endeavoured to keep the proposal as simple as possible in order to facilitate its implementation through local government agencies.

2. THREE MAJOR LAND USES

Three major land uses are proposed for the study area : food and fuelwood production, ecological rehabilitation and ecological conservation. Each land use has specific objectives yet each one is closely interrelated as shown in the schematic diagram (Fig. 5).

Food and Fuelwood Production : The continued production of food and fuel is considered to be necessary for the health and wellbeing of many people living in Lae now and in the immediate future. In the longer term, it is probable that fuelwood production will prove to be more sustainable in the ranges than food gardening owing to

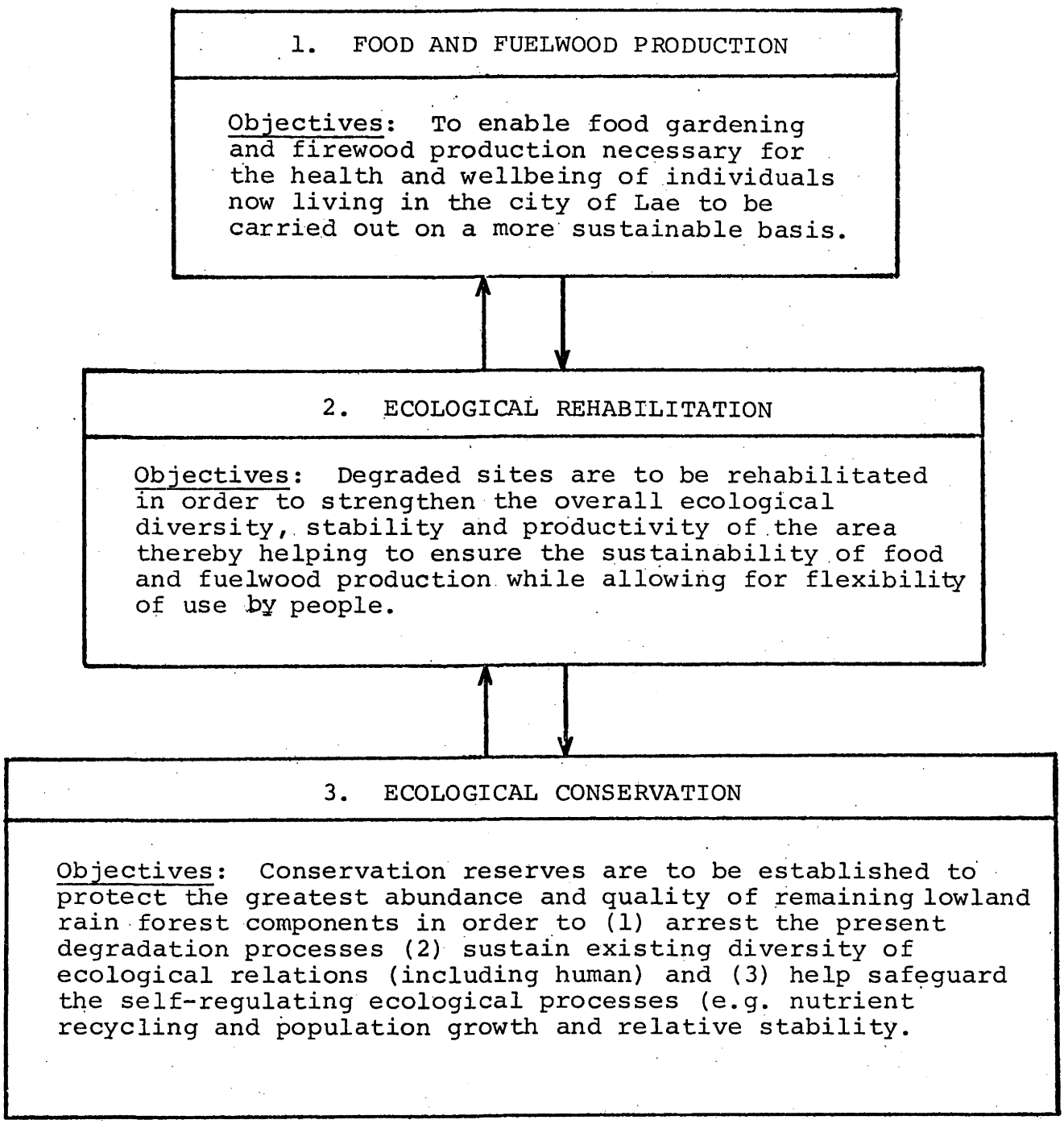

Figure 5 Objectives of three major land uses proposed for the Atzera Range adjoining Lae

the inherent difficulties of large numbers of people growing annual food crops in hilly terrain. (Sholto Douglas and de Hart, 1973). Nevertheless, there is more to gardening than simply growing food and firewood for the majority of people who still use predominantly traditional behaviour patterns. It is their way of life. Furthermore, in large part, the success of the proposed management plan will depend on the use of basic traditional patterns of behaviour. These are complemented by more appropriate management and administrative techniques for ecological conservation and rehabilitation in addition to shifting cultivation in order for the production of food and fuel to be carried out on a more sustainable basis.

The underlying rationale for this dual land-use is that an urban population undergoing rapid change should not reduce its options for the production of basic resources such as food and fuel but rather it should improve existing ones and plan to provide further opportunities for individuals, families and the local community to be self-reliant. This planned "option-diversity" should allow the population more flexibility in finding solutions to their future problems, especially if, for example, some of the new food and fuelwood production systems being planned are kept to a human scale (i.e. small). Small-scale projects[1] are more easily managed and monitored. If a problem arises it is more likely to be detected early allowing time for corrections to be made, or if the management project turns out not to be working as effectively as planned, changes can be made without too much disruption to Lae's social and economic development.

Theoretically, the way to develop a sustained yield of food and fuelwood is to determine (1) the degree of influence exerted by the techniques of cultivation and (2) the optimal ecological conditions for growing the particular crops. Research and monitoring of the food and fuelwood production systems

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1 This emphasis on small-scale projects and on self-reliance, mentioned previously, is consistent with the Papua New Guinea Government's Eight-Point Improvement Plan for pursuing economic development.

proposed will give the first kind of information. The second kind of knowledge concerns the concept of carrying capacity.

Allan (1965) defines carrying capacity as "the maximum population density the system is capable of supporting permanently in the environment without damage to the land". This view of carrying capacity provides ecological guidelines for land use planning but its determination is very difficult. For example, the degradation of land is a cumulative process which often goes undetected until it is patently obvious to even the untrained eye. Also, as in the present study, further social problems can arise that are associated with changes in food crops which may not appear to detrimentally affect the land but which nevertheless affect the nutritional quality of the food eaten.[1] I agree with Clark (1971) who suggests that carrying capacity should be considered as a gradient rather than as a critical limit. Any change in population density or management techniques along this gradient will cause some environmental change, which in turn will either increase or decrease the rates of change along this gradient. And of great relevance to the Atzera Range Project, there is nothing to prevent the introduction of new or modified approaches to resource management that not only decrease rates of degradation (e.g. conservation practices) but can be aimed specifically at *reversing* the environmental degradation process itself (by rehabilitation techniques) and thereby simultaneously increasing ecological carrying capacity. Indeed this initial proposal has ecological conservation as its foundation with ecological rehabilitation as the stairway to the development of more sustainable production systems.

Ecological Conservation : There have always been human activities that resulted, directly or indirectly, in people protecting scarce

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1 Increasing numbers of gardens are being established on impoverished soils that are unable to support the less hardy crops of higher nutritive value such as beans, maize and bananas.

natural resources. Tribal boundary areas between human populations where few people ventured were in effect conservation reserves. Generally, hunting and gathering were not practised in these places, thereby giving protection to communities of plants and animals. Taboos or restrictions on the hunting or gathering of particular species of animals and plants at certain times or in certain places were techniques that helped to conserve species (Liem, et.al. 1976). These human activities (even if not carried out specifically to protect plants and animals), usually promoted the more equal distribution of scarce local resources among the population in both the short and longer term; that is, resource conservation[1] occurred.

Conservation, from this viewpoint, is a practical form of long-term use of land. But more importantly, it is a demonstration by people of a sustainable healthy relationship between their culture and nature. The Atzera study area does not reflect this kind of relationship. Rather it provides concrete evidence of the lack of "traditional conservation".

The breakdown of traditional boundaries, the introduction of modern tools such as steel axes, shotguns and bulldozers have lead to increased human impact on local ecosystems. In addition, the increase in human population, urbanisation and increasing expectations of selling natural resources for money have had their dramatic effects (Rongap et.al., 1976; Liem et.al. 1976). It is in the light of such changes that conservation should be approached today. In the short-term ,practical resource conservation can be achieved by government sponsored protective measures, but in the long-term conservation must once again be through individuals governing their own behaviour based on a new understanding of themselves and their surroundings as parts of an interrelated <u>whole</u> ecological system.

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1 Dasman et.al., (1972) defines conservation as the rational use of the earth's resources to achieve the highest quality of living for the majority of people.

This is ecological conservation (i.e. whole ecosystem maintenance).

The specific objectives of ecological conservation as a land use are given in Figure 5. Accepting that in the absence of quantitative data on carrying capacity, the amount of ecological diversity within an ecosystem serves as a partial indicator of existing relations between the human population and the other parts of the system (Clark, 1971), the ecosystems of the Atzera Range close to Lae are in poor health. Therefore, conservation reserves are essential for providing a minimum of ecological requirements for the successful functioning of the local ecosystems with respect to their more sustainable use by the people of Lae in both the short and long term.

Ecological Rehabilitation : The rehabilitation of local ecosystems traditionally has been left to nature. More specifically, to natural population recruitment following hunting and gathering activities, and to rejuvenating fallows for disused garden sites. However, this kind of rehabilitation is only possible while human populations continue to live within the natural constraints imposed by local ecosystems usually with the aid of "traditional conservation" measures aimed at restricting certain kinds of human activities. These rehabilitation processes are not occurring effectively in the study area. Furthermore, owing to the high degree of disturbance to ecosystems in the area of study, it seems that the process of degradation will not be reversed, or even stopped without active rehabilitation measures carried out by human hand. Active rehabilitation measures are required with specific objectives (Fig. 5) which will (1) reverse the present degradation processes, especially deforestation and soil erosion, (2) increase the diversity of plants, animals and ecological relationships (e.g. pollination, seed dispersal, soil fertility and friability) and (3) improve ecosystem development and productivity.

3. CLASSIFICATION OF LAND USE AREAS

A comprehensive survey of the study area is planned as part of the PNGHEP in order to map waterways, topography, geomorphology and the distribution of soils.[1] Detailed maps of land systems will then be produced which should provide a basis for a comprehensive land use classification. For this report a preliminary categorisation of sites suitable for each land use has been made based on field work (Appendix 1) and general ecological principles. These have been summarised in Figure 6 which also includes active management practices proposed for each major land use. This figure also shows in a schematic form the significant relationships between each land use, site characteristics and their ecological management.

Ecological Conservation : There are ecosystems in various stages of degradation, that are very vulnerable to human intervention and therefore require immediate protection. The most important of these are the numerous creeks and watercourses which ramify through the ranges and reflect the very large rainfall of the locality. These should be considered as a whole system of interrelated waterways : they all rise in the same range, and traverse related sections of Lae (Fig. 1). At the sites where these creeks flow out of the ranges onto the coastal plain the creek sides are important places for the dispersal of water power, especially now that deforestation has increased the run off from their watercatchments.[2] In addition

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1 This kind of information could also be valuable for determining ecologically sound boundaries to the council zoned land should this be necessary in the future.

2 This has important management implications for the local government agencies, especially with respect to the presence of houses in these areas and the altering of creek banks and beds. At the moment, the informal network of foot trails and human development around these interfaces along the foothills does give emphasis to the essential interrelatedness of a city and its hills. Significant erosion of creeksides and beds is already occurring probably in proportion to the degree of human intervention in the water catchment of each creek. Whenever trees are felled, shrubs cleared and the ground cover of vegetation and litter removed less rain soaks into the soil and more flows over the surface of the land. Hence increased runoff of water occurs, usually in larger and larger amounts. The resultant loss of soil nutrients, soil structure and soil itself has devastating and long lasting ecological implications for human populations.

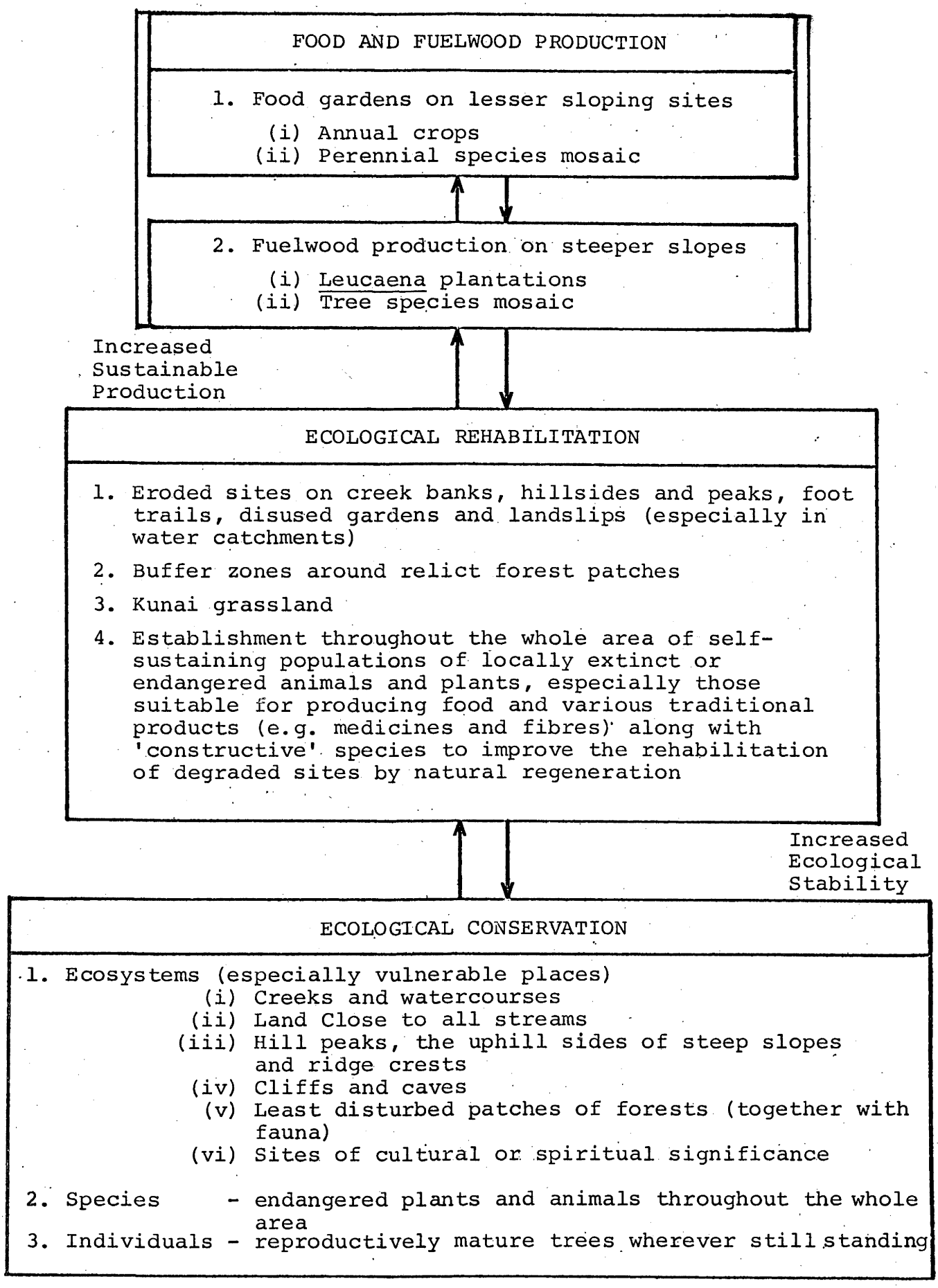

Figure 6 Categories of sites and ecological management for each major land use proposed for the Atzera Range adjoining Lae

the main creeks provide people with access routes to their bush gardens and the hills in general. Some fish are still collected in these streams and, more important to large numbers of people in the settlements, they provide water for drinking, washing and pleasant places for resting or playing.

The land close to all streams requires protection to help safeguard water quality and quantity. The hill tops, uphill sides of steep slopes and ridge crests, all sites which are vulnerable to soil erosion once their vegetation cover is disturbed therefore all must be protected. Cliffs border creeks in several places and provide special habitats for a variety of smaller plants (e.g. mosses, liverworts, orchids) and animals (e.g. beetles and lizards). A few limestone caves are also known to occur in the study area (Niall, pers. comm.) and probably provide homes for bats and other animals. All these sites require protecting to help conserve habitat diversity which is essential for sustaining species diversity.

The greatest diversity of plants occurs in the least disturbed patches of lowland tropical rainforest. These conservation sites are few in number and tend to exist only in inaccessible areas.

Dr L. J. Webb describes tropical rainforests in the following way :

> "Tropical rain forest which is in equilibrium with its environment provides the cheapest form of protection of that environment, and constitutes the most reliable productive ecosystem, without artificial inputs, in the long term. The floristic, faunistic, and structural diversity of the forests encourages relative stability of species populations by processes of self regulation, and maintains soil fertility by the nearly closed nutrient cycling system" (Webb, 1977).

With the degree of uncertainty that exists in human settlements today and especially places which are undergoing rapid transition, any site with these kinds of characteristics helps to keep options open for alternative ways of living and allows greater flexibility in approaches to solving human problems. Furthermore, any practical way of rehabilitating degraded ecosystems so that they are able once again to retain these characteristics, even if at a lower quality, should be practised.

Ecological Rehabilitation : Ecological rehabilitation is a process that over a specific time period is aimed at reversing ecosystem regression first at the most degraded sites such as those of active soil erosion on creek banks and hill sides, landslips, foot trails and garden sites. These particular sites are unlikely to support woody rain forest plants through self-regenerative processes at the moment. Therefore, active rehabilitation measures are advocated to (1) stabilise soil and reduce runoff, (2) provide durable vegetation cover and habitats for animals (3) either re-establish the greatest number and abundance of natural components of the lowland tropical rainforest in harmonious self-sustaining systems *or*, establish ecosystems that will produce food and fuelwood for human use in a healthy human-sustainable way.

Creek banks have been classified within conservation reserves but owing to the increased water runoff within their catchments the topsoil is eroding into stream beds while their banks are being undercut and widened because of the greater force of the increased flow of water. It is therefore suggested that rehabilitation of creek banks be introduced to help slow down their erosion, help hold valuable soil in place and increase the number of suitable habitats for fish and other aquatic life. A major objective of growing plants in the watercatchments of all streams is to reduce the surface flow of water by re-establishing conditions which encourages rainwater soaking quickly into the soil. All of these objectives are compatible with those of ecological conservation (Fig. 5).

Sites of relict patches of rainforest require less active rehabilitation management. It is sufficient to protect them from further human intervention, except for rehabilitation measures such as planting appropriate species in or around the forest patches to buffer them against further disturbances and to promote natural regenerative processes. Webb (1977) uses the term "constructive species" when referring to species that can improve the rehabilitation of degraded sites by natural regeneration. Animals such as flying foxes, rodents and birds can also be

"constructive" in relation to seed dispersal and seed germinability (e.g. Howe and Primack, 1975).

Kunai grasslands are a special case that requires particular rehabilitation techniques owing not only to its ecological characteristics but also to its origins and maintenance. Whenever clearings are made in the rain forest regrowth vegetation will slowly colonise them. When these clearings are not allowed to regenerate fully but are again cleared, invariably with the aid of fire, at fairly short intervals (e.g. by intensive shifting or slash-and-burn agriculture) then the ecological conditions of these clearings are changed in certain fundamental ways (Gillison, 1976). Most important of these changes are deterioration in both soil quality (e.g. fertility and friability) and quantity (erosion). These changing soil conditions coupled with high fire frequencies tend to select against the natural regeneration of woody plant species and encourage colonisation of these clearings by non-woody species. A stage is eventually reached when not only are these clearings covered in kunai grasslands but they are maintained as durable grasslands through repeated burnings. The reasons suggested for this procedure is to maintain an abundance of thatch, flushing out small game and for recreation (Gagné, in press). The most common grass species are *Imperata cylindrica* and *Themeda australis*. Kunai grasslands occur over a large area of the Atzera foothills close to all housing settlements as a result of intensive slash-and-burn gardening. In addition, small patches of kunai are scattered throughout the study area. Kunai inhibits natural forest regeneration and reduces the availability of food and firewood to the Lae people. Rehabilitation of these latter patches should be easiest to carry out and should precede rehabilitation of the more extensive areas which will require a more carefully planned approach and special management techniques (see section 4).

In general, rehabilitation management should correspond with the human-intervention regime known to have occurred at each specific site or in the area. This regime comprises the kind of

intervention (e.g. hunting, gardening or burning), its intensity, frequency and extent (scale of disturbance). Each degraded site can also be classified as temporary, semi-permanent, permanent or irreversible (e.g. parts of large landslips) to give an indication of the length of time a site may require ecological rehabilitation (Gillison, 1976).

Food and Fuelwood Production : The sites for these activities will be in zones that are the most suitable places for growing food and fuelwood *outside of* the conservation reserves and areas being rehabilitated. Quality of soil and slope of the land are of special importance in terms of productivity and sustainability. In general, food gardens should be sited on lesser sloping land because annual plants are usually grown and the gardening of annual crops is more likely to cause soil erosion on steeper slopes than growing tree crops.

Owing to the cultural complexities of growing food and firewood which involve many psychological aspects as well as physical (see, for example, Clarke, 1971 and Waddell, 1972), it is proposed that only broad landuse zones be mapped based on the detailed land survey referred to previously (page 11). Specific sites for gardening and for fuelwood plantations should be left as much as possible with those people who will be most closely involved with these activities. There are sound ecological reasons, nevertheless, for keeping these sites as small as possible and to be separated from each other in ways that reduce the chances of unfavourable interactions such as the distribution of weeds and insect pests, within existing local ecological conditions. Access trails may also have to be considered in this ecological light.

4. ECOLOGICAL MANAGEMENT TECHNIQUES

Each major land use requires special kinds of techniques for their management to be successful. The management techniques outlined below are based on ecological knowledge and make use of traditional information and skills wherever possible.

1. Food Gardens

(1) Annual crops : Figure 7 illustrates the management of short-rotation food gardens to grow annual crops. Well established traditional techniques are complemented by the use of carefully chosen fallow trees to make existing approaches to food gardening more sustainable. These fallow trees not only help to protect the soil from erosion but also improve its fertility and friability. A list of suitable species is given in Appendix 1. These species were chosen as fallow plants because they are known to fix atmospheric nitrogen in the soil by nodulating or have a local reputation for improving soil. In addition, woody legumes are considered more suited to the hilly terrain than the non-woody legumes widely used in broad acre agriculture on flat lands. *Leucaena leucocephala* is most suitable for firewood and *Gliricidia sepium* is reasonable, whereas *Erythrina variegata* is not good for firewood but could be used for posts. All three species will recover when cut and presumably could be used, as living supports for some varieties of beans and yams to climb on. In addition, the cut leaves and branches not of useful size could be used as a green manure (along with any regrowth) to improve soil fertility.

At all times the risk of erosion must be reduced. A variety of factors are important to this end such as the size of each garden, garden spacing and their access tracks together with the methods of preparing the soil for planting crops. An average size for a garden is about 0.1 ha (¼ acre) although there is probably a relationship between size and soil fertility as reflected in food production. It is important to keep individual gardens small and to use modern garden tools carefully. Garden spacing should be considered with respect to the possibility of weeds and insect pests finding their way easily from one garden to another.

It is proposed that the use of fire in site preparation be retained at present until more research has been carried out on the specific effects of fire on short-term food production and longer term consequences for soil quality including the maintenance of soil, animal and plant communities. In

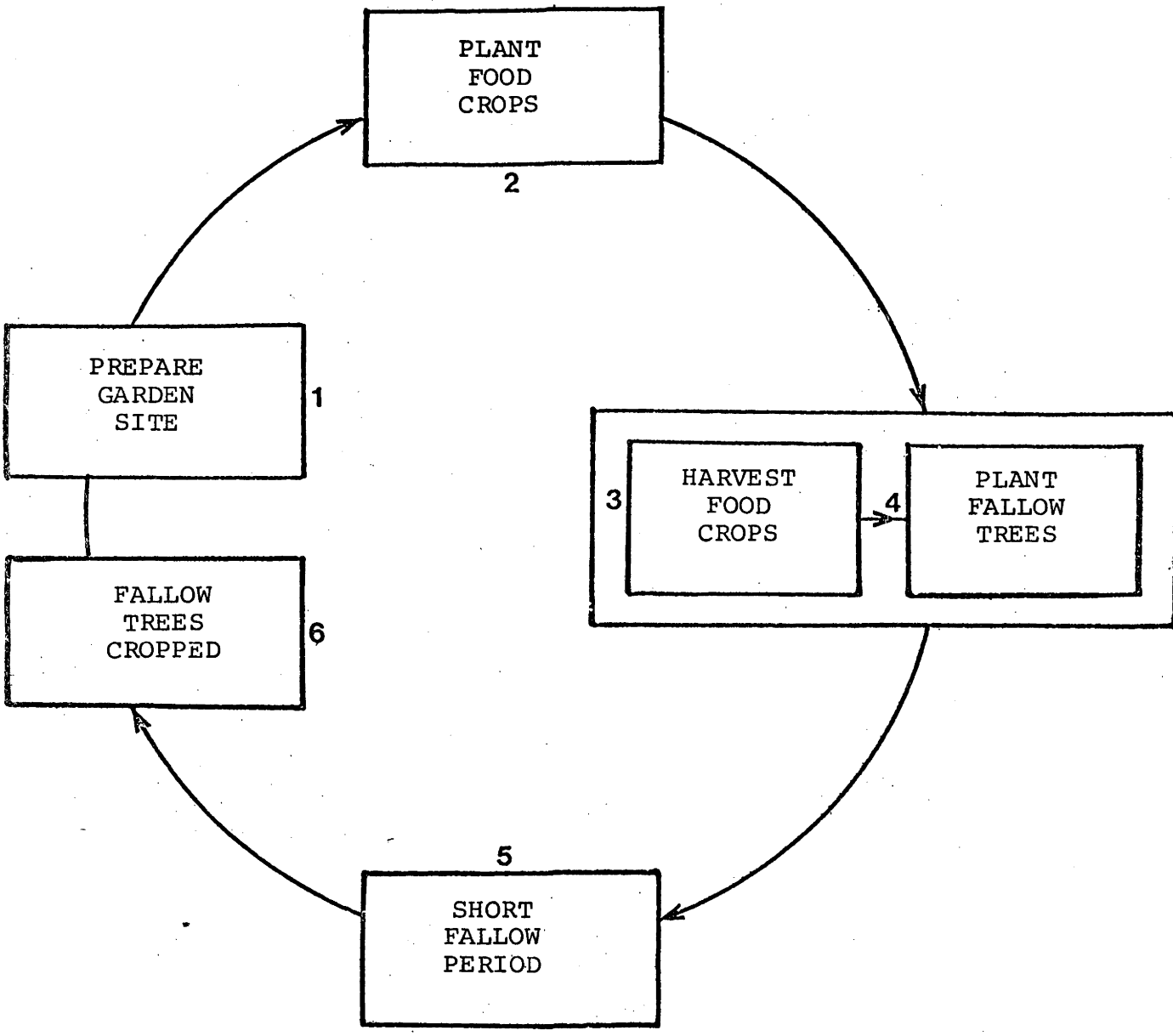

Figure 7 Schematic diagram of short-rotation food gardening with the choice of firewood cropping.

addition, it is not considered practical at this time to modify such a well established traditional gardening technique.[1] It is proposed that fire be excluded from conservation reserves and rehabilitation areas, however, as definite detrimental effects are known with respect to the objectives of these land uses and the control of fire in these two landuse areas can be more easily achieved.

The rhythm of use of garden sites will depend ultimately on the size of the food and firewood production area and the number of gardeners wishing to use this limited resource. Traditionally, a set-of-gardens at various stages of production was managed by a family. This situation also occurs to a large extent in the study area. An upper limit on the number of gardens to be managed by a family might have to be considered. More detailed information is required on the rate of restoration of soil nutrients and their composition (e.g. phosphorus, nitrogen and potassium) by fallow trees. If this information were known, it could be possible to use a set-of-gardens on the same sites for food and firewood production in a continuous sequence for a much longer period than is occurring at present.

Enrichment of the fruits and vegetables grown in short-rotation gardens should be carried out to improve the nutritional quality of garden produce. Table 1 is a suggested list of food plants based on their nutritive value. New varieties of foods are continually being produced and a way of testing new seed or root stock for local conditions could be established to enable their more rapid introduction. Certainly foods of high nutritive value such as maize, peanuts, winged and mung beans and bananas should be grown by all gardeners.

(2) Perennial species mosaic : The establishment of a mosiac of cultivated food trees is a way to enrich food productivity on a large scale. It is proposed that suitable fruit and nut trees (Appendix 1) should be planted in association with hill gardens. (If people know a tree has value as food they are less likely to cut them down too).

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1 With the introduction of compost gardening in the Atzera foothills and coastal plains by the Lae City Council, the idea of using on-site leaves and small branches as mulch or compost material instead of burning them will probably develop quickly amongst the hill gardeners.

Table 1. A list of food crops recommended for gardens because of their nutritive value (Jeffries, pers. comm.)

Starchy staples:	Taro	Colocasia esculenta
	*Chinese taro	Xanthosoma sagittifolium
	Yam	Dioscorea spp.
	Sweet potatoe	Ipomea batatas
	Cooking banana	Musa
Protein crops:	*Peanuts	Arachis hypogaea
	*Beans: wing, snake, haricot and mung	
Green/yellow vegetables:	*Aibika	Abelmoschus manihot
	Amaranthus spinich	
	Chinese cabbage	Brassica sinensis
	*Corn or Maize	Zea mays
	*Pumpkin	Cucurbita
	Tomato	
Fruits:	*Pawpaw	Carica papaya
	Passionfruit	Passiflora edulis
	Sweet banana	Musa
	Grenadilla	
	*Pineapple	Ananas comosus
	Citrus	
Other:	Sugarcane	Saccharum officinarum

* These are highly recommended.

Food species of particular interest are *Artocarpus communis* (breadfruit), *Canarium indicum* (Galip), *Gnetum gnemon* (Tulip), *Mangifera minor* (Wild Mango) and *M. indica*, *Nephelum lappaceum* (Rambutan) and *Persea americana* (Avocado).

2. Fuelwood Production

(1) *Leucaena* plantations : *Leucaena leucocephala* (glauca)[1] is a versatile plant species with characteristics well suited to fuelwood production (National Academy of Sciences, 1977). It can be used directly as firewood or for the production of charcoal and distillation products should these be required in the future. Although a grassland species that has been introduced to Papua New Guinea, it is well established and abundant around Lae as a shade tree in coffee plantations. In such conditions it can grow to about 6m (20 ft), with a stem diameter of 7cm, in two years and lives at least 22 years (Henty, pers. comm.). On a three-year old plantation of *Leucaena* at the Agricultural Station of the University of Technology in Lae, trees are 8m (26 ft) high Trees on this plantation were grown very closely together in rows spaced 2½m apart and their stem diameter was variable. A "giant" variety of *Leucaena* also grows on the central plain near Lae. It can grow to 9m (30ft) in two years but the soft wood of the stems is not as good firewood.

In addition to this rapid growth and suitability for firewood, *Leucaena* is notable for its soil building characteristics. It is a member of the legume family and has a good nitrogen fixing property that enables it to thrive in less fertile soils. Its roots penetrate deeply into the soil aerating and improving soil structure. Nitrogen, phosphate and potash are accumulated in its leaves and as the plant sheds its leaves regularly, a build up of litter occurs and valuable organic matter is formed in the top soil thereby encouraging recycling of essential elements.

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1 In this report, *Leucaena* refers only to *L. leucocephala* and not to other species of the genus *Leucaena*. The National Academy of Sciences (1977) gives a comprehensive description of this species. Literature published before 1960 uses the scientific name *Leucaena glauca* for the plant.

Leucaena is also peculiarly suited to soil erosion control owing to these characteristics and should reduce surface water runoff (carrying with it soil and nutrients) in catchment areas owing to its deep rooting habit. This species also shoots from the stump after the cutting of stems (i.e. coppices) vigorously and readily so that harvesting will not jeopardize its protective role : their roots remain to protect the top soil.

Leucaena plantation management is based on coppicing husbandry or short-rotation forestry (Figure 8). This approach consists of growing trees very close together in rows for regular short-cycle harvesting (Stanford, 1976). Juvenile vigour, a quickly closed canopy and intense competition, induce large height increments and, subsequently, increases in girth. After 3-4 years the growth is harvested as close to the ground as possible. Dormant buds in the stump are thereby excited into maturation, and grow quickly into many new shoots (stems) owing to the intact root system. These stems are again harvested in 3-4 years and so the cycle is repeated many times.

Coppicing has three important advantages over large-cycle forestry. First, the yield per hectare per year can be many times greater. Second, repeated harvesting at intervals of 3-4 years provide a much better short-term return on establishment costs. Third, both the size and time scale of the operation can be more readily understood by people and integrated with their daily patterns of living.

The following cultivation procedures for *Leucaena* are known to suit the study locality. Direct seeding in rows of 1 x 1 or 1 x 2m interspacing should be done along the contour. Stems can be thinned at a later stage, if larger stems are required. Prior to planting seed, the ground should be prepared in a way suited to the site. For example, kunai grassland sites will require initial burning and the digging out of underground rhizomes. Composted organic waste material produced by the Lae city council could also be used to improve soil fertility prior to seeding if plantation sites are on accessible parts of the Atzera foothills.

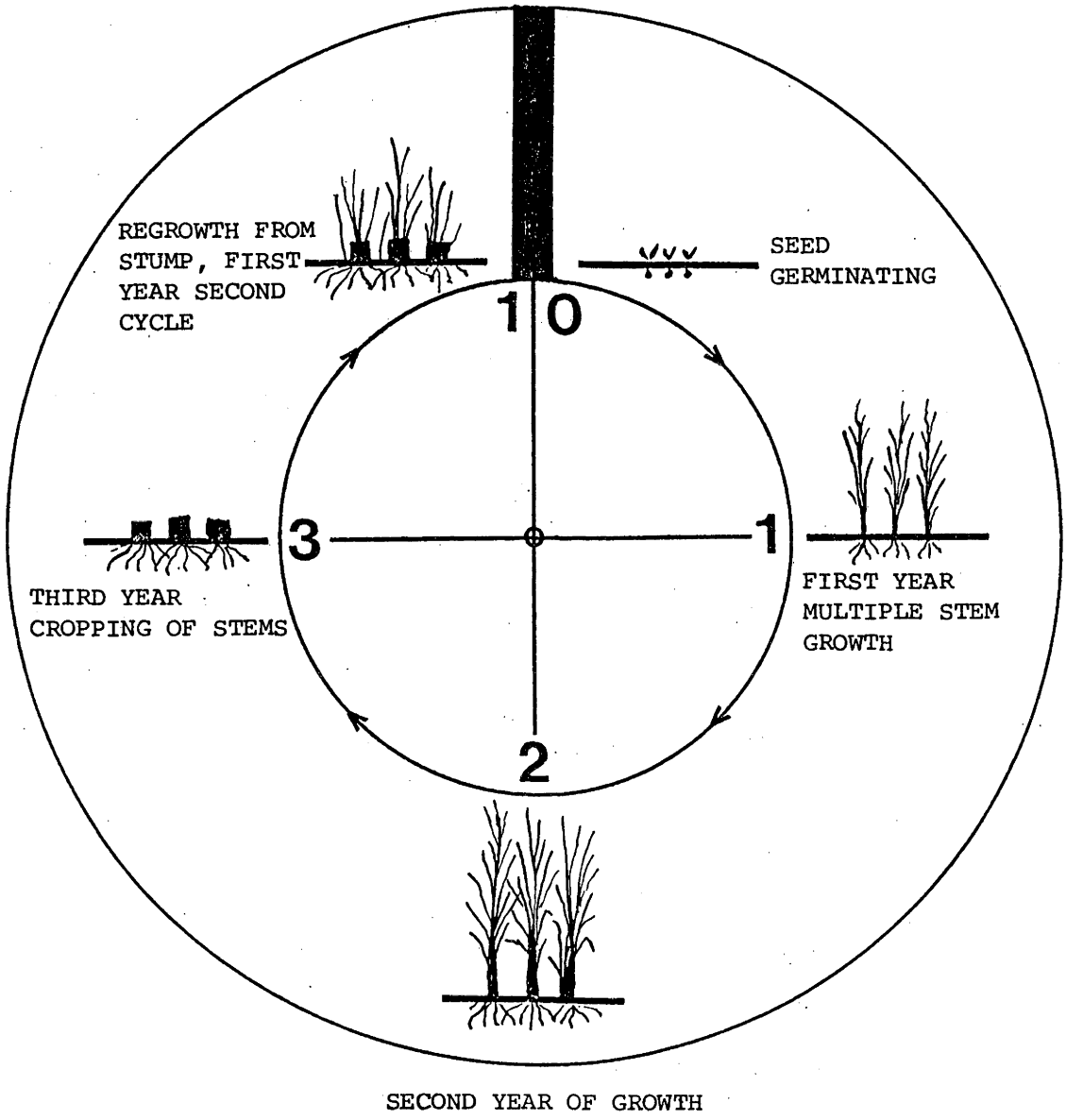

Figure 8 Schematic diagram of coppicing or short-rotation forestry management of Leucaena leucocephala showing a 3-year cropping cycle.

Rows of seedlings must be kept free of weeds for about 6-9 months, until closure of the canopy occurs. Trees flower and produce seed in their first year. During this period of establishment protection from fire is especially important. It may be necessary to clear a firebreak around the site during establishment.

After the canopy closes, little tending of the growing trees is required. At the first harvesting cutting of stems must be done about 30cm (1ft) above the ground and harvested as close to the base of the shoots on subsequent cycles. The bark should not be torn away from the edges of the stump during cutting otherwise underlying tissues may be damaged. Fungus infections of the stump can be discouraged by making a clean cut with an axe on an angle to shed water readily. Cut stems should be stacked for drying (about 2 weeks) prior to home use or cash sale.

At each harvesting, it is important that the leaves and small branches that are not used for firewood should be left on the ground to form a mulch of litter around the cut stumps. Care must be taken to prevent this leafy material being burned. The recycling of the elements in the leaves and branches will occur with the build up of soil organic matter which promotes the development of micro-organisms in the soil (especially fungi and bacteria). This practice, in addition to the inherent ability of *Leucaena* to fix atmospheric nitrogen, should help ensure a sustainable yield of firewood (as well as round poles for a variety of building purposes).

A point that requires stressing is the great versatility of *Leucaena*. It can be used in different ways to develop small size effective agro-forestry ecosystems (Davidson, 1976) which will produce food and/or forest products as well as being a tool for ecological rehabilitation (see page 22). It is therefore proposed that *Leucaena* plantations produce more than firewood. They should be diversified into an agro-forestry ecosystem of trees and annual food crops (Table 2). These plantations could also be sited on denuded hillslopes or those cultivated previously.

Table 2 *Leucaena* plantations for firewood and food cropping
The total area is 2 ha (5 acres) of which 0.4 ha (1 acre) at a time is sown consecutively with *Leucaena* and foodcrops. A 3-year cropping cycle for firewood is shown.

THREE YEAR CYCLE	FUELWOOD AND FOOD CROPS									
	0.4 ha plot		0.4 ha plot		0.4 ha plot		0.4 ha plot		0.4 ha plot	
0	PLANT Leucaena	Foodcrops	-	-	-	-	-	-	-	-
½	+	Harvest Food	PLANT Leucaena	Foodcrops	-	-	-	-	-	-
1	+	-	+	Harvest Food	PLANT Leucaena	Foodcrops	-	-	-	-
1½	+	-	+	-	+	Harvest Food	PLANT Leucaena	Foodcrops	-	-
2	+	-	+	-	+	-	+	Harvest crops	PLANT Leucaena	Foodcrops
2½	+	-	+	-	+	-	+	-	+	Harvest Crops
3	CROP Leucaena	PLANT Foodcrops	+	-	+	-	+	-	+	-

Code: + = *Leucaena* growing; - = no crops

There are further social advantages in this diversified system too as individuals and families can make good use of appropriate traditional gardening skills and be more self-reliant while waiting for *Leucaena* to reach harvestable size.

Food crops such as sweet potato, peanuts or maize could be planted between tree rows for the first 6-9 months after direct seeding of *Leucaena* and subsequent to each harvesting while the remaining stumps are allowed to coppice. It may be possible to grow shade tolerant annual crops of *Dioscorea* and aroids in between tree rows at other times.

(2) Tree species mosaic : Associated with *Leucaena* plantations a mosaic of tree species can be grown in suitable habitats for longer-term timber production either for fuelwood or building materials. Recommended species are given in Appendix 1. Teak *(Tectona grandis)* grows well in the study area as evidenced by the large plantation growing on the Atzera hillslopes adjoining the Buimo Corrective Institution. Other species of particular interest are *Pometia pinnata* (Taun), *Syzygium malaccense* (Lau lau), *Terminalia kaernbachii* (Okari) and *T. catappa* (coastal species), *Pterocarpus indicus* (Nari, New Guinea Rosewood), *Dracontomelum mangiferum* (Mun, New Guinea Walnut) and *Eucalyptus deglupta* (Kamarere).

3. Ecological Rehabilitation

A comprehensive list of plant species recommended by the Office of Forests to be grown in specific places for rehabilitation purposes is given in Appendix 1. These species are listed under the ecological setting to which they are best suited : creek banks, water catchment areas (hillsides and tops), grassland, buffer zones around relict forest patches. For many of the recommended species, valuable information is provided on their natural history, availability of propagules and techniques of propagation along with their usefulness for providing food and various traditional products.

The following rapidly growing palms were recommended by Dr F.B. Essig : *Actinorhytis calappario* and *Gailubia costata* (used for flooring materials), *Caryota rumphiana* (axe handles, stakes) and *Ptychococcus elatus* (the black palm). These species can be grown from seed but should not be planted out into the bush until seedlings are 30cm high.

It is proposed that buffer zones of appropriate species (Appendix 1) be planted around rainforest patches to help encourage theirnatural reneneration as well as protect these patches from outside disturbances. The use of well known fruit, nut or timber trees could also be used as "buffer-zone trees" to indicate the boundaries of conservation reserves and food and fuelwood areas.

For rehabilitating grasslands the Office of Forests recommends to burn the grass first and plant *Leucaena* as a pioneer species, followed by other species as required. The ability of *Leucaena* to grow rapidly from seed, stabilise soil and restore its fertility and be easily controlled make it an outstanding "rehabilitation plant". It should be used to rehabilitate eroding sites (whether colonised by kunai or not), by planting dense rows of *Leucaena* along the contour to cover the "rehabilitation site". If these sites are located in conservation reserves, natural regeneration by rainforest species should occur once the fertility of the soil has been restored. These larger tree species should be allowed to over-grow the *Leucaena*, and, in time, the site should relate harmoniously with the wider reserve. On the other hand, for similar eroding sites in production areas, the propagation of food and fuelwood trees following soil rejuvination on the site allows for on-going rehabilitation to proceed in a way consistent with the objectives of this land-use.

Ecological rehabilitation of the more intensive areas of kunai grasslands close to Lae could be done by siting the *Leucaena* plantations in these areas. These plantations would then become a more efficient form of ecological management not only producing fire-wood and food but also rehabilitating areas of kunai.

Presently, some intensive gardening is occuring in kunai grasslands around Lae both on the coastal flat and Atzera foothills. This is an important use of these low productive grasslands. The compost gardening programme being implemented by the Lae City Council

could extend into those foothills close to Haikoast, Atzera and Taraka settlements. In addition, the composted contour mound method of gardening being used in former kunai grassland at the Wau Ecology Institute could be used (Gagne, in press).

Soil fertility can be restored in these gardens by using compost and/or by the rotation of food crops with appropriate legumes (e.g. *Pueraria*). However, rehabilitation techniques will be necessary in many sites. On hillslopes behind Atzera Settlement, numerous techniques are already being used to control erosion. For example, living and dead pole-fences and vertical drains are being used as techniques for stabilising soil and directing the flow of water. Nevertheless, in many cases, slopes above 30^{o} are common and ecological rehabilitation using *Leucaena* is proposed.

In these situations, a management programme could be devised whereby steep hillslopes in proximity to food gardens could be planted with bands of *Leucaena* five metres wide along the contour with interspacing of 1 x 1m. These contour bands of *Leucaena* could then be used as an on-going source of fertiliser rather than firewood. Following initial harvesting of *Leucaena* for firewood, the remaining stumps are allowed to coppice. The regrowth could be cut and used as a green manure on the food gardens close by. Such a management technique would allow for a well established root system to develop thereby providing a more complete protection of the soil surface and also ensure a larger supply of nutrients stored in the *Leucaena* leaves giving them greater value as a fertiliser. Management schemes such as this would not only reduce soil erosion and reverse degradation processes but also provide another way of transforming shifting cultivation into more intensive sedentary (stationary) practices requiring less land.

4. Ecological Conservation

Whereas the growing of food and fuelwood for human use and the rehabilitation of degraded sites following human intervention involves a large amount of effort and time, conservation measures require less. They rely more on human co-operation and on people taking more care as to how they use the Atzera hills.

Without human intervention the lowland rainforest of the Atzera Range would have been more continuous with simplified successional habitats along creeks owing to movements of riverine alluvia or in sites recently disturbed by strong winds, landslips and earthquakes or perhaps outbreaks of root-rot fungi. For the most part, these disturbed areas of vegetation would have been a minor component of the total natural vegetation subject to continual shifts in local distribution. The impact of humans has been to promote a huge increase in the extent of these kinds of disturbed habitats while maintaining a high level of rapid disturbance within them. For large numbers of rainforest animals (invertebrate and vertebrate species) this human impact would reduce the total area of available habitat, break it up into discontinuous patches and simplify it both structurally and floristically (Webb, 1976; Dwyer, 1978). This is the current situation in the study area where remaining simplified patches of rainforest form an archipelago of small islands of forests linked usually by tongues of more disturbed vegetation. The overall effect is a local reduction in animal and plant species diversity due to either a shortage of habitat, or their habitat "islands" were too small or, more generally, many species could not successfully compete with a few hardier species[1] which were better adapted to the man-induced set of disturbances. To this situation must also be added intensive hunting of particular food animals, (e.g. wallabies, tree kangaroos, cuscus and ringtail possums), and the gathering of plants for human use.

Ecological conservation measures include the protection of all such endangered species of animals as well as plants throughout the whole area in order to help retain existing ecological diversity. Therefore, hunting of animals in conservation reserves should stop and be encouraged in more remote areas of the Atzera Range outside the study area.

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1 These pioneering species (or r-strategists; Pianka, 1970) have characteristic attributes such as short life, high reproductive rate, large dispersal powers and small size.

It is even proposed that reproductively mature trees should not be felled, for not only are they a source of fruit for animals and seeds for their regeneration (or human propagation) but their roots and buttresses give soil on-going protection from water erosion.[1]

The establishment of conservation reserves is the other main management technique for conservation. These comprise all of the ecosystems (especially vulnerable places) listed in Figure 6. With respect to land close to all streams, it is proposed that this include all vegetation, within 50m either side of the water's edge. This riverine corridor is consistent with the recommendation of Webb (1976) that all vegetation should be protected within twice the height of the forest along any watercourse. This conservation reserve will help to stabilise creek banks and beds and trap soil disturbed higher up in their water catchments. All creeks, their banks and corridor of vegetation, hill peaks, the uphill sides of steep slopes and ridge crests, all form integral components of ecological conservation reserves. It is proposed that human activities likely to reduce vegetation cover in these vulnerable places such as hillside gardening and burning be prohibited in these reserves.

It will be the task of council rangers to seek the co-operation of all people visiting the study area in following these conservation practices. This will involve a large education component to their work. In addition, however, most people visiting the area are gardeners who have a special interest in conserving the Atzera ecosystems and all gardeners will be required by the Lae City Council and their Settlement Committee only to garden under special permit conditions (see page 27).

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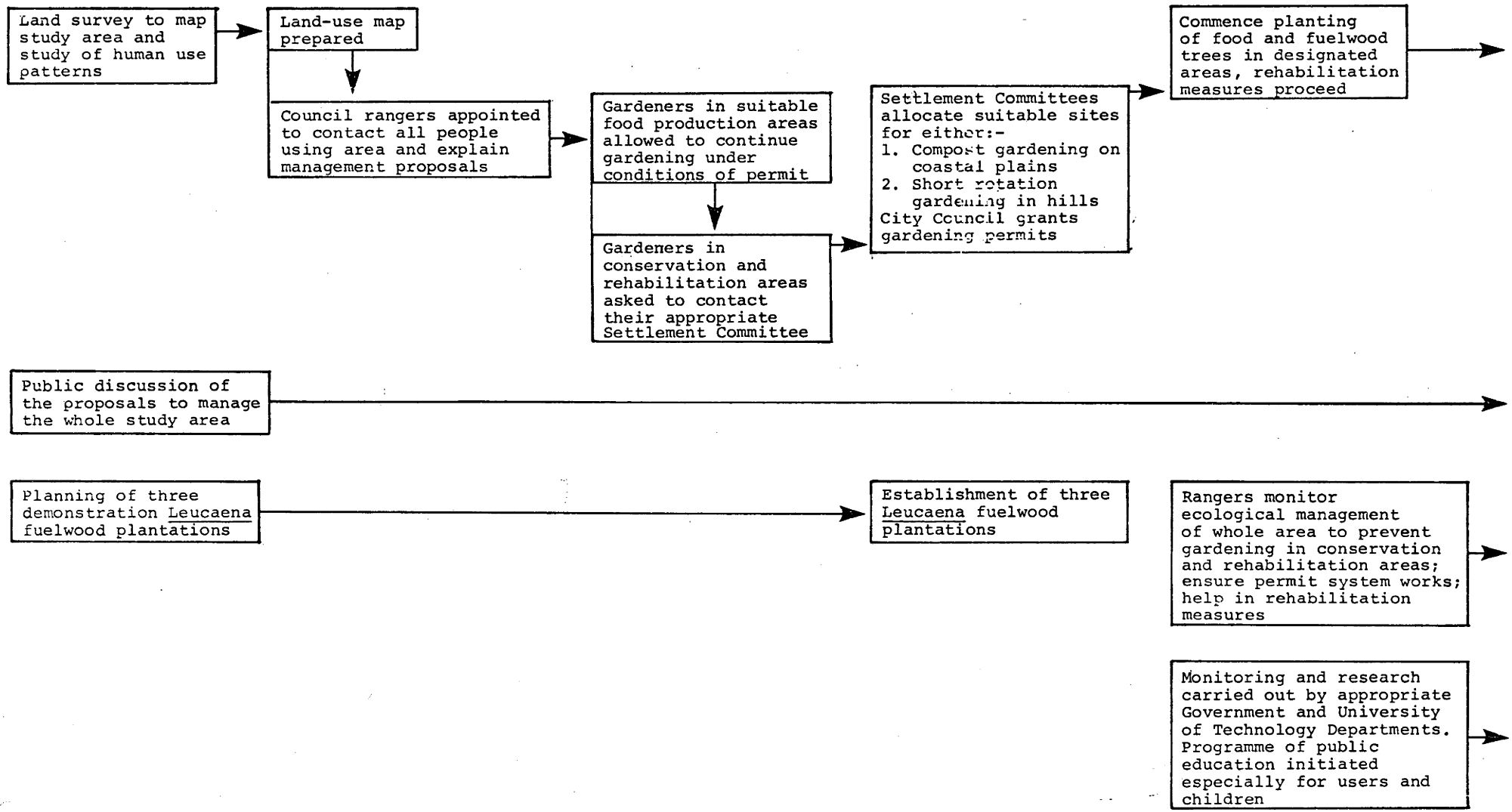
1 Even the roots of dead fig tree stumps may hold soil for up to 3 years (Henty, pers. comm.).

5. INTEGRATED PLAN OF MANAGEMENT

After interviewing several gardeners at their garden sites in the ranges, it became evident to the writer that an informal management system already exists with respect to the allocation of land for cultivation and its availability to different groups of people. This system should be more clearly understood and, if soundly based and equitable, formally included by local government agencies into an integrated plan of management for the whole area. The underlying principle involved here is that if people are provided with the proper understanding and skills to be able to manage their own activities wisely then a more durable form of management is likely. Furthermore, it is more economic as there is less need for expensive controlling agencies to be formed. Figure 9 outlines the major aspects of the proposed plan of management for the study area. Public discussion of this proposal is necessary from the start in order to avoid misunderstanding of the nature of the problems and their likely solutions. It will involve the gardeners, themselves, along with their pool of knowledge and skills in the planning process. It also helps the various government agencies to improve the level of understanding of the local community on the management proposal which, in turn, will help them to decide how fast they should implement changes. Finally, public discussion fosters social concern about the environmental consequences of the unplanned use of the Atzera Range thereby helping to encourage the introduction of durable solutions that may seem too restrictive at first.

While public discussion is efficiently organised and promoted in a balanced way, a survey of human use patterns in the study area is suggested to determine the distribution and abundance of gardeners in the hills. Ecological information on the forms of cultivation, the variety of crops that are grown and the amount of garden space required to support an average family. In addition, more detailed information is required on the usefulness of the existing informal system of controlling hill gardening. The land survey, mentioned on page 11, should be completed as soon as possible because detailed land-use maps are necessary before the proposed

Figure 9. Schematic diagram of major aspects of the integrated plan of management proposed for the study area.



plan of management becomes practical. Following the preparation of land-use maps it will become possible for rangers appointed by the Lae City Council to begin exploring the whole area and contacting the people using it for their livelihood. At an early stage, the planning of three demonstration *Leucaena* plantations should be underway.

The number of gardeners in the study area and their distribution should be known in order to estimate the demand for the limited amount of land suitable for food and fuelwood production (determined by the land survey). This information, together with the area of a set-of-gardens required to support a family, should provide a better guide on how many permits for short-rotation gardening are to be granted by the Council.

The introduction of a permit or long-term lease system by the Lae City Council is of great importance as the means of providing effective control over gardening in the hills. It is the way in which people will gain long-term security of tenure on their garden sites. If this lease system is successful (i.e., gardeners feel secure), then the present barrier to growing trees will be overcome and the success of the short-rotation gardening more assured. Therefore, this management technique will have to be planned carefully in consultation with all people likely to be affected by its introduction. In addition, its administration by the City Council and the employment of rangers to ensure that the permit conditions under which gardening is allowed in the hills are carried out by gardeners are significant new aspects of Council responsibility. This will also entail budgeting for vehicles and their maintenance as part of the overall plan of garden management.

The permit or long-term lease system to be introduced by the Council should allow gardening only under a certain set of conditions. These should include that all gardening is to be short-rotation or other approved forms (e.g., contour compost-mound gardens; Gagne 1978) and to occur in specific areas

categorised as food production areas only. No reproductively mature trees are to be killed throughout the whole area or fires to be started in the conservation reserves or rehabilitation areas. When gardeners are provided with specific food or fuelwood trees (already available from the Office of Forests) these must be planted in, around or en-route to their garden sites to form a tree species mosaic in the food and fuelwood production areas or on rehabilitation sites. In this way, gardeners would help to manage the natural resources of the area in general for both short and long-term gains. Management costs could also be kept lower.

Gardeners already established in designated conservation reserves and rehabilitation areas will be required to plant *Leucaena* (or appropriate species designated for these areas) on current gardens after harvesting all food crops and on their other disused gardens in these land-use areas. These gardeners have the choice of either participating in the Council's compost gardening scheme on coastal flatlands or of obtaining a short-rotation garden permit to continue gardening in the hills. It is suggested that the Settlement Committees of each settlement be responsible for allocating suitable gardening sites to these prospective gardeners under final supervision of Council rangers.

The establishment of three *Leucaena* plantations to help demonstrate to the public this way of growing firewood (and also the concept of agro-forestry) should be started by the Council in suitable sites near to each major settlement in consultation with each Settlement Committee. Families to manage these plantations could be chosen from those found by rangers to be gardening in conservation and rehabilitation areas.

The Council rangers will have a high degree of responsibility for monitoring the different aspects of the proposed plan of management. For example, they will be responsible for preventing gardening in conservation and rehabilitation areas, and in helping to ensure that the permit conditions are understood and carried out. More specifically, they will be involved in regular field surveys, and are to keep in close friendly contact with gardeners.

All aspects of this plan of management will require continual monitoring and modification in the light of new problems as they arise. Therefore, an active research and monitoring programme should be run parallel with each specific activity as an integral component of the whole ecological management plan. Various Government Departments, staff at the University of Technology at Lae and the Director of the Morobe Province Research Centre have agreed to help with this programme.

Finally, a dedicated, comprehensive approach to public education is required to help ensure that not only does everyone understand the plans for managing the Atzera Range but that they also find these acceptable. Even if the plans are technically very good, they will only be implemented effectively if they are acceptable to the people. This should readily occur as the plan of management is mostly based on the application of their own practical skills of cultivation, conservation and rehabilitation: skills that are relevant to both urban and village lifestyles. Public walks into the Atzera Range could be arranged to examine and discuss the effects of deforestation and erosion along with the proposed solutions. Children growing up in Lae should be taught carefully the most appropriate kinds of practical skills for food and fuelwood production and the principles of ecological conservation and rehabilitation. Family and school outings specifically to teach these skills could easily be promoted by Settlement Committees.

6. CONCLUSIONS AND RECOMMENDATIONS

Human Impact on the Atzera Range adjoining Lae : The study area is a significant source of food and firewood to many people living in self-help settlements. Both intensive gardening, close to settlements, and extensive shifting-cultivation further in the hills, is practised in the Atzera Range. This steeply sloping Range dissected by numerous streams, along with shallow soils and high rainfall, means that once vegetation cover is removed the land becomes susceptible to erosion. Serious erosion of fertile top soil and of creek banks is occurring. The colonisation of large areas by kunai and other grasses is well advanced. If current trends of urban growth continue, a way to help maintain the forests and water quality is to manage the natural resources of the study area on an ecological basis. It is recommended that, as a general approach, a wide variety of ways for people to obtain food and fuel be investigated and that existing ways of producing food and firewood be improved. Emphasis should be given to establishing efficient sustainable ways of growing food and firewood and to the ecological management of the Atzera Range adjoining Lae as a whole.

Land-use Planning : Food and fuelwood production in the Atzera hills can be made more efficient and sustainable by slowing down and stopping environmental degradation processes. This can be done by protecting especially vulnerable places (ecosystems) and through active rehabilitation of degraded sites. The greatest abundance and quality of remaining lowland rain forest components should be conserved to help ensure more sustainable production occurs as well as to keep options open for future human use. Food and fuelwood production should only be carried out in the most favourable locations in the hills. Owing to the traditional ways of growing food and firewood involving many psychological aspects, as well as technical, the specific sites for gardens within these favourable areas should be chosen by the gardeners themselves.

It is recommended that three major land-use zones be established: food and fuelwood production, ecological rehabilitation and conservation. These zones should be mapped following a survey of waterways, topography, geomorphology and soils. The conservation land-use zone should include all creeks and watercourses and land within 50m either side of the water's edge; hill tops, uphill sides of steep slopes and ridge crests;

cliffs and caves; least disturbed patches of forests and sites of cultural and spiritual significance.

Ecological Management Techniques : Techniques for managing each major land use should be based on an understanding of the ecological characteristics of the study area and in sympathy with the new urban setting of the people.

(1). Food Gardens

Management should be aimed towards transforming shifting cultivation into more intensive sedentary (stationary) practices requiring less land. The maintenance of adequate soil of high nutrient status not only improves crop production but also reduces the necessity to shift gardens as often. The proposed technique of short-rotation gardening will help achieve this objective by growing woody fallow plants to protect and enrich soil in rotation with annual foodcrops. Larger scale production of fruit and nut trees in areas close to garden sites will also help improve the overall productivity of the area. It is recommended that short-rotation gardening be developed using woody fallow plants to help protect and fertilise garden sites following the harvesting of food crops and that larger scale planting of a variety of suitable fruit and nut trees be carried out.

(2). Fuelwood Production

Leucaena leucocephala shows the greatest potential as a plant for fuelwood production. It is good firewood, grows very rapidly, enriches soil by nodulation and coppices vigorously. Coppicing husbandry could be easily integrated with individual and family patterns of living.

It is recommended that fuelwood production be based on coppicing of *Leucaena* and that three demonstration *Leucaena* plantations of 2 hectares be established that include the opportunity for food cropping (i.e., agro-forestry plantations). It is also recommended that a mosaic of long-lived trees suitable for fuelwood and timber production be planted in fuel production zones.

(3). Ecological Rehabilitation

A number of plants suitable for rehabilitating degraded sites is included in the list of plant species provided by the Office of Forests for "The Atzera Project" (see Appendix 1).

It is recommended that the planting of these "rehabilitation plants" be started as soon as practical and, further, that *Leucaena* plantations, compost-gardening (recently initiated by the Lae City Council) and contour-mound gardening be investigated as ways of rehabilitating kunai grasslands.

(4). Ecological Conservation

Conservation techniques rely largely on people taking more care as to how they use the Atzera hills and on the co-operation of these users with local government authorities.

It is recommended that all human activities likely to reduce vegetation cover in conservation land-use areas (conservation reserves) such as hillside gardening and lighting of fires be prohibited. It is also recommended that conservation measures include the protection of endangered animal and plant species with hunting being encouraged only in the more remote parts of the Atzera Range and reproductively mature trees being protected within the study area.

Integrated Plan of Management : An integrated plan of management is outlined to help co-ordinate the various management prodedures to be carried out by local Government agencies, research organisations, Settlement Committees and users.

It is recommended that public discussion of "The Atzera Project" be organised and promoted by all parties involved along with a survey of human use patterns to determine the distribution and abundance of hill gardens and the ways people use the Atzera hills.

It is recommended that the Lae City Council introduce a permit or long-term lease system to be administered by the Council in co-operation with Settlement Committees to help control hillside gardening. The permit conditions should state that all gardening is to be short-rotation or other approved forms and is to occur only in areas designated as food production areas.

It is recommended that at least two Council rangers be appointed to help administer the plan of management.

It is recommended that a programme of research and monitoring

of "The Atzera Project" be organised by appropriate departments of Government, the University of Technology and the Morobe Province Research Centre.

It is recommended that a comprehensive programme of public education be organised by all parties involved in "The Atzera Project".

7. ACKNOWLEDGEMENTS

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As part of my intensive study in Lae, I consulted with the following members of the Lae City Council : Mr. Ron Malcolm (Associate Town Clerk, Messrs. John Clark and Vince Dube. I visited the Agricultural Research Station at Bubia to discuss "The Atzera Project" with Mr. Jim Sumbuk (Director) and Mr. Graeme Young. Several visits

were made to the Papua New Guinea University of Technology to consult with academic staff : Professor John Davidson (Forestry Department), Professor Alan Quartermain and Dr. Ken Wilson (Agriculture Department). Information on contour compost-gardening was supplied by Dr. Wayne Gagné of the Wau Ecology Institute and historical aspects of human impact on the Atzera Range were provided by Sir Horace Niall, who was visiting Lae. Another visitor to Lae, Dr. F.B. Essig (University of South Florida, U.S.A.), recommended particular species of palm to be grown in the study area. James Pokris interviewed hill gardeners from Taraka, Atzera/Boundary Road Settlements and provided valuable information and guidance with respect to the whole Project. Mr. Hartmut Holzknecht (Director, Morobe Province Research Centre) arranged for an Advisory Committee meeting to be held at the end of my fieldwork in Lae to discuss "The Atzera Project" as well as a field excursion with members of this Committee. In addition to the people already acknowledged, the following academic staff of the University of Technology discussed the Project at this Committee meeting : H. Templeton (Civil Engineering Department), D.K. Das (Agriculture Department) and D. Dale (Chemical Technology Department).

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9. APPENDIX

Appendix 1. Recommended Plant Species for "The Atzera Project"

TERRITORY OF PAPUA AND NEW GUINEA

DEPARTMENT OF PRIMARY INDUSTRY

Office
Department of Forests,
Division of Botany,
Post Office Box 314,
Lae, T.P.N.G.

Telegrams
Telephone
Our Reference 126-1-19
If calling ask for
Mr. EEH:DMO.

16/5/78

Dr. J. Harris,
C/- Centre for Resource & Environmental Studies, A.N.U.,
P.O. Box 4,
CANBERRA, A.C.T. 2600. AUST.

ATZERA MANAGEMENT PROJECT

Dear Dr. Harris,

Recommended species for various situations:

1. CREEK BANKS.

Bambusa forbesii Holttum

A small, thin-stemmed bamboo, suitable for binding soil on steep banks; only thrives in forest openings, as maximum height is about 7 m. Shoots edible, but small. Plant by clump division.

Bambusa vulgaris Schrad.

Large bamboo, resists soil movement and water erosion, and tolerates silt deposition to some extent (?ca. 20 cm/year). Useful for temporary buildings, utensils etc. Plant by clump division or rooted cuttings.

Gigantochloa apus (Schult.) Kurz

Large bamboo, but stems slightly smaller than B. vulgaris, though thicker-walled and stronger. Somewhat less vigorous and hardy; would do well on alluvial deposits below cliffs and banks. Durable in buildings, and useful for weaving into baskets etc. Propagated by culm-layering; could not be made available in quantity at short notice.

Ficus spp., including F. botryocarpa Miq., F. calopilina Diels, F. wassa Reinw.

The figs are not particularly soil-binders, but do well on slopes where other vegetation is sparse; leaves are used as food, and fruit attracts birds and bats. Seed can be raised in nursery; growth is slow at first, probably suitable for planting in 12 months.

Leucaena leucocephala (Lmk.) de Wit

Will help bind soil on banks of moderate slope which are stable enough to permit establishment. Plant seed in rows ca. 3 m apart, across slope, at rate of ca 10 gm/m of row. Rows must be kept free of weeds and spaces between cut until the plants form a cover (6-9 months). Control of vines will be required from time to time.

Pterocarpus indicus Willd. Nar, nari.

Large, deep-rooted tree. Establish from cuttings (up to 10 cm diam. x 1.5 m long) from May to August (when the trees are leafless). Timber used for furniture (trade name, N.G. Rosewood) and for kundus and carvings.

Psidium guayava L. Guava

Small tree; can only persist where other growth is kept low. Fruit is useful. Propagate in nursery from seed.

Vetiveria zizanioides (L.) Nash

A coarse grass, 1-2 m tall, with tough fibrous roots; suitable for planting across bare slopes. Unless periodically cleaned it will be overgrown by vines etc., in time. Planted from divided clumps; a nursery area for initial propagation would be needed.

Villebrunea sp.

A sprawling small tree, rooting along the branches, forming dense thickets. Easily cut, so not a serious weed. Establish from cuttings, most seasons.

2. WATER CATCHMENT AREAS; slope moderate to steep, soil of moderate fertility; protected stream-sides, hill tops. Large trees, able to form a forest canopy.

Artocarpus communis J.R. & G. Forst. Breadfruit

Fast-growing, with soft wood. Propagated from seed in nursery; better types could be bought in markets, also at Madang, Rabaul, etc. A seedless form is available, but not well-known here; propagation by root-cuttings, and stocks limited.

Canarium indicum L. Galip

Large tree; begins bearing at 5-7 years. Timber not valuable. Propagate from seed in nursery. Some is available in National Botanic Garden; the original seed came from Madang.

Dracontomelum mangiferum Bl. Mun

Large tree, with wide buttresses. Begins bearing from 5-10 years; there are probably select varieties in cultivation, which may also be smaller trees. Fruit for propagation may be bought at Lae market. The timber is valuable - trade name N.G. Walnut.

Mangifera minor Bl. Wild mango

Large tree, sometimes used as a peeler log, hard to saw. Fruit not of high quality but gathered and eaten when available. Seed could be bought from villagers; main season seems to be May-August.

Parartocarpus venenosus (Zoll. & Mor.) Becc.

Fruit is used on Willaumez Peninsula, New Britain; seed could be bought there. Trees in Botanic Garden (some 10 years old) have not yet fruited.

Pometia pinnata Forst. Taun

The common wild form in Morobe Province is not valuable as a food tree, but forms exist elsewhere in P.N.G. with a large fleshy aril (c.f. rambutan); a form from Fiji is growing in the Botanic Garden, fruits Nov. - Jan. A useful timber tree; the Fijian form is characterised by a long straight bole. Propagate from seed, in nursery.

Pouteria maclayana (F. Muell.) Baehni

Wild andsemi-cultivated forms vary in quality of fruit. A good variety is bearing in the Botanic Garden and a limited amount of seed is available from Feb. - Sept. Propagate from seed in nursery.

Spondias dulcis Bl.

Large tree with great variation in fruit quality; some investigation is necessary before seed is collected. Good fruit is on sale, at times, in Rabaul market. A West Indian species, S. mombin, with fruit of fair quality, is available here.

Syzygium malaccense (L.) Merr. & Perry Lau lau

Rather slow-growing, but some forms eventually become large trees. Fruit quality varies greatly; those planted as street trees in Lae are acceptable. Nursery treatment. When of milling size, of some value as timber; watergum.

Terminalia kaernbachii Warb. Okari

Fast-growing, eventually tall, tree; at first intolerant of shade, but outgrows most regrowth species in a few years. Great variation in quality; good seed available from Popondetta and Port Moresby (on sale at markets), also from Boana, but quantity there limited. Grow in nursery but in large containers and plant out promptly or growth will be checked. Good furniture timber but rarely cut.

2a. Trees which do not reach canopy; understorey or forest margin.

Gnetum gnemon L. Tulip

Small tree, to 10 m. Leaves and seeds are eaten. Normally as forest understorey but sun-tolerant and could grow at garden-margins, etc. Seed slow to germinate.

Pangium edule Reinw.

Regrowth and understorey tree; sun-tolerant and suitable for creek-sites and other openings; to 20 m tall. All parts poisonous. The large seeds are, after suitable maceration, a valued food. If care can be given, plant in situ, otherwise, raise in nursery.

Sterculia schumanniana Mildbr.

Medium-sized tree of regrowth, forest margins and openings. Seeds edible. Widespread; a good variety from Fergusson Island is available in the Botanic Garden. Raise in nursery.

3. REHABILITATION OF GRASSLAND.

Leucaena leucocephala as pioneer, followed by other species as required. Burn grass, plant seed in rows.

4. FUELWOOD PRODUCTION.

Begin with Leucaena on degraded soil. Natural regeneration will occur on some slopes and stream gulleys if these are closed to gardening. This may be up-graded by cutting species known to be useless (Dendrocnide, Piper) and vines.

Teak may be planted in some areas; this requires nursery treatment, stumping and some after-care.

5 & 6 SUSTAINABLE GARDENS.

Trees to restore soil fertility:

Legumes: (1) Leucaena leucocephala

(2) Erythrina variegata L.

(3) Gliricidia sepium (Jacq.) Steud.

2 & 3 may be planted in situ as cuttings, or raised in a nursery. Both will recover if cut (not below 0.5 m) and pieces of Erythrina will root on the ground, eventually forming a terrace if contour-planted.

Non-legumes: some common regrowth species have a reputation for improving soil, others are known to nodulate. The following may be tested:

(1) Homalanthus populneus (Geisl.) Pax

(2) Macaranga spp.

(3) Mallotus spp.

(4) Parasponia rugosa Bl.

Cultivated food trees, which require a certain amount of care, even if only removal of vines and competing regrowth, may be planted around sustainable gardens, e.g.:

Artocarpus heterophyllus Lmk. Jak

Not accepted so far, but probably will be.

Dracontomelum mangiferum Bl.

See above

Inocarpus fagifer (Parkinson) Fosberg "Tahitian chestnut

Wet places. The nut is eaten roasted.

Lucuma nervosa DC.

Not known here, but accepted in parts of P.N.G. Limited seed available from Botanic Garden.

Mangifera indica L. Mango

Irregular bearer in Lae, but worth planting for the odd good crop.

Nephelium lappaceum L. Rambutan

Popular when available. Rather troublesome to establish, and fruiting is seasonal, usually May-July.

Persea americana Mill. Avocado

Easy to establish from germinated seeds planted in situ.

Psidium guayava L. Guava

Hardy and does not require high fertility.

Syzygium aqueum (Burm.f.) Alston "Rose Apple"

Stream-sides. Watery fruit with pleasant flavour. Bearing trees in Botanic Garden, and fruit on sale at Lae Market in season.

S. malaccense (L.) Merrill & Perry **Lau-lau**

See above.

7. RE-ESTABLISHMENT OF ANIMAL SPECIES.

Suitable habitats exist now, but hunting is intensive.

8. RARE OR LOCALLY-EXTINCT PLANT SPECIES.

These may be re-introduced as forest and stable streamside habitats are established. Palms, including Calamus, may be planted when the forest cover has begun to develop.

9. BUFFER ZONES AROUND RELICT FOREST PATCHES.

Fast-growing species, which will persist in forest, are required, e.g.:

* Chisocheton schumannii C.DC.

Dysoxylum gaudichaudianum (Miq.) Juss.

Elaeocarpus sphaericus (Gaertn.) K. Sch.

* Euodia elleryana F. Muell.

* E. alata F. Muell.

Gmelina moluccana (Blume) Backer

* Harpullia arborea Radlk.

* Litsea irianensis Kost.

Terminalia complanata K. Sch.

T. microcarpa Decne

T. sepicana Diels

* These are smaller species which will not form part of the final canopy.

Seed of all the above species is available locally. Several have fruit which attracts birds and bats; others are food-plants for butterfly larvae.

E. E. Lucky

for (M. GALORE)
Assistant Director, Botany.