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Remote Sensing for Conservation of Tropical moist forests : a study in Indonesia

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A thesis submitted for the degree of

Master of Philosophy

in the University of London

1985

ABSTRACT

The Indonesian archipelago extends in a great 6000km arc from the northern tip of Sumatra to the eastern border of Irian Jaya. It includes a wide diversity of ecosystems ranging from the floristically rich and economically important lowland tropical rain forests to the 'moss' and sub-alpine meadows of the higher mountains and from fresh-water swamp forest to the dry monsoon forest and savanna woodlands of the lesser Sunda islands.

These forests are of importance for the protection of watersheds and catchment areas, for the maintenance of water supplies, and for their general and local influence upon climate. They are the habitat of a large number of rare, endangered and endemic plant and animal species; also many other birds, mammals, reptiles and insects which form a colourful, scientifically valuable and irreplaceable part of the national heritage and world genetic resources.

This study examines an area of great ecological importance in Sulawesi, and an attempt is made to map a number of ecosystems in the area. Landsat multispectral imagery (1972) was the basis of the mapping and field work was completed in 1980. The satellite imagery proved to be a satisfactory mapping tool in these tropical moist forest conditions.

ACKNOWLEDGEMENTS

Without the considerable support provided by the expedition Operation Drake, this study could not have been attempted. I am particularly indebted for assistance in the field to Mr Erla Wardhana, Mr Dedy Darnaedi, Mr Arie Budiman, Mr Lukman Effendi and Mr Richard Tarlov. I would also like to thank Dr Keith McLachlan, Dr Tony Allan, Mr Philip Stott and Mr John Latham for their advice and encouragement. With regard to the computer processing of the data, I am grateful to the generous support provided by the Royal Airforce Establishment, Farnborough. I thank the people of the villages of Lappanga Matube and Morowali for their kind hospitality.

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CHAPTER ONE

INTRODUCTION

1.1 Scope of the Study

The intention of the research was twofold. First, to see if computer processed digital LANDSAT imagery could be used to map accurately land cover and vegetation associations in this tropical environment,and secondly, if the results proved to be accurate to produce a map at a scale of 1:100,000. The study area, some 200,000ha, was at the time of the initiation of the study, under consideration as a potential nature reserve, with possible future development as a National Park. However, there were conflicting claims for the land (timber concessions, possible mineral extraction, transmigration project), and the Central Planning Consultancy in Jakarta (CPC) recommended that no decisions be made on the future of the area until extensive vegetation, ecological, biological, zoological and marine studies had been made. As a result of this need to collect information and map the area, I became involved with an international scientific team, working within the framework of the expedition 'Operation Drake.' The logistic and scientific support provided by this expedition enabled access to this remote study area.

As a result of the scientific work carried out in the study area, it was eventually declared a Nature Reserve, and a management plan was prepared by the World Wildlife Fund (WWF). The aim of this thesis is to present my results and additional information in the hope that it may provide a basic methodology for similar future studies. It should be noted that the methodology has been designed to embrace basic theories of conservation, ecology and management planning, with particular reference to the tropics.

1.2 Tropical Moist Forests of the World - Current Status

A global appraisal of the current status of tropical moist forests can only be based on the material available:

> Not all existing information is available, and that which is available is often obselete, not relevant, too uncertain, or dispersed in various documents handled by different working units. Definitions and terms used in country appraisals vary considerably which makes syntheses difficult (Sommer, 1976)

However the FAO have attempted to synthesize all available data (FAO, 1976:

1. The total annual climatic climax area of the tropical moist forests has been estimated to be approximately 1,600 million ha.
2. The total annual growth potential may be assumed

at 1,200 to 2,900 million m^3.

3. The estimated area affected by exploitation in the year 1973 may vary from 5.5 to 9.0 million ha.

(Sommer, 1976)

Sommer, (1976) points out that although sizeable areas of forest are destroyed at local or regional level, the parts affected by human activities, compared with the still existing total surface area are rather small.

1.3 The Conservation Values of Tropical Moist Forest Ecosystems

Tropical moist forest areas have a number of values which are generally considered to be important. Poore, (1976) has outlined some of the values of importance as follows:

1. They are the habitat of species and genotypes of plants and animals in which these can perpetuate themselves and express their evolutionary potential.
2. Certain areas represent undisturbed samples of the range of variation in the ecosystems.
3. River basin protection from siltation and other undesirable consequences.
4. They may act as a buffer against epidemics affecting both man and his domesticated plants and animals.

(Poore, 1976)

1.4 The Conservation of Tropical Moist Forests

The basic proposition of those concerned with genetic resource conservation is, to quote Helsop-Harrison (1974, p161) "that the diversity of the living kingdom is now, or is likely to be in the future, of direct value to man." As the most species-rich forest communities in the world, the tropical moist forests constitute a genetic resource of the first importance and represent, in the words of Poore (1976), p138), "a source-book of potential foods, drinks, medicines, contraceptives, abortifacients, gums, resins, scents, colourants, specific pesticides, and so on, of which we have scarcely turned the pages." The need to survey and map these resources and to develop gene conservation programmes is being increasingly realised (Kemp et al, 1972). Yet according to Stott (1978), many such programmes are unlikely to prove sufficient, and points out the deepening conviction that, for a larger percentage of rain forest taxa, there is really no alternative to *in situ* conservation (Whitmore, 1975, p76), coupled with the fact that, once destroyed, the species diversity of tropical moist forest is essentially a non-renewable resource. Both point to the ultimate need to conserve adequate samples of living ecosystems as envisaged in the UNESCO programme of Man and the Biosphere (UNESCO, 1973, 1974). This involves, not only the will of governments to set aside tracts of undisturbed forest for conservation purposes, but also a significant development of research into the functioning of rain forest ecosystems so that ecologically sound management plans may be developed (Lamb, 1977).

1.5 The Possible Effects of Removal of Substantial Areas of Tropical Moist Forest

Modification of Climate

Poore (1979) has suggested that the "climate of the world is changing, partially through processes which are not caused by man, which further are beyond man's control and which are very imperfectly understood."

It is possible for humanly induced climatic modification either to cancel out or accentuate an underlying natural trend. "There is still considerable doubt about the effect of large-scale charges in land use on regional or even global climate." (Poore, 1976). The same author goes on to point out that the radiation balance can be affected by the removal of forest or changes of land use which in turn affect albedo, surface roughness and the apportionment of radiation between the sensible and latent heating of the atmosphere.

Questions have been raised about the possibility of effects on the carbon cycle of the biosphere, and the carbon dioxide content of the atmosphere.

The Irreversible Nature of Destruction

In most tropical moist forests there are a large number of different species in any one area. Many species are represented by only a few individuals and seed dispersal mechanisms are often inefficient, so that the possibilities for re-colonization are slight. Certain species are, however, adapted to colonizing new clearings very quickly. Widespread destruction can lead to the elimination of various types of forest and the species they contain.

Reduction of Genetic Diversity

Perhaps the most important consequence of the reduction of genetic diversity is the loss of the vast presently unknown potential, which involves a large proportion of forest plants. "The range of chemical compounds found in tropical moist vegetation is unmatched elsewhere, yet scarcely investigated." (Poore, 1976). The same author also points out that the removal of tropical moist forest could reduce the efficiency of local agriculture, by removing "breeding sites, and carryover feeding grounds for pollinators, the predators and parasites of pests."

Effects on the Soil

In tropical soils the decomposition of dead plant and animal material and its uptake by the vegetation is very rapid, with biological activity being confined to a shallow surface layer. "It follows that many sites in the tropical moist forest appear to be more fertile than they really are." (Poore, 1976). Successful change of use depends on knowledge of the characteristics of the different soils, careful evaluation of land suitability, methods of clearing, erosion control and cultivation.

Water and Catchment Protection

The disast rous consequences of flooding, droughts and erosion have been reviewed by Pereira, 1973.

1.6 Conservation Planning in Indonesia

The government of Indonesia is conscious of the value of its natural resources and of the need for more effective conservation and management. The growing need to provide more natural areas for recreational use by rapidly expanding urban communities, and the role which such areas could play in development of both domestic and international tourism, is also recognized. High priority is being given to environmental management and to limiting ecologically harmful effects of development.

The government's recognition of the importance of environmental conservation has been recently demonstrated by the appointment of a state Minister of Development Control and Environment, the greatly increased budget allocated for the Directorate of Nature Conservation, and Indonesia's recent signature of The Convention on International Trade in Endangered species. This concern has also been reflected in some cases by provincial governments, such as that of west Java which, concerned with the increasing flood havoc, in 1977 imposed a total prohibition on cutting of natural forest throughout the province.

Nature conservation, including the establishment and management of nature reserves and national parks, is the responsibility of the Directorate of Nature Conservation (PPA), which is part of the Directorate-General of Forestry, under the Ministry of Agriculture. Many reserves already exist, though their distribution is uneven and a number of major ecosystems are as yet inadequately represented.

In 1974 the Food and Agriculture Organization of the United Nations (FAO), acting as executing agency for the United Nations Development Programme (UNDP) was commissioned to assist the government in identifying problems and priorities in relation to nature conservation. The project was also to draw up plans for future action, including the development of national parks.

The project was designed essentially as a preparatory project to investigate the problems and prepare an action plan. The result of this was the publication of a detailed report and action plan (FAO, 1977). The recommendations of this action plan were in general accepted by the government, and a follow up project was given high priority. A three year implementation phase entitled "National Parks Development" was then included under the UNDP second country programme for the period 1979-1982, starting in January 1979.

The long term objective of this project was to assist in the development of an effective system of national parks and reserves to safeguard viable and representative examples of the Indonesian flora and fauna together with the unique genetic resources they contain, and where appropriate to develop the economic potential of such areas through tourism. Some of the immediate objectives were to provide assistance in preparation of new nature conservation legislation, and to carry out an extensive programme of field surveys to evaluate existing conservation areas and to identify priorities for establishment of new reserves and for the development of national parks.

Recommendations

The FAO have outlined the main objectives in planning new conservation areas (FAO, 1977), and state that they should not merely be to achieve the present national target of 11.4 million ha. as quickly as possible, but to develop a comprehensive system of parks and reserves which would assure the protection of representative examples of all major ecosystems, of sufficient size to ensure maintenance of their ecological and genetic diversity. Other important objectives have been outlined as being the protection of watersheds and river catchment areas, the protection of natural landscapes of outstanding interest or beauty, and the provision of wilderness recreation areas to satisfy the growing needs of the urban population. The greatest urgency for conservation is now seen as the outer islands where pressures on the natural environment are growing rapidly.

More specific recommendations as laid out by the FAO (1979).

1. Conservation needs should take official precedence over commercial and other interests. (Since only 5 percent of the land area is to be set aside for parks and reserves, this will still leave 95 percent for the other forms of land-use).

2. Priority should be given to safeguard valuable existing reserves, such as Kutai and Leuser (Which were reported as still being logged in 1979), and to establishment of new reserves to fill the obvious gaps in the present systems, especially lowland rain forest in Kalimantan, Sumatra, Sulawesi, Maluku and Irian Jaya, and coastal mangroves.

3. Priority should be given to protection of major watersheds and catchment areas, such as Dumoga and Danau Lindu/Lore Kalimantn in Sulawesi, and their inclusion either in reserves or national parks or

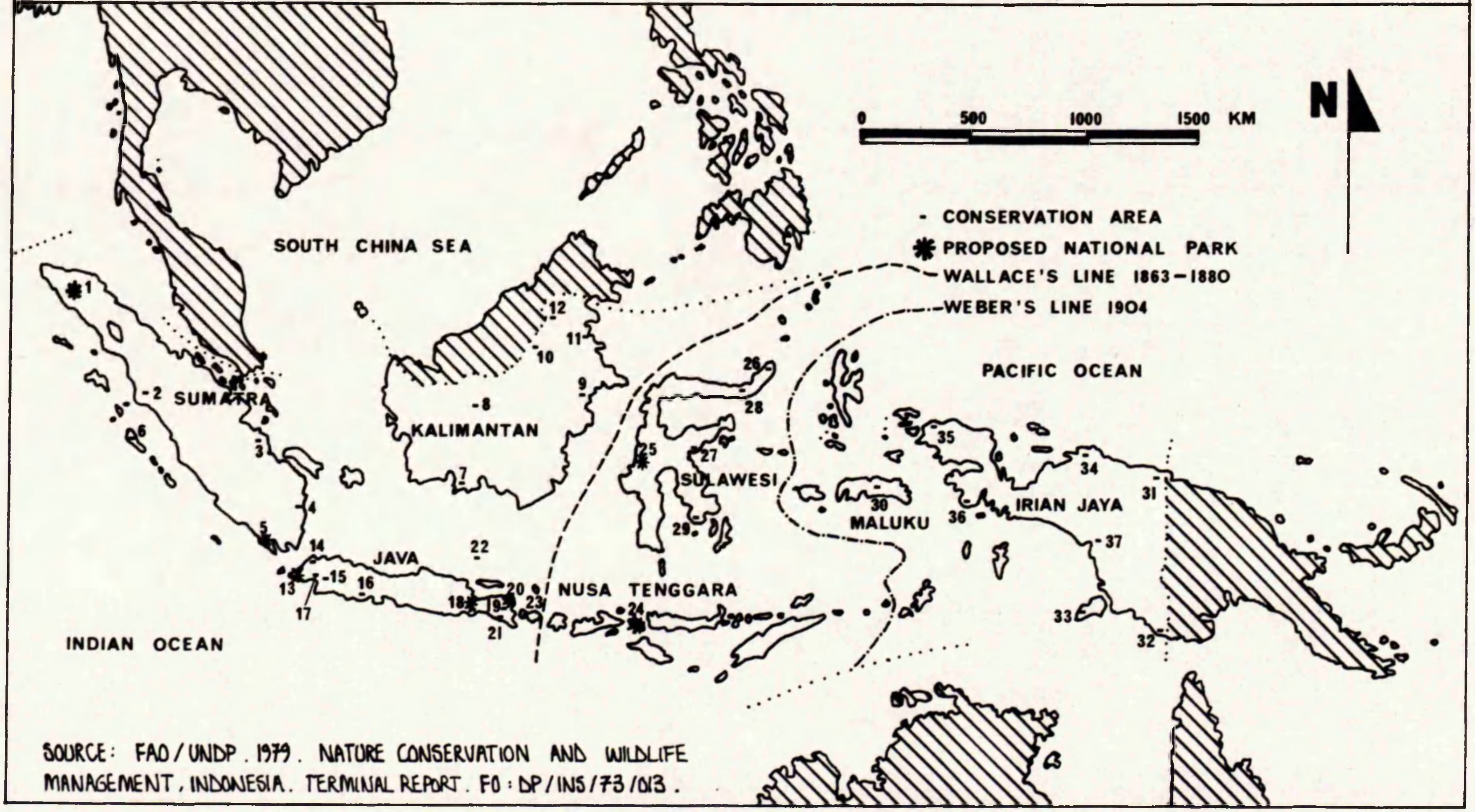
protection forest under the forest department, provided that their effective protection can be assured.

4. Survey, establishment and subsequent protection of suitable marine and coastal conservation areas.

Fig 1 on page 22 shows the location of existing and proposed conservation areas in Indonesia.

FIG 1

INDONESIA – LOCATION MAP OF EXISTING AND PROPOSED CONSERVATION AREAS



SOURCE: FAO/UNDP. 1979. NATURE CONSERVATION AND WILDLIFE MANAGEMENT, INDONESIA. TERMINAL REPORT. FO: DP/INS/73/013.

KEY TO FIG 1. EXISTING AND PROPOSED CONSERVATION AREAS

SUMATRA

1. Gunung Leuser
2. Kerinci
3. Berbak
4. Way Kambas
5. Sumatra Selatan
6. Siberut

KALIMANTAN

7. Tanjung Puting
8. Bukit Raya
9. Kutai
10. Kayan River
11. Kayan Delta
12. Mutlak

JAVA

13. Ujung Kulon
14. Ranca Danau
15. Gunung Gede-Pangrango (Cibodas)
16. Pangandaran
17. Gunung Halimun
18. Bromo-Tengger-Gunung Semeru
19. Kawah Ijen-Merapi
20. Baluran
21. Meru Betiri

22. Palau Bawean

23. Bali Barat

NUSA TENGGARA (LESSER SUNDA ISLANDS)

24. Komodo

SULAWESI

25. Lore Kalimanta

26. Gunung Tangkoko Batuangus

27. Morowali

28. Dumoga-Bone

29. Rawa Opa/Watumohai

MAUKU (CERAM)

30. Way Mual/Way Nua

IRIAN JAYA

31. Penunungan Siklop(cycloops)

32. Wassar

33. Pulau Dolok

34. Waropen-Mamberamo

35. Penunungan Tamrau

36. Kumawa

37. Gunung Loentz

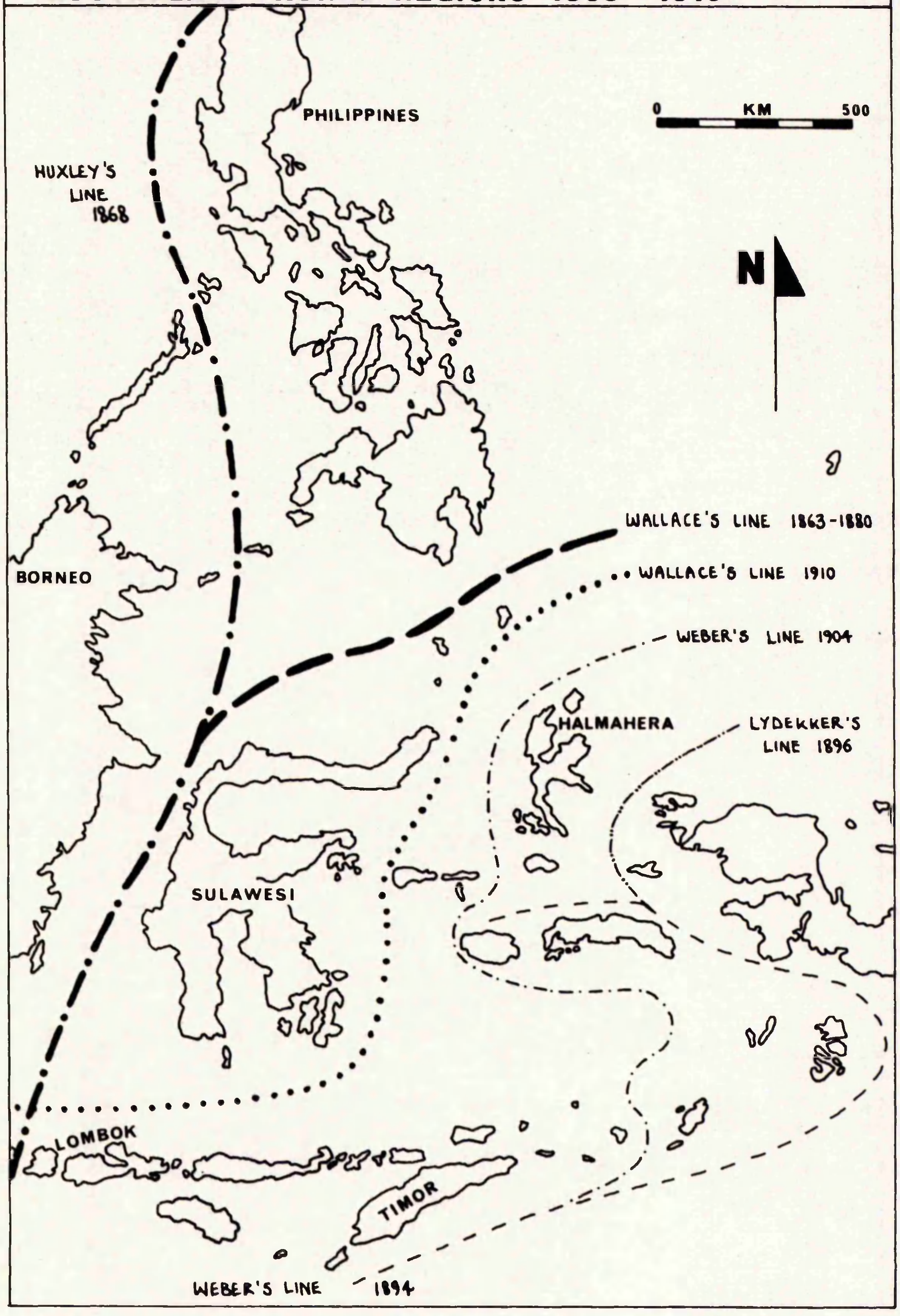
1.7 Conservation Planning in Sulawesi

Introduction

Sulawesi, with an area of 190,000 km^2 is about twice the size of Java, and is a 'major pivotal island' in the Indonesian archipelago. Physically it is distinguished by its extraordinary shape with its long arms ridged with mountains and converging towards the central highlands. Lying just to the east of Wallace's 1863-1880 line it is particularly interesting ecologically, and it is part of the intermediate zone, often termed 'Wallacea' between the Indo-Malayan region to the west and the Australo-Papuan to the east. (FIG 2 on page 26 shows lines suggested for separating Oriental and Australian floral/ faunal regions). Sulawesi has, by virture of its long geographical isolation, evolved a fauna which includes a higher percentage of endemic species than any other in the Indonesian islands. This gives the island special significance in the zoogeography of the region.

The forested mountains and valleys of Sulawesi with their unusual wildlife, including such species as the anoa (Anoa depressicornis), macaques (Macaca nigra), maleo (Macrocephalon maleo), tarsier (Tarsius spectrum), and phalangers, are a natural treasure house of unique scientific and cultural value. The primary forests in which this endemic fauna is dependent for survival are rapidly being depleted by shifting cultivation, commercial timber exploitation and other influences.

FIG 2
LINES SUGGESTED FOR SEPARATING ORIENTAL AND AUSTRALIAN FAUNAL REGIONS 1863 – 1910



With the increasing population pressure and the subsequent need for more agricultural land some depletion of the forest is however inevitable.

Only about 1.2 percent of the forested land in Sulawesi is included in existing reserves, compared with over 50 percent already assigned or under survey for timber concesssions. However, the Directorate of Nature Conservation is giving high priority to the development of new conservation areas in line with the National target of 11.4 million ha.

At present Sulawesi has five nature reserves of varying legal status, as follows: 1. Lore Kalimanta National Park; 2. Gunung Tangkoko Batuangus Nature Reserve; 3. Dumoga Bone Nature Reserve (proposed National Park); 4. Morowali Nature Reserve (proposed National Park); 5. Rawa Opa/Watumohai Nature Reserve (proposed National Park).

Each of these will be discussed briefly in the following section, except Morowali which will be dealt with in detail in section 2.

Lore Kalimanta National Park

The proposed Lore Kalimanta National Park, based on an enlargement of the original Lore Kalimanta Game Reserve established in 1973, represents a first step in development of what is planned to become a comprehensive system of Parks, Reserves and other conversation areas throughout Sulawesi.

This park plays an important role in ecosystem conservation, and possibly tourism development. The park also has the vital function in protection of a major watershed and catchment area (FAO, 1977). The total area of the park will be approximately 250,000 ha.

Gunung Tangkoko Batuangus Nature Reserve

This nature reserve contains some important endemic species including; macaques (*Macaca nigra*), anoa (*Anoa depressicornis*), maleo (*Macrocephalon maleo*), and tarsier (*Tarsius spectrum*). Recently more effective patrolling of the reserve has stopped illegal hunting and removal of timber which was formerly rife. As a result of recommendations made by WWF/FAO/PPA the reserve was doubled in size in November 1978, by the addition of the adjoining Gunung Dua Saudara area, bringing the total to 8745 ha.

Dumoga Bone Nature Reserve

The original proposal in 1977 was to establish this reserve to protect the Dumoga river catchment, and to serve the valuable function of an ecosystem reserve. It was further suggested that the reserve should be extended westwards across the main watershed to protect the catchment of the Bone river which is subject to periodic disastrous flooding, linking it up with the smaller proposed Bone reserve. This gives a single conservation area of some 300,000 ha. protecting a major part of the central watershed, including the upper catchment basins of two major rivers vital to agricultural production in the lowlands. The proposed reserve would also be of great value in safeguarding a relatively extensive tract of undisturbed lowland rain forest which is unusually rich in endemic wildlife.

Rawa Opa/Watumohai Nature Reserve

The present Watumohai Hunting Reserve in SE Sulawesi (approximately 50,000 ha.) consists of extensive savanna grasslands to the southern coast where there are mangroves, an important ecosystem seriously under-represented in existing conservation areas. Adjoining it to the northward are the Rawa Opa swamplands which includes both fresh-water swamps and swamp-forest, and which, apart from their botanical value, are unusually rich in wild life.

Establishment of a nature reserve is proposed to include the present Watumohai Hunting reserve and the adjoining Rawa Opa swamplands, giving a total area of some 100,000 ha.

1.8 Conclusion

In the first chapter an attempt has been made to summarize the important theories about tropical moist forests of the world, including the status, possible effects of removal and the conservation value of tropical moist forests. The second half of the chapter was devoted to conservation planning in Indonesia and specifically within Sulawesi. Examples of a National Park and Nature Reserves have been outlined. Chapter two provides an introduction to, and discussion of, the study area in detail.

CHAPTER TWO

INTRODUCTION TO THE STUDY AREA

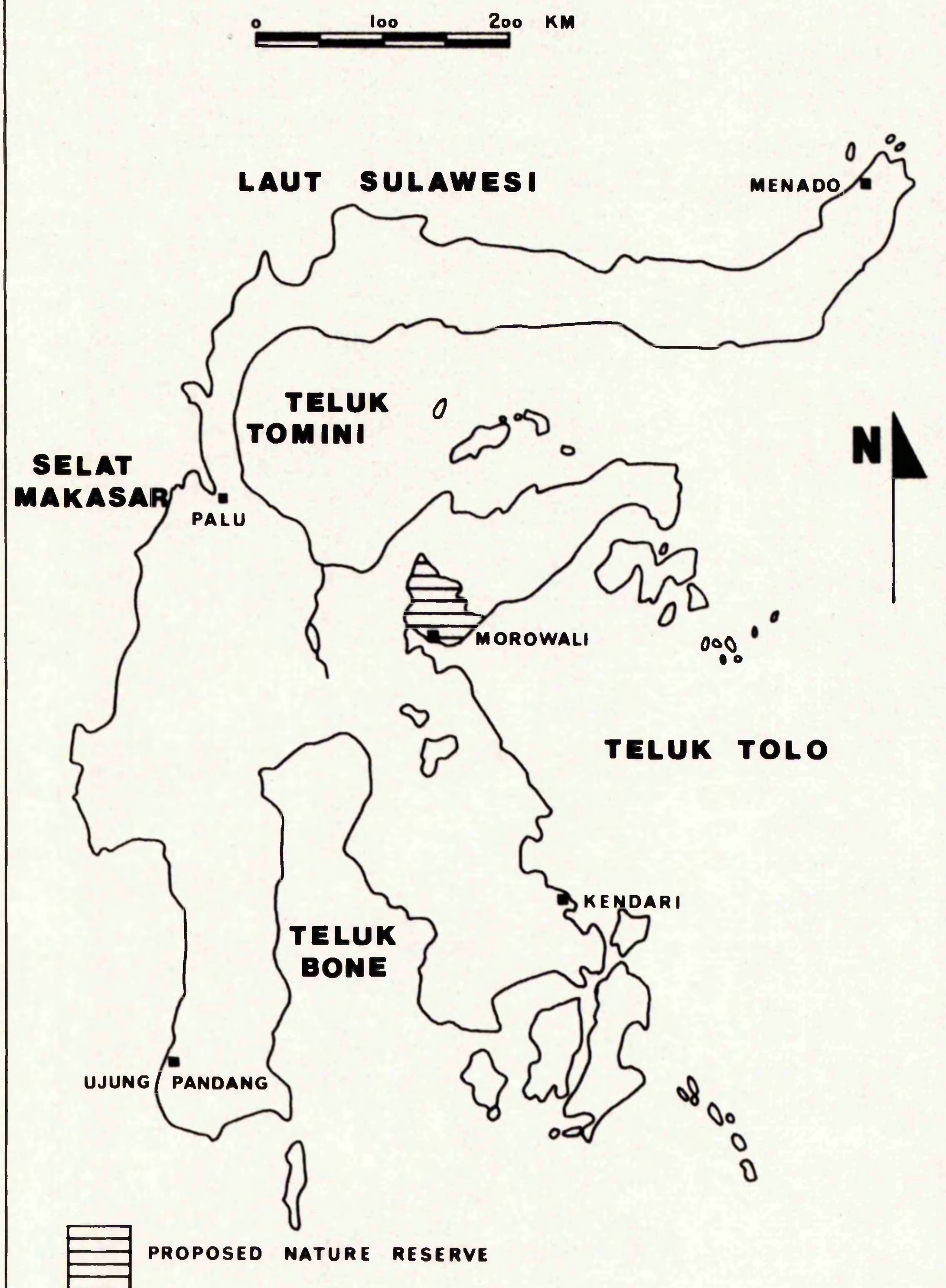
In early 1977 a flight survey was carried out in Sulawesi to locate potentially suitable areas for conservation purposes in connection with the government's planned target of 5 percent of the land area. The only area positively identified as having the desired diversity of habitats, including still undisturbed lowland rain forest, was the Morowali area on the southeastern coast of central Sulawesi. FIG 3 on page 32 shows the location.

During the summer of 1978 a two man team (APM Van der Zon of the FAO Nature Conservation and Wildlife Management Project, and Yaya Mulyana of PPA, Bogor) visited the Morowali area to carry out a preliminary investigation to confirm its possible suitability as a Nature Reserve or National Park (FAO, 1978).

FIG 4 on page 33 shows the proposed boundary of the proposed reserve, which extends from the main watershed of the eastern peninsula of Sulawesi southwards to Tomori bay and includes the catchment basins of the Solato, Tiworo, Morowali and Ranu rivers and the Western catchment basin of the upper Bongka river which flows to the north. Three major NW-SE running mountain ridges, Pegunungan Tambusisi/Patolawajo,

FIG 3

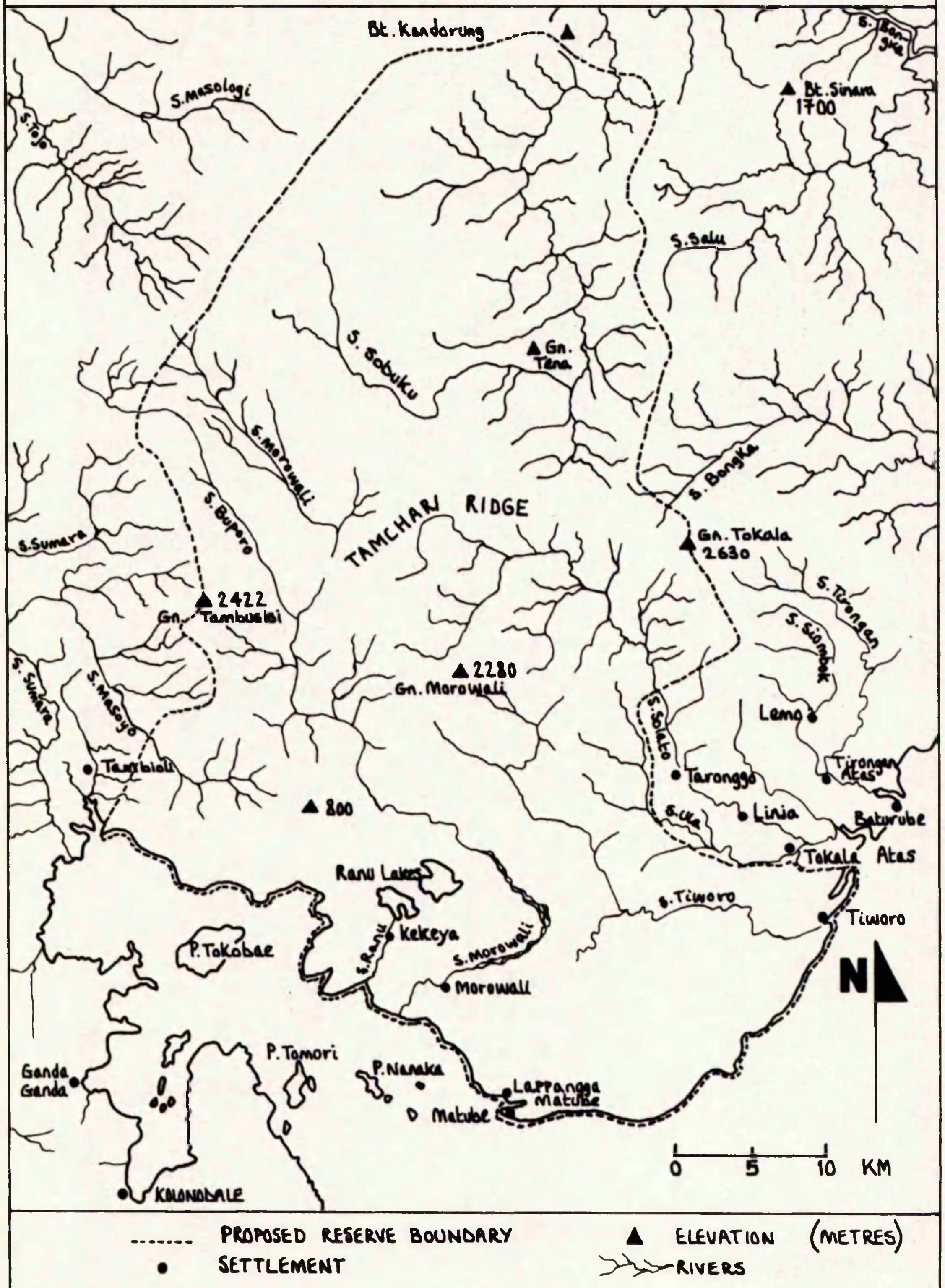
LOCATION OF STUDY AREA IN SULAWESI



SOURCE : VAN DER ZON . A.P.M. & MULYANA . Y. 1978 .

FIG 4

PROPOSED MOROWALI NATURE RESERVE



SOURCE: WWF, 1980.

Pegungungan Morowali and Pegunungan Tokala from the northern, mountainous part of the proposed reserve, with often steep slopes and narrow and deep stream valleys. There are several peaks over 2000m, but exact heights are unknown. The highest peak in the central mountain range exceeds 3000m while other lower peaks include Bukit Morowali (2280m), Bukit Ramansuleiman (2628m) and Gn. Tambusisi (2422m). The Pegunungan Tokala are a complex of isolated high limestone peaks whereas the other mountains are ultrabasic and basic intrusive rocks. The southern part of the proposed reserve is a large alluvial plain just above sea level, with some very swampy areas near the coast. Further inland are two beautiful lakes completely surrounded by still untouched virgin forest. They are connected by an area of fine swamp forest and are drained by the Ranu river.

2.1 Proposed Boundaries

As shown in FIG 4, it was proposed that the reserve should include the south western catchment basin of the Bongka river and the whole catchment areas of the Morowali, Ranu and Solato rivers from the central watershed down southwards to the Teluk Tomari including the Morowali plains but excluding the lower Solato valley and the new Matube village, "Lappanga Matube". Prior to more detailed survey it was tentatively suggested that the boundaries should be as follows:

> Starting from the mouth of the Ula river, following it upstream to the point where the main path from Tokala to Morowali crosses the river; thence in a straight line northwards for about 4km to the crest of the ridge, just to the west of the Solato river; thence following this ridge to the top of the Gn. Tondolili peak of the Tokala mountains, which are the watershed between the Solato river and the Bongka river; thence following the highest crest of this watershed in a northerly direction via the B. Rapansuleiman (2628m) to the B. Moa (1800m); from the B. Moa in a northerly direction following the highest crest of the watershed between the S. Bongka and the S. Watupa/ S. Sabuku, over the B. Kaya-Merangke, B. Maliwuku, B. Lingko, to the B. Wombo; thence from the B. Wombo in a straight line crossing the Sabuku river to B. Syonsyu and from B Syonsyu in a straight line to the ridge to B. Kondorung in the central watershed; following the crest of this central watershed in a southwesterly direction over a distance of about 24km to the point where the main watershed between the S. Morowali and the S. Sumara with its tributaries Sojo and Kanapa joins the central watershed (Taku mountains), then following the highest crest of the watershed between the S. Morowali and the S. Sumara in a southern direction to the top of Gn. Tambusisi (2422m); from the top of the Gn. Tambusisi following the highest crest of the Tambusisi mountain first in a southwestern, then southeasterly, southern and thence western direction to the watershed between the two small rivers

> K. Puntuloha and K. Masojokadi; thence following a line 500m to seaward of mean low water mark of the Tomari bay first in a southeasterly direction to Tg. Mposo, thence in an easterly and northeasterly direction to the point of origin at the Ula rivermouth. (FAO, 1978)

2.2 Climatology

The data presented in sections 2.2, 2.3 and 2.4 are taken from the Land and Water resources report, produced by the Central Planning Consultancy, Jakarta, 1979.

Air Temperature

Monthly temperature generally follows the variation in intensity of extra terrestrial radiation which in Central Sulawesi is at its maximum in April/May and October/November. In Central Sulawesi, the mean annual temperature at sea level is about 27° C. The mean monthly variation is small (about 1° C.) but the diurnal range between daily maximum and minimum temperature may be up to 20° C.

Relative Humidity

Mean annual relative humidity at sea level in the province of Central Sulawesi is about 75 percent. It is expected that relative humidity will increase to 80 percent in the wetter region near Morowali. The mean monthly variation in relative humidity is small (about 5 percent) but the diurnal range between maximum (early morning) and minimum (around noon) maybe up to 50 percent.

Wind Speed and Direction

Wind direction in the area is governed by the intensity of the westerly or south-east monsoon. Mean annual wind velocity of 2m/s is over most of the area.

Sunshine and Radiation

The mean monthly sunshine percentages vary up to 15 percent throughout the year with the maximum values coinciding with the periods of maximum extra terrestrial radiation in April/May and October/November. This is confirmed by the only radiation data recorded at the Bora station where the mean daily incoming radiation is about 290 langleys/day (1 langley = 1 cal/cm^2). The importance of collecting radiation data cannot be overestimated in order to optimise agricultural crop production.

Rainfall Data

The system of hydrological data collection and flow data is very much in its infancy in the area. The majority of present day stations were only established in 1971. Most rainfall data are sent to Jakarta for storage, analysis and publication. However a large proportion of data collected remains with the collector, basically because insufficient funds are available to forward the data on the weekly summary cards to Jakarta. Lack of funds also limits the amount of time spent on routine network inspection and the replacement of faulty equipment. Consequently records are often incomplete and unreliable.

At present the lack of population in the Morowali area makes it difficult to set up river gauging or rainfall stations.

Areal Distribution

In Central Sulawesi there is a large variation in mean annual rainfall (from 600mm near Palu in the west to 4500mm near to Morowali in the east). In the Morowali area there is high rainfall because of the south-east monsoon. Mean annual rainfall over the Morowali area varies and exact data do not exist, but at Kolonodale it is 4500mm/ yr. Topography and aspect have an important effect on the rainfall within the region. High rainfall totals experienced in the Morowali coastal area are directly related to the length of fetch over the sea.

The mean number of rain days in the Morowali area is 200/yr with a mean daily rainfall of over 20mm.

2.3 General Physiography

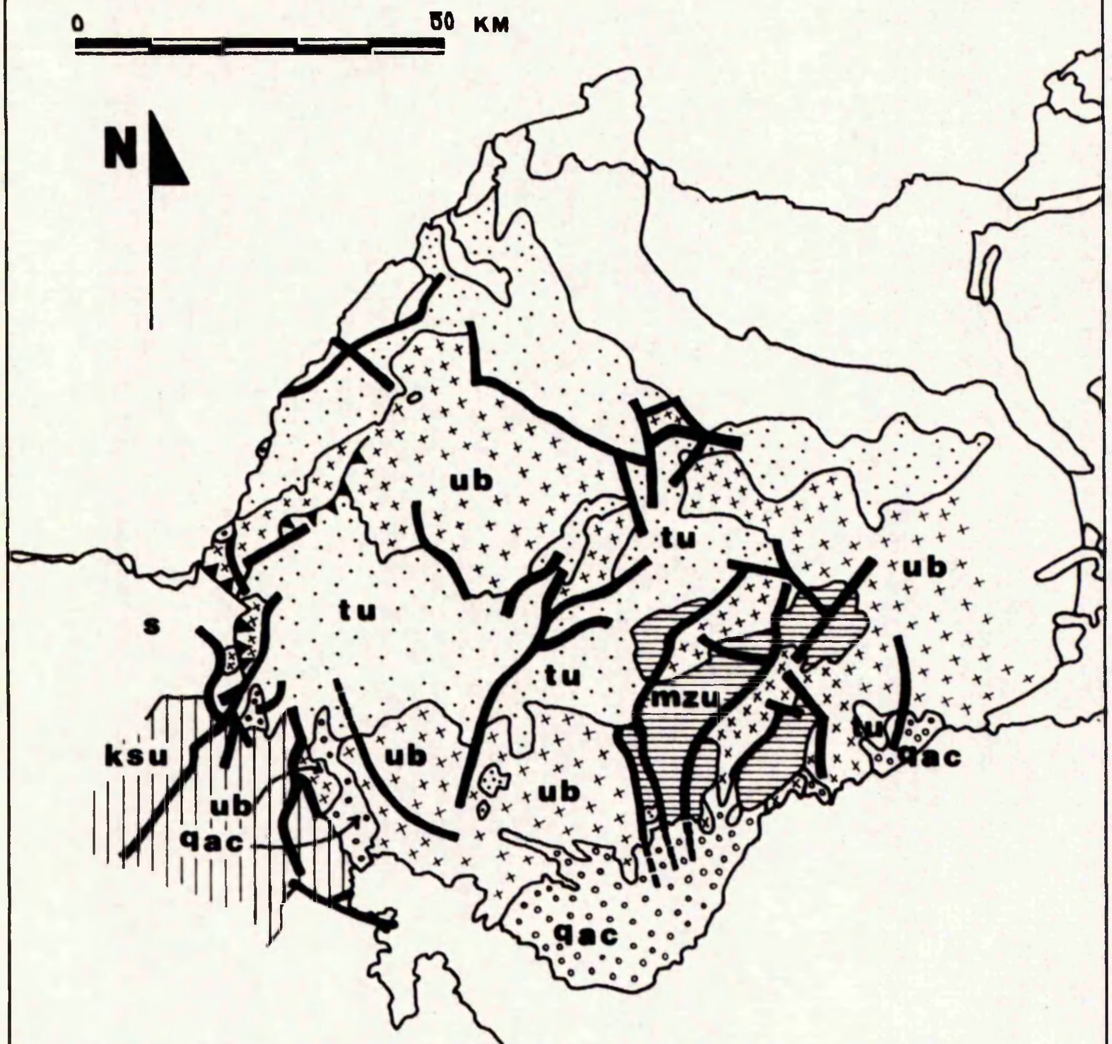
There are a number of strike-slip faults and overthrust fold systems that contribute to the geological complexity of the area. The principal faults are shown in FIG 5 on page 40. Interpretation of LANDSAT imagery and aerial photography has been used for geological mapping and has identified a multiplicity of different fans and faults and fracture zones. A full description of the lithological units shown in FIG 5 on page 40 is given in TABLE 2 on page 42. TABLE 1 on page 41 shows the groundwater potential. The mountains are steep and geologically young and erosion is quite rapid. The scars of many landslides on the upper slopes are visible on aerial photographs. These landslides have occurred despite the dense cover of primary forest. The maintenance of an undisturbed forest cover on this deeply dissected terrain is important for the conservation of the river catchments.

Formation of the Morowali Delta

The large delta fan, 350 km^2 in area, has been formed with contributions from - on the eastern front the river Tirongan the river Tokala and the river Tiworo, and on the western front by the rivers Morowali and Ranu. The southern part of the delta has been formed as a result of changing river courses of the Morowali

FIG 5

LITHOLOGY AND GROUNDWATER POTENTIAL



SYMBOLS		LITHOLOGICAL UNIT	SYMBOLS		LITHOLOGICAL UNIT
qac		ALLUVIUM, COASTAL DEPOSITS AND RECENT CORAL	ub		IGNEOUS & METAMORPHICS PLUTONIC INTRUSIVES
mzu		SEDIMENTARY CLASTICS SANDSTONES & CONGLOMERATES	s		METAMORPHIC ROCKS
tu		SEDIMENTARIES, SULAWESI MOLASSE AND TINOMBO FORMATION			LINES OF MAJOR FAULTS DASHED WHERE APPROX
ksu		VOLCANIC ROCKS			MAJOR THRUST FAULTS TEETH ON UPPER PLATE

SOURCE : EXTRACT FROM GEOLOGICAL MAP OF INDONESIA, UJUNG PANDANG SHEET AND LAND & WATER RESOURCES REPORT, CENTRAL PLANNING CONSULTANCY, 1979 .

TABLE 1

LITHOLOGY AND GROUNDWATER POTENTIAL

SYMBOL	LITHOLOGICAL UNIT	GROUNDWATER POTENTIAL
Qac	Alluvium, coastal deposits and recent coral sedimentary clastics	High
Mzu	Sandstones and conglomerates	Variable
Tu	Sedimentaries Sulawesi molasse and Timobo formation	Variable
Ksu	Volcanic rocks	Low
Ub	Igneous and metamorphics and Plutonic intrusives	Low
S	Metamorphic rocks	High in fault zones

Source: Land and water resources report. Central Planning Consultancy, Jakarta, 1979.

TABLE 2

DESCRIPTION OF LITHOLOGICAL UNITS

SYMBOL	LITHOLOGICAL UNIT
	SEDIMENTARY ROCKS
Qac	ALLUVIUM AND COASTAL DEPOSITS Clay, sand, gravel and locally coral reefs; Marine clay near Danan Tempe. Pleistocene terrace deposits along Walanae river contains elephant bones.
Mzu	SEDIMENTARY ROCKS - UNDIVIDED Sandstone, quartzite siltstone, slate, platy bituminous limestone, radiolarian chert, calcareous shale, bituminous shale and marl. Conglomerate contains boulders of pink granite.
Tu	SEDIMENTARY ROCKS - UNDIVIDED Conglomerate, sandstone and shale uncomformable on ultrabasic rocks, unit Ub, east of lake Poso.
Ksu	SEDIMENTARY ROCKS - UNDIVIDED Shale and slate, black, grey, green and red, intercalated with arkosic sandstone, conglomerate, limestone marl, radiolarian chert, and some phyllite and quartzite. Rocks

TABLE 2

DESCRIPTION OF LITHOLOGICAL UNITS

SYMBOL	LITHOLOGICAL UNIT
	SEDIMENTARY ROCKS
Ksu	near large intrusions are strongly metamorphosed. Most rock barren of fossils, but some fossils of Cretaceous age have been found near Babokan.
	INTRUSIVE ROCKS
Ub	ULTRABASIC AND BASIC ROCKS Dunite, peridotite, harzburgite, pyroxenite, gabbro, serpentinite, basalt and some diorite in N.E. Sulawesi. These rocks are structually complex. Most contacts with lower Miocene and older rocks are faulted.
	METAMORPHIC ROCKS
S	SCHIST Glaucophane-schist, eclogite, gamet-schist, amphibolitic-tremolite-achinolite-schist, muscovite schist, chlorite-schist, albite-orthoclase-gneiss, and quartz. Feldspar-gneiss. Divided up into two faces: glaucophane-schist and epidote-amphibolite.

TABLE 2

DESCRIPTION OF LITHOLOGICAL UNITS

SYMBOL	LITHOLOGICAL UNIT
	SEDIMENTARY ROCKS
S	Metamorphism, which produced glaucophane is younger than the epidote-amphibolite faces of this unit, the radiolarian chert of units Ksu, and Kl and the ultrabasic and basic rocks, probably late Mesozoic or Tertiary in age. Found mostly in east-central and southeast Sulawesi.

Source: Land and water resources report. Central Planning Consultancy, Jakarta, 1979 river, from Tanjung Poso, representing its earliest course, to the present day river channel.

2.4 Water Resources and Potentially Irrigable Land

Morowali and Ula-Solato Plain

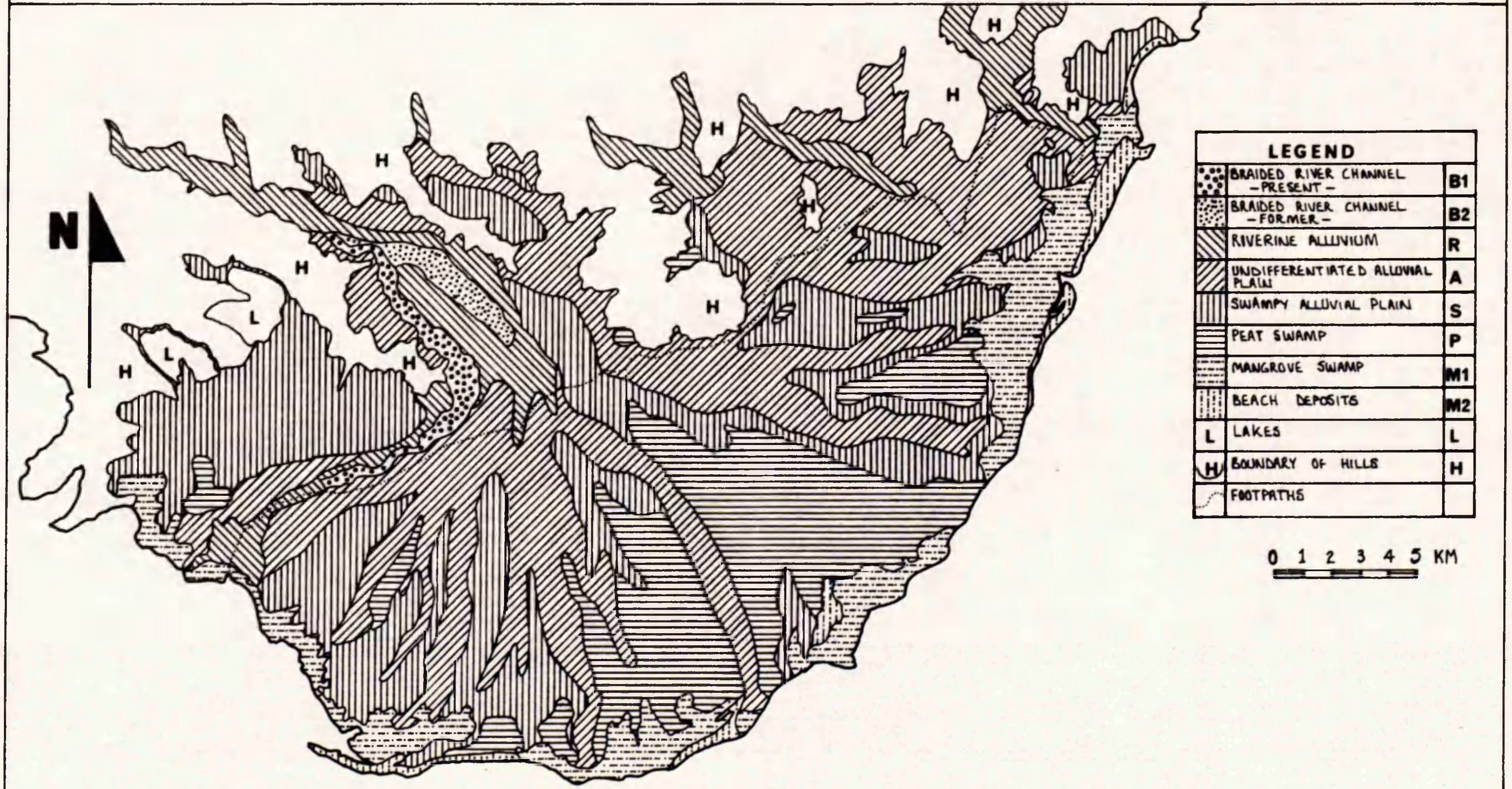
The 57,000 ha Morowali/Ula-Solato plain has considerable potential for development (CPC, 1979), but now it has been declared a nature reserve it will not be developed. I think it is however, important to give a brief outline of the area from an agricultural point of view so that conservationists are aware of the pressures on the land. The plain is divided into two parts; the Morowali plain proper (44,500 ha) which is still almost entirely forested and which extends over the alluvium of the Morowali and Tiworo rivers; and the Ula-Solato plain (12,600 ha) in the east, which extends north to the Siambak river and which is under shifting cultivation. Shifting cultivation at present extends south and west to the river Ula.

Landforms and Soils

The Morowali plain is a complex alluvial fan deposited by the Morowali and other rivers draining the mountains FIG 6 on page 46 shows a reconnaissance landform map. Soil textures are very variable and often quite coarse, flooding is of short duration and the swampy areas are not very deep. The main river courses have migrated

FIG 6

RECONNAISSANCE LANDFORM MAP OF MOROWALI AND ULA-SALATO IN CENTRAL SULAWESI



SOURCE: LAND AND WATER RESOURCES REPORT. CENTRAL PLANNING CONSULTANCY. JAKARTA 1979.

back and forth across the fan, leaving a complex pattern of abandoned and small seasonal channels radiating outwards towards the sea. The Ula-Solato plain has had a more simple history of deposition, resulting in more uniform soils.

Beds of pebbles and cobbles are particularly prevalent along the Morowali and its earlier courses, and the very coarse sediments carried by the river have given it a braided channel (unit B2 on FIG 6) so coarse in places that the normal forest cover has failed to establish itself. This former braided channel is the head reach of a series of early distributory channels, such as the Nunuang, which flows south towards Tanjung Bea and Matube. Sand and cobbles are found along the course of the Morowali river at sites, and this indicates the possible presence of similar agriculturally unsuitable soils anywhere along the former courses (units R and A in FIG 6).

Soils in unit R are expected to be generally coarse textured, ranging from loam to sand and gravel, and thus to have limited or local potential for upland crops only, though the low fertility inherent in coarse textured soils may be compensated for by the high mineral content of the sand layers. In unit A, a very wide range of textures from clay to sand and gravel may be encountered in a complex distribution, though more uniform medium-fine textures are probable in the

Ula-Solato plain, so the latter would be suitable for rice. The soils are moderately well drained though pockets of slightly swampy land occur.

Unit S has poorly to very poorly drained swampy soil, generally medium to fine textured though with local sandy horizons, and deep mulch soils may be widespread with local surface layers of peat. By contrast, more severe swamp conditions occur in unit P: no field survey has been carried out here - but possibly are uniformly peaty, probably with raw peats overlaying riverine sands. Depth of peat might not exceed one metre but this would need field confirmation.

Processes of alluvial deposition assisted by peat accumulation in the main areas of the plain have left depressions along the base of the hills which have become swampy in places, and the two Ranu lakes have formed in this way. Soil conditions in the Ranu area are not known but the land is swampy and probably peaty.

There is a narrow zone of mangrove swamps and sandy beaches along the coast (unit M in FIG 6). The coastline is not very stable and recent erosion of the sand spit at Matube which necessitated the removal of this fishing village to a new site on the adjacent mainland (Lappanga Matube) demonstrates the importance of preserving unit M for protection against erosion.

Present land use over this area is predominantly primary forest. Forest has been cleared from the

Ula-Solato plain which carries grassland and secondary scrub, and a very low level of shifting dryland cropping. The river Ula is the southern boundary of this area. In the centre of the Morowali plain, the fishing village of Matube has moved to a new site and some forest clearing has commenced. The village area is being enlarged to allow for rice cultivation and additional dwelling space. There is a grassland plain up to one km wide extending along the Morowali river, mainly on the south side from the sea, and a number of new settlers located at 2km and 4km along the old Dutch track from Morowali to Tokala Atas. The primary forest has been disturbed by some local logging of Agathis and by extensive cutting of Rotan and by tapping Damar.

In summary TABLE 3 on page 50 shows the gross area and potential land suitability for each landform unit.

It is not known why the forests of the Morowali plain have remained uncleared, while all the adjacent plains such as the Ula-Solato, Sumara and Moahino are under shifting cultivation. Shifting cultivation is also widespread around Kolonodale and the Tambahaho plains, even on some very steep slopes, while all the hills formed on ultrabasic rocks remain under primary forest. There is the possibility that the high content of base metals in these rocks are toxic to plant growth. It has been noted that the forest of the Morowali plain is rather poor, in that it has a low diversity of species

TABLE 3

POTENTIAL LAND SUITABILITY OF THE LANDFORMS OF THE MOROWALI AND ULA-SOLATO PLAINS

LANDFORM UNIT	POTENTIAL LAND SUITABILITY	AREA (ha) MOROWALI	AREA (ha) ULA-SOLATO
B1	Unsuitable for agriculture	730	-
B2	Unsuitable for agriculture	540	-
R	Locally suitable for upland crops	4170	2000
A	Variable suitability for upland crops, and for rice locally in Morowali and extensively in Ula-Solato	11220	6220
S	Suitable for rice	14030	3220
P	Marginally suitable for rice and selected dry land crops	8640	70
M1	Suitable for fisheries and coastal protection	290	380
LAKES	Suitable for nature conservation, perhaps fishery	780	-
	TOTAL AREA	44510	12610

Source: Land and water resources report. Central Planning Consultancy, Jakarta, 1979.

and these specialised flora may be the result of base metals in the alluvial sediments derived from the ultrabasic rocks (as evidenced by the chromite-bearing alluvial sands).

Water Resources Potential

Five main rivers cross the Morowali and Ula-Solato plains, from east to west, the Siambak, Solato, Ula, Tiworo and the Morowali. In the west of the Morowali plain are the two Ranu lakes.

Annual rainfall is approximately 4000 mm. The main demand for water is dependent of the development of the plains for irrigated rice-land and FIG 6 shows the distribution of landform units which are suitable for rice (units A and S) and marginally suitable for rice (unit P). The water resources potential of the area has been broken down into the five main river systems, which will be considered in turn from east to west.

Solato and Ula

There is a large area of suitable riceland (6400 ha) stretching a considerable distance inland from the coast. On the Solato, a possible diversion site has been chosen at the point where the river emerges from the high ground onto the plain. The catchment area at this location is 325 km^2 and average annual catchment rainfall is 3900 mm. Average daily flow is about 25 m^3/s which probably falls to 15 m^3/s in the driest months.

Floods occur regularly each year. It would seem likely that a large part of the 3300 ha of suitable land for irrigation could be supplied with sufficient water from the Solato for double cropping.

The Ula catchment has an area of about 130 km^2 and average rainfall of 4000 mm. Average daily flow is about 11 m^3/s and in the driest of months of an average year may fall to 7 m^3/s. The Ula does not overtop its banks at times of flood according to local reports. Water supply should still be sufficient during times of drought.

Tiworo

This area is the most suitable for irrigation (landforms A and S) along the course of the Tiworo in narrow strips up to 2km wide. A large peat swamp occupies a significant proportion of the right bank of the Tiworo fan and this area is only marginally suitable for rice.

The catchment area of the Tiworo is only 50 km^2 where it emerges onto the coastal plain from the high ground. Average annual rainfall is 4000mm. It has an average daily flow of 4.5 m^3/s which may fall to 2.5 m^3/s in the driest season. During a once in five year drought the flow would be only about 1 m^3/s which is inadequate for irrigating the 7000 ha of suitable land for rice.

Morowali

The land which is suitable for irrigated rice in the Morowali catchment runs alongside old river courses over a wide area of the alluvial fan. The catchment area from a location 5 km upstream from the major right hand bend in the river course is 250 km^2 with an average annual rainfall of 3900 mm. Average daily flow of 21 m^3/s will probably fall to 12 m^3/s in November in an average year. During a one in five year drought, the flow in November would be about 6 m^3/s which is sufficient for irrigating 4000 ha of riceland in the dry season (assuming average water requirements of 1.51/s/ha).

2.5 Conclusions

In conclusion, the water resources potential in the Ula-Solato plain appears adequate for supplying future irrigation water demand. In the Morowali plain, there is likely to be a large deficiency in water for dry season irrigation of the land suitable for rice. The prospects of supplementary groundwater resources from the shallow alluvium are good but the underlying basic and ultrabasic rocks are unlikely to have much potential. Water quality for irrigation and domestic water supply are considered to be good.

The remoteness and size of the study area provides an opportunity to evaluate the potential usefulness of

LANDSAT imagery for thematic mapping, and especially vegetation mapping. Although aerial photographs were available for part of the area, cloud covered a substantial part of the photography. The available LANDSAT image however, was virtually cloud free, and covered the whole area within a single scene, ensuring continuity of data.

In the next chapter the literature covering such studies using LANDSAT data in tropical environments will be reviewed.

CHAPTER THREE

INTRODUCTION TO THE LITERATURE

The main single source is the proceedings of the annual international symposia on remote sensing of environment, held by the Environmental Research Institute of Michigan; Baltaxe, 1980, covers the application of Landsat data to tropical forest surveys.

In the following review two main types of survey are covered: those using visual interpretation of images and those using computer processing of digital data.

3.1 Surveys Negated by Cloud/Inadequate Landsat Cover

An aspect of paramount importance when carrying out studies of this nature in tropical areas is the amount of cloud cover on the available imagery and aerial photography. The problem is usually overcome by building up a cumulative image with partially covered imagery from different dates. Baltaxe, 1980, describes a case where as many as twenty scenes were used to build up a cumulative image during forest studies in Brazil. In some cases persistent cloud cover can present an insurmountable problem.

3.2 Forest Surveys Using Visual Interpretation of Landsat Imagery

Forest Mapping in Brazil using 1.1 million black and White Prints

Nossier et al (1975), used visual interpretation of black and white images of the four spectral bands at 1:1 million scale for mapping the natural vegetation cover over an area of some 620,000 km^2. (Baltaxe, 1980).

Deforestation Monitoring in Brazil

In 1977 a programme was initiated to monitor deforestation in the Amazon region over an area of 5 million km^2. Cloud cover was a problem in some areas and cumulative images of different dates were used. The interpretation was carried out for periods 1973-75 and 1976-78 on black and white prints of bands 5 and 7 at a scale of 1:500,000. This is an example of a study where the extent of the area and the temporal cover required could only feasibly be carried out with the use of Landsat data. Baltaxe (1980), points out that "there is also the corollary that since monitoring is a continuous activity it is also particularly susceptible to any prolonged interruption in the acquisition of new Landsat data".

Forest Mapping and Deforestation Monitoring in Thailand

In South East Asia, the Royal Forest Department of Thailand has used Landsat imagery for a variety of applications since 1973 (Morain and Klankansorn, 1978).

A survey was carried out to determine the existing area of forest, using black and white prints, diazo colour composites, some analysis on a colour additive viewer, interpretation of aerial photography of selected areas and field checks on a small number of sample plots. A map distinguishing between forest and non-forest at a scale of 1:500,000 was produced.

Forest Mapping of Bolivia

Baltaxe (1980), reports how Landsat provided the first opportunity to produce a Land cover/Land use map of the entire country. 1:250,000 black and white prints, of bands 5 and 7, were the main types of imagery used for interpretation, but some colour composite diapositives, and 1:1 million prints and enhanced colour composites were used together with a colour additive viewer and an electronic density slicer.

Interpretation of Vegetation Types in Brazil Using 1:1 million Black and White Diapositives

"To identify and define the boundaries of homogenous areas of vegetation in a strip 10 km wide either side of the Trans Amazonia highway from 200 km east of Altamira to 260 km west of the town". (Disperati and Keech, 1978), used mainly aerial photographs, as well as some radar imagery and black and white Landsat diapositives.

Forest Type Mapping in India Using Colour Composite and Black and White Prints

Baltaxe (1980) reports on how Shedha (1977) "made a comparison between the use of aerial photogaphs and Landsat imagery for forest cover type and land use mapping". It was concluded that Landsat data provided considerable potential for the rapid and low cost mapping of a range of forest types, enabling more expensive aerial photography to be directed at more valuable forest types.

Vegetation Mapping in the Tropics Using 1:1 million Colour Composite Prints

Test areas in the tropics and sub-tropics were used by Williams and Coiner (1975) to see whether Landsat colour composites at 1:1 million could be used for small scale vegetation mapping. "For quite a wide range of natural conditions the standard colour composite images lend themselves well to separating forest and other vegetation types". (Baltaxe, 1980).

3.3 The Use of Computer Analysis of Digital Landsat Data for Forest Surveys

Forest Type Mapping in India by Computer Classification

The Indian National Remote Sensing Agency (NSRA) used digital Landsat data to classify and map forest areas (Medhaven, Unni, 1978).

The methodology started with the location on the ground of homogenous sample areas of at least 8 ha in the various forest and land use classes and their delineation on topographic maps. The spectral signatures of these training areas were derived from the digital data and used with the results of the preliminary classifications for analysis and adjustment.

One of the conclusions is that the computer classification produced useful information about a remote and little known area in a short time, to serve as a basis for more detailed surveys in selected parts of the area.

Mangrove Forest Mapping in Bangladesh by Computer Classification

A Landsat mosaic of images at 1:1 million was prepared and used to map the approximate location of areas of coastal accretion suitable for stabilization by mangrove planting. Baltaxe (1980) also reports on another study in the same area to distinguish two mangrove species of different productivity. "Virtually pure stands of each species, as well as mixtures of the the two, occurred in the test area. The stands also displayed different degrees of crown closure adding a further variable to the classification." (Baltaxe, 1980). However, the accuracy levels were not considered sufficiently high to warrant using computer classification of Landsat data for the detailed mapping of the two species.

Forest Mapping Over the Entire Philippines by Computer Classification.

Landsat data were used to update information on the country's forest resources, with the objective of locating their distribution, stratifying them into several classes, and measuring their area. (Baltaxe, 1980).

A 1:1 million band 5 imagery assembly was used to locate areas for ground and air surveys. Aerial reconnaissance, previous aerial photography, some ground survey, topographic, soil and old forest maps were used to locate training areas for a computer classification.

"The signatures so obtained were then used for 'a bulk classification procedure' by which an entire scene was classified". (Baltaxe, 1980).

Plantation Mapping in Brazil by Computer Classification

"The computer classification of Landsat data has been used in a sub-tropical area of Brazil to map plantations of pine and eucalyptus (Shimabukuro et al, 1978). The data consisted of a CCT dating from 1975. Forest maps of the plantation areas at a scale (not stated) apparently of about 1:75,000 were used to select training areas, check the results and assess their accuracy, supplemented by some 'spot field checks'. An image-100 system was used for the computer analysis" (Baltaxe, 1980).

Forest and Land Use Mapping in Indonesia by Computer Classification

A clustering procedure was applied to the Landsat data, which was compared with 1:50,000 aerial photography to select classes for a maximum likelikhood classification. "The results of the classification were produced in the form of a photomap at 1:250,000". (Baltaxe, 1980).

Forest Type Mapping in Peru by Visual Interpretation and Computer Classification

The Oficima Nacional de Evaluacion de Recursos Naturales (ONERN) and the Environmental Research Institute of Michigan (ERIM) collaborated in the use of Landsat data to investigate the possibility of mapping stands of the economically important aguaje palm and other types of forest in the remote area of the Peruvian Amazon region (Danjoy and Sadowski, 1978). Because of the expense of obtaining cloud free aerial photography over the area (c.1 million km^2) the use of Landsat data offered the possibility for a first reconnaissance survey of this region.

Investigation was carried out initially with visual interpretation of 1:1 million black and white film diapositives of all four spectral bands and of some diazo colour composites.

Computer analysis was carried out on the digital data using spectral signatures obtained from training areas on the visual interpretation and from a clustering procedure. The signatures were then analysed on 2-dimensional feature space plots. After separable signatures had been selected these were used as input to a maximum likelihood classification procedure. After the classified data had been geometrically corrected, the results were produced as coloured maps.

"This work provides a good demonstration of a situation where the use of Landsat data enabled the survey of moist tropical forest to be carried out for an area of difficult access and not covered by aerial photographs or topographic maps". (Baltaxe, 1980).

Deforestation Monitoring in Thailand by Computer Classification

In north east Thailand a complex method of landscape modelling was employed by Miller et al (1978) to study the dynamics of the expansion of shifting cultivation. Ground truth was obtained from aerial photography. "To analyse changes in land cover a so called differencing technique was employed by which the radiance value for each cell in each band of one scene was substracted from that of the same band and cell in a scene of a different date". (Baltaxe, 1980).

Mapping Mangrove Forest in Thailand by Computer Classification

Siripong et al (1979) mapped mangrove areas in southern Thailand by computer processing Landsat -1 data. "After preprocessing the data by principal component transformation and using a training procedure to obtain spectral signatures the mangrove forests could be satisfactorily classified". (Baltaxe, 1980).

Mapping Araucaria Stands in Brazil by Computer Display of Enhanced Digital Data

"As a basis for the monitoring and control of the selective exploitation of Parana pine (Araucaria angustifolia Keech et al (1978) mapped the stands of this species in southern Brazil. The computer analysis (on INPE's Image-100 system) of Landsat data was considered the only feasible method for the survey of such an extensive area in a limited time". (Baltaxe, 1980).

"Visual interpretation of black and white band 7 images at a scale of 1:250,000 revealed a correlation between grey level intensity and density of Araucaria stands. Confirmation was by aerial photography interpretation and field checking".

"The interactive digital analysis used contrast enhancement, band ratioing and variations of colour coding. It was found that enhancement by histogram stretching permitted the consistent identification of Araucaria stands in areas of terrain shadow". (Baltaxe, 1980).

3.4 Conclusions

The use made of aerial photographs and satellite imagery in forest mapping in the tropics shows that there is a need for a remote sensing system to provide data on forest conditions in the vast and frequently inaccessible wooded tracts of the tropics. The experience gained to date shows that conventional photography in the visible and infra-red where available is useful, but the presence of cloud makes the acquisition of such imagery expensive and on occasions impossible. Satellite acquired data have been just as prone to interference from clouds and only radar imagery as deployed in the RADAM Project in Brazil and the NIRAD Project in Nigeria have enabled cloudy equatorial areas to be successfully and comprehensively mapped.

On the basis of the methods outlined in the preceding review, a methodology for mapping for Morowali area has been developed. This methodology was formed around the available Landsat imagery, aerial photography, the accessibility of the area, and the facilities available for processing and producing hard copy from the Landsat imagery.

In Chapter Four the methodology used and ground checking procedure and results will be discussed in detail.

CHAPTER FOUR

REMOTE SENSING METHODOLOGY USED IN THE STUDY AREA

A vegetation map interpreted from an uncontrolled aerial photograph mosaic (shown in PHOTOGRAPH 1 on page 66 was used as the base for testing Landsat digital data for mapping vegetation/land use in this tropical environment. FIG 7 on page 67 shows this map. The aerial photographs were flown in 1972 at approximately the same time as the imagery was sensed and were conventional black and white at a scale of 1:60,000. PHOTOGRAPH 2 on page 69 shows part of an aerial photograph of the Morowali river delta, and PHOTOGRAPH 3 on page 69 shows an aerial photograph of the Ranu rivermouth.

The methodology is a multistage approach, and was implemented in the following way. Landsat digital data were used in conjunction with selected sample areas on aerial photography and ground checking.

4.1 Aerial Photographs and Landsat Imagery of the Study Area

Landsat coverage of the area was only available for the 27th of October 1972, and this image was virtually free of cloud cover over the study area. As this was the only image with less than 10 per cent cloud cover available, it was not possible to select a specific date of

PHOTOGRAPH 1

AERIAL PHOTOGRAPH UNCONTROLLED
MOSAIC OF THE MOROWALI PLAIN

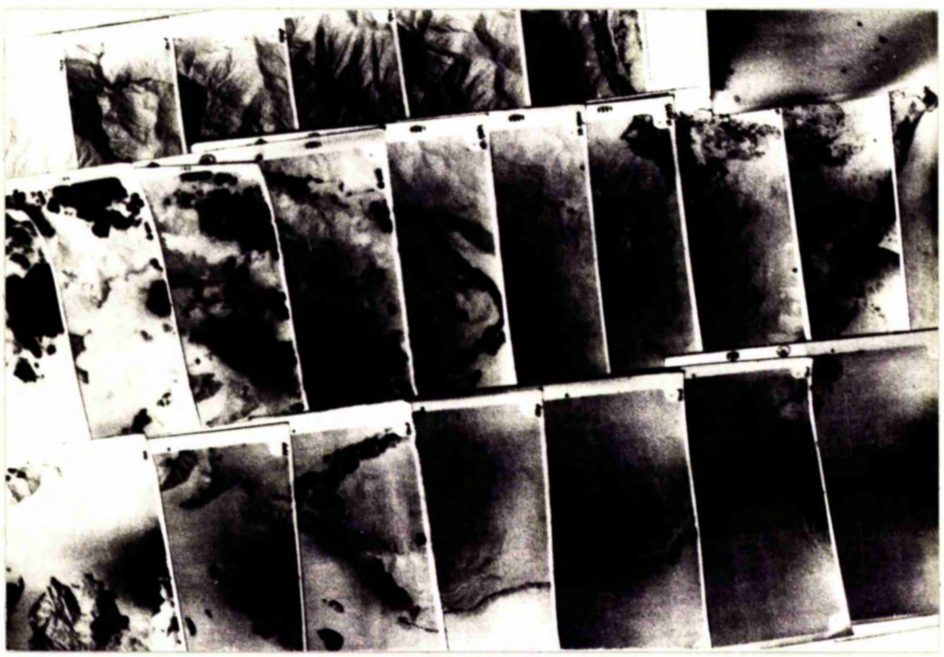
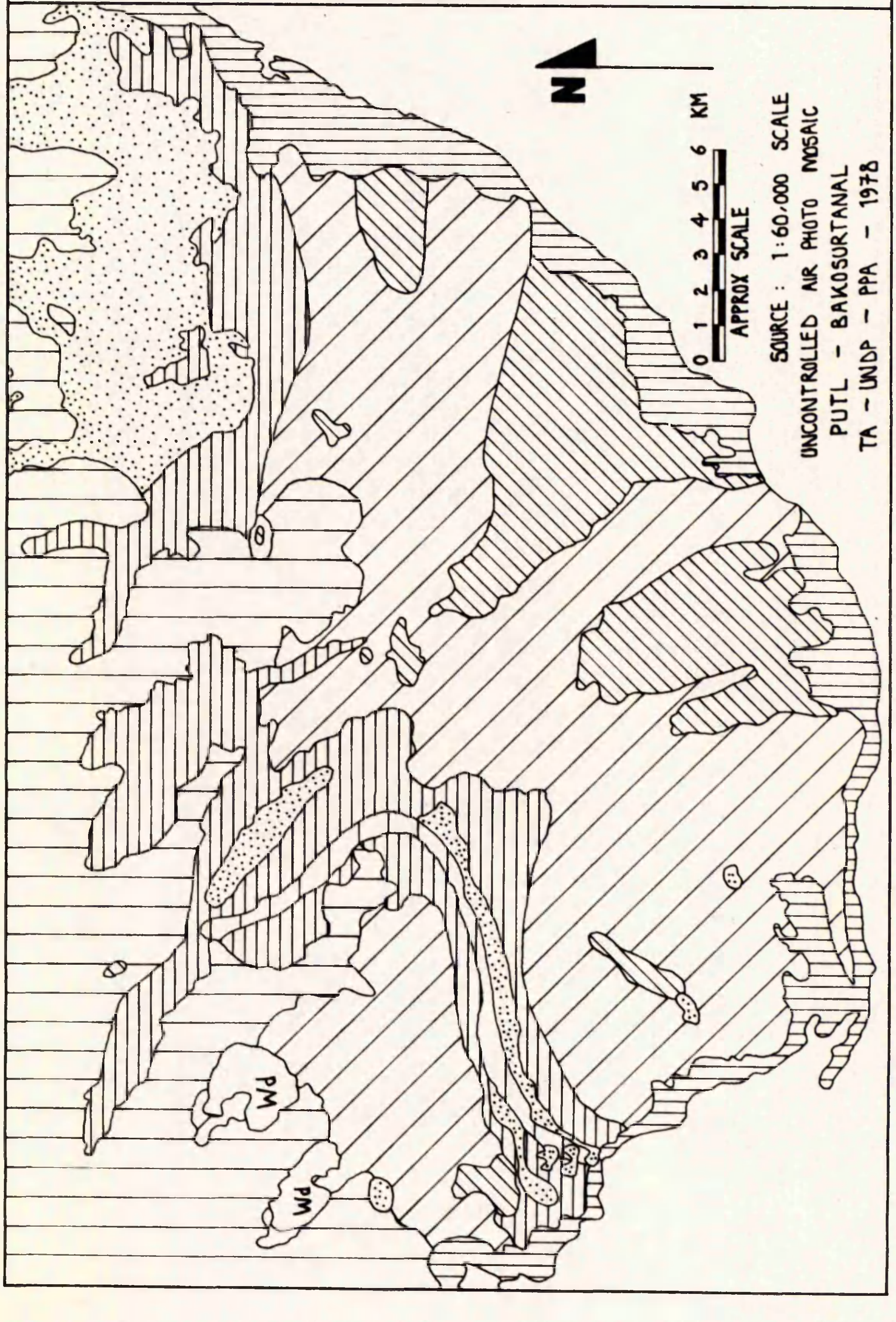


FIG 7

AIR PHOTOGRAPH MOSAIC VEGETATION MAP

LEGEND OVERLEAF



LEGEND FOR FIG 7
AIR PHOTOGRAPH MOSAIC VEGETATION MAP

N

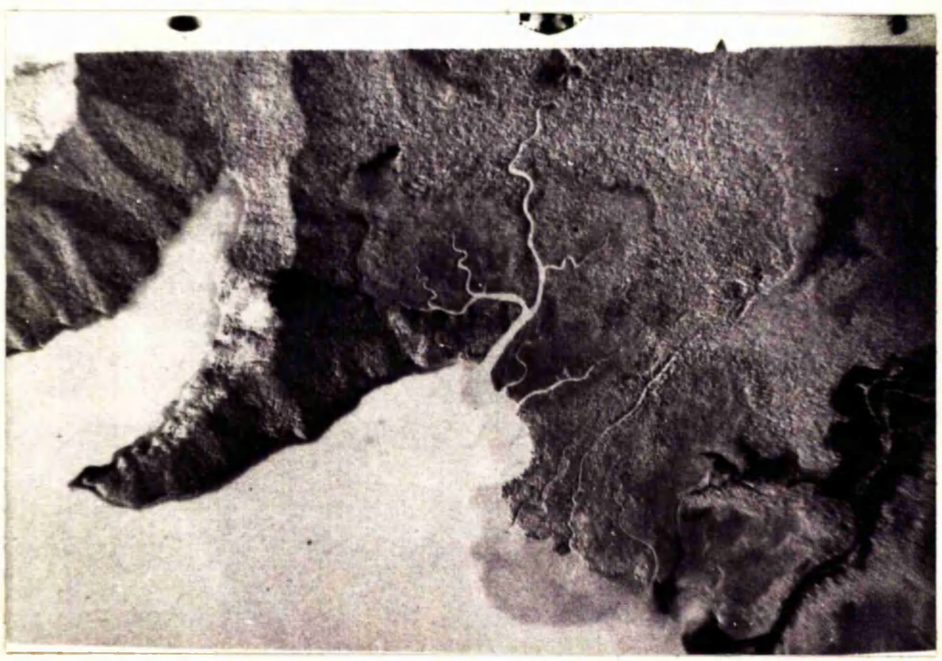
CLASS	SYMBOL	
MANGROVE FOREST HUTAN PAYAU		Hm
SWAMP FOREST HUTAN RAWA		Hs
RIVERBANK VEGETATION WITH *CASUARINA EQUISETIFOLIA* HYDROPHYLOUS FOREST		Hg
GRASS PLAINS AND SHIFTING CULTIVATION ALANG - ALANG		GA/La
LAKE DANAU	Wd	Wd
DRY DECIDUOUS FOREST ~ LOWLAND MONSOON FOREST HUTAN MUSIM		Hd
HIGH ALTITUDE FOREST		Hc
ALLUVIAL PLAIN FOREST EDAPHIC FOREST		He

PHOTOGRAPH 2

AERIAL PHOTOGRAPH OF THE
MOROWALI RIVER DELTA

PHOTOGRAPH 3

AERIAL PHOTOGRAPH OF THE RANU RIVERMOUTH



acquisition for analysis. Due to lengthy delays in obtaining the CCT from EROS, preliminary experimental processing was carried out utilising the negatives, which were also obtained from EROS.

The aerial photographs which were available for a small part of the study area, were of less than 10 per cent cloud cover. They were flown in 1972 by KLM Aerocarta for the Indonesian mining company, P T Indochrome, for preliminary survey of the area for potential open-cast chromite mining. These photographs only covered the southern part of the area.

4.2 Processing of the Data

Before the arrival of the CCT, preliminary experimental processing was carried out after digitizing the negatives under a television camera. The processing was carried out at RAE Farnborough, on the Space Department's IDP 3000 facility.

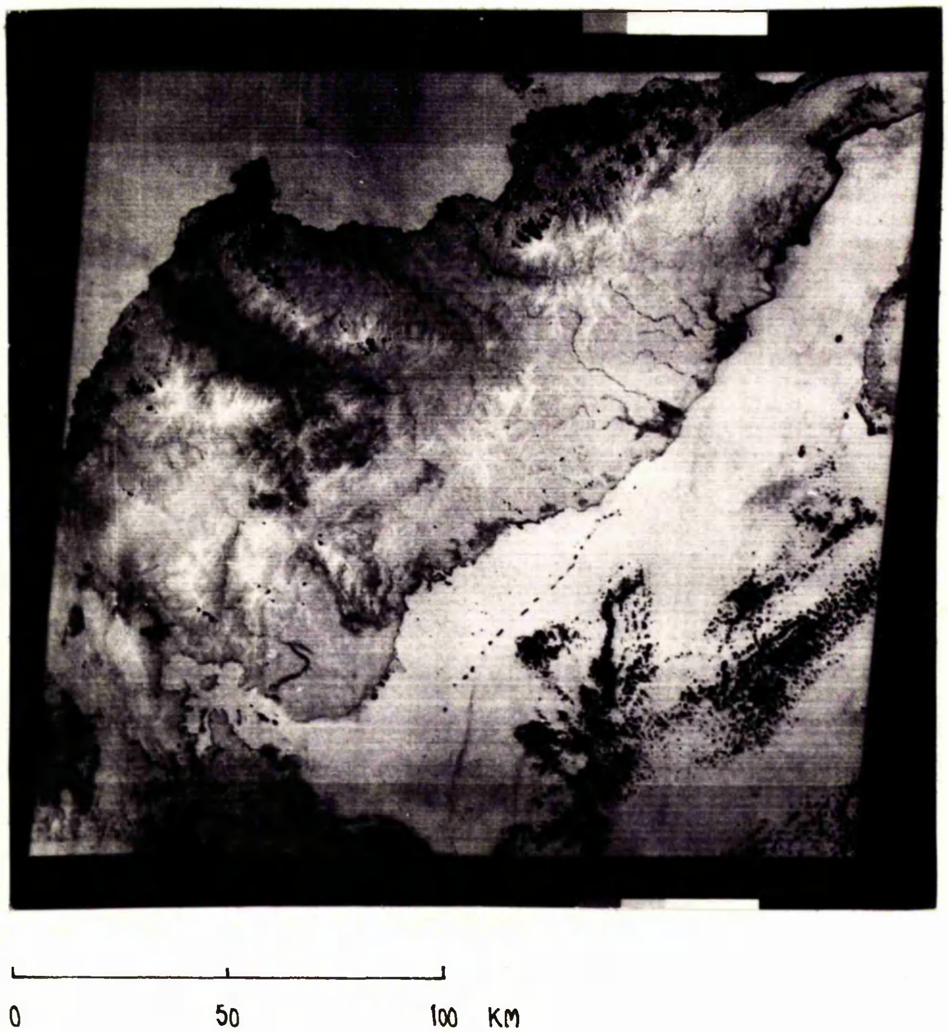
Band 4 was scanned under the television camera, and stored on tape. Band 5 was then scanned, followed by band 7. Before scanning subsequent bands, registration was carried out visually (on the CRT display), and as a result there was unavoidably quite a large degree of inaccuracy introduced, compared with digital registration.

MSS bands 4, 5, 6 and 7 are shown in PHOTOGRAPHS 4, 5, 6 and 7 on pages 71 - 74.

When all three bands had been digitized and stored

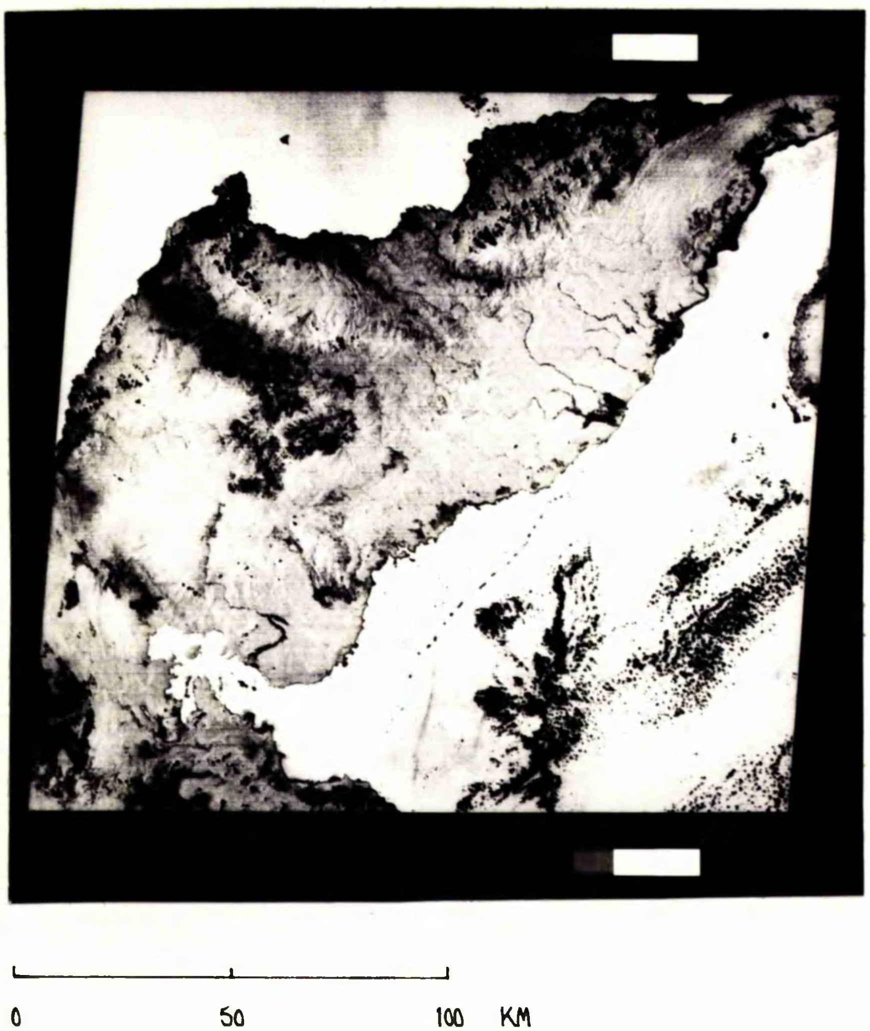
PHOTOGRAPH 4

PHOTOGRAPH OF 1:1 MILLION SCALE LANDSAT BAND 4



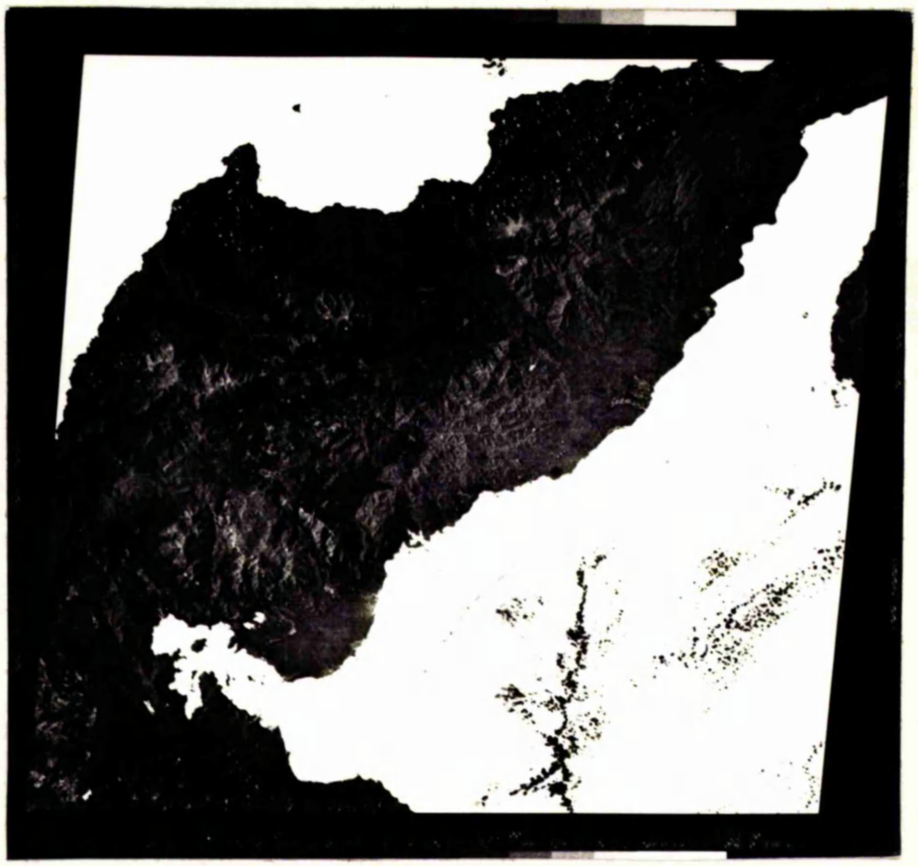
PHOTOGRAPH 5

PHOTOGRAPH OF 1:1 MILLION SCALE LANDSAT BAND 5



PHOTOGRAPH 6

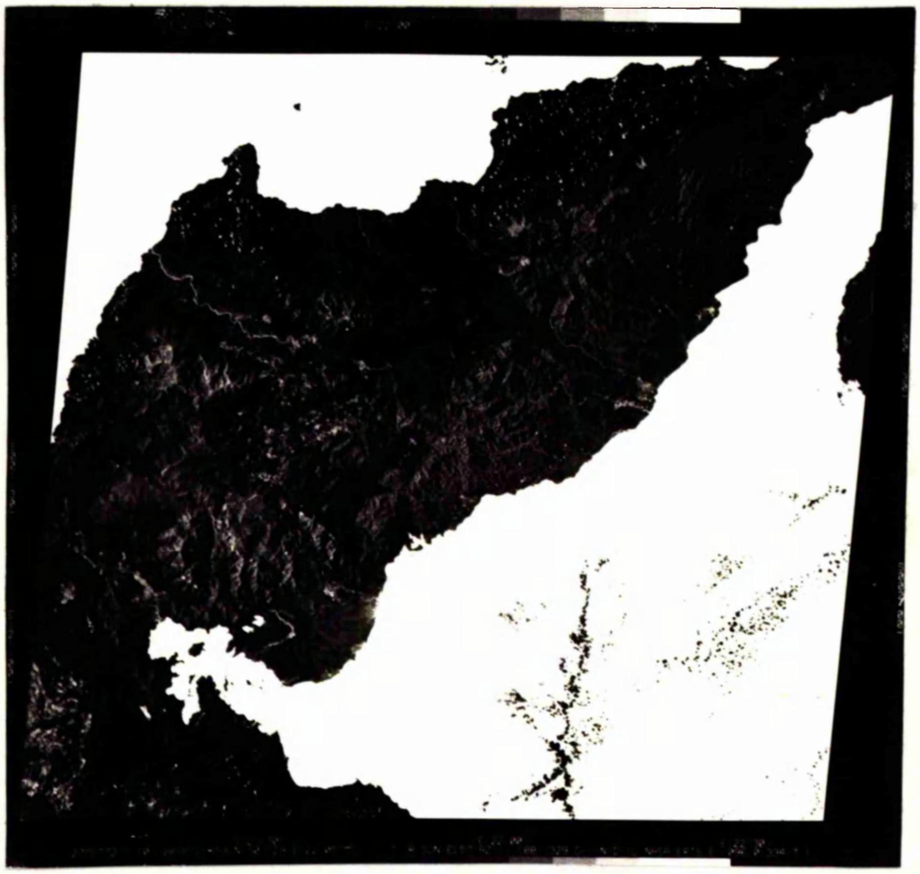
PHOTOGRAPH OF 1:1 MILLION SCALE LANDSAT BAND 6

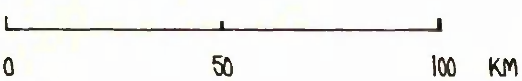


0 50 100 KM

PHOTOGRAPH 7

PHOTOGRAPH OF 1:1 MILLION SCALE LANDSAT BAND 7





on tape the processing was carried out in the same way as with a CCT. Taking a window out of the southern part of the study area, the bands were combined into a standard false colour composite, with band 4 on blue, band 5 on green and band 7 on red. A variety of ratios were attempted, starting with 5 substracted from 7, but with little extra differentiation. Ratios of bands 5 and 7 and 4 and 5 were also tried. A complex ratio of 4/7 on blue; 4/5 on red and 5/7 on green was tried and produced quite a reasonable result, and a classification was tried on an area of lowland monsoon forest.

Enhancement Techniques

Linear contrast enhancement (stretching) and edge enhancement were applied in the processing of the negatives to bring out the land cover differences. Contrast stretching modifies the pixel's brightness (intensity) independently of other pixel values while edge enhancement changes the value of the pixel as a function of the values of neighbouring pixels. Contrast enhancement enables the user to match or stretch a pixel's digital range associated with features of interest over the full dynamic range of the film, thereby maximizing the tonal variation. Edge enhancement boosts the brightness of a pixel whenever the signal from the pixel appears to be different (including an edge) from the average background as determined by averaging pixels within a box.

The linear enhancement programme transforms the original Landsat data into a new data (image) range specified by the user. Information on the original image is obtained by viewing frequency histograms.

The linear enhancement programme transforms the user specified input data range into a data file having a new data range with corresponding bounds specified by the user. This programme was implemented on the IDP 3000. The original Landsat data can easily be derived from the histograms. The user must be careful with this stretch because if the spread of the input data is very small, the image can be over-stretched - that is, the contrast increased so much that is results in a blocky pattern (ie a small range of input values when re-assigned to output values may create large gaps in the output grey tones or colours).

Edge enhancement is a two-dimensional high-pass filtering programme used to generate images with enhanced linears. High frequencies are represented by rapid changes in brightness over a few pixels. High frequencies can be enhanced with a high-pass filter and low frequencies with a low-pass filter. Most linears portrayed on images are comprised of high frequencies.

Spatial filtering adjusts the brightness of an individual pixel as a function of the brightness of neighbouring pixels.

Following this some rotations in colour were attempted using green/blue; red/blue and red/green. These experimental processes were then applied to the northern part of the study area.

There were however severe problems with using the film negatives in this way, in that they were inaccurately registered onto each other. Over areas of water, especially the coastal and Ranu lakes areas, there were problems with CRT screen flaring. With inaccurate registration of the bands digital processing as attempted here was found to be unsatisfactory. Bearing these limitations in mind it was decided to use the CCT for this study.

With the CCT for the 27th of October 1972 it was possible to begin digital computer processing of the data. However because of the shortage of time prior to field work it was not possible to get the desired quality of hard copy for field checking.

From the whole image a subscene of the southern part was extracted and displayed. From this subscene a window of 171 x 171 pixels was extracted and displayed in the top left of the screen (showing every other pixel and every scan line). With this sample window, some digital processes were carried out in order to attempt to optimise the data for interpretation of vegetation/ land cover boundaries.

To start with simple ratios were tried. Taking first band 5/7 then 6/7 (not very good) then 4/7 (quite good) and finally 5/6 (quite good).

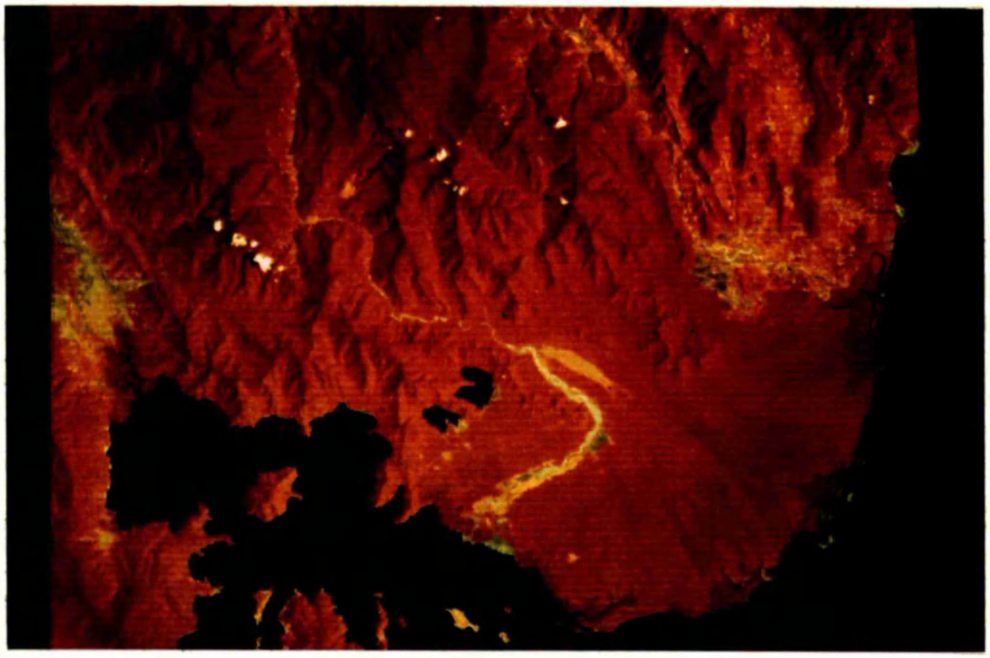
Following this, intensity normalised ratios were attempted, taking first 4+5+6+7/4 (no extra differentiation apparent) then 4+5+6+7/5 (no improvement) then 4+5+6+7/6 (again no improvement) then 4+5+6+7/7 (not satisfactory).

Next some optimisation processes were applied to a standard false colour composite with band 4 on blue, band 5 on green and band 7 on red. This was optimised three times, applying maximum linear stretch each time (finding maximum likeness; using an area of mangrove forest). This result was then rotated with colour, first taking green/blue then red/blue, then red/green. This produced an image differentiating a number of different ground cover types.

A standard colour composite of 5, 6, and 7 was again tried, but this time using 5 on green, 6 on blue and 7 on red, producing quite a useful result. As band 4 suffered some rather bad striping, the omission of band 4 improved the result. This was then optimised three times, again applying maximum linear stretch each time (using maximum likeness on an area of mangrove forest). This was rotated with colour, using green/ blue, red/green and red/blue. The result of these manipulations is shown in PHOTOGRAPH 8 on page79 which was one of the two images used for field checking. (Unfortunately the hard copy used for field checking was not the desired end product, but consisted of

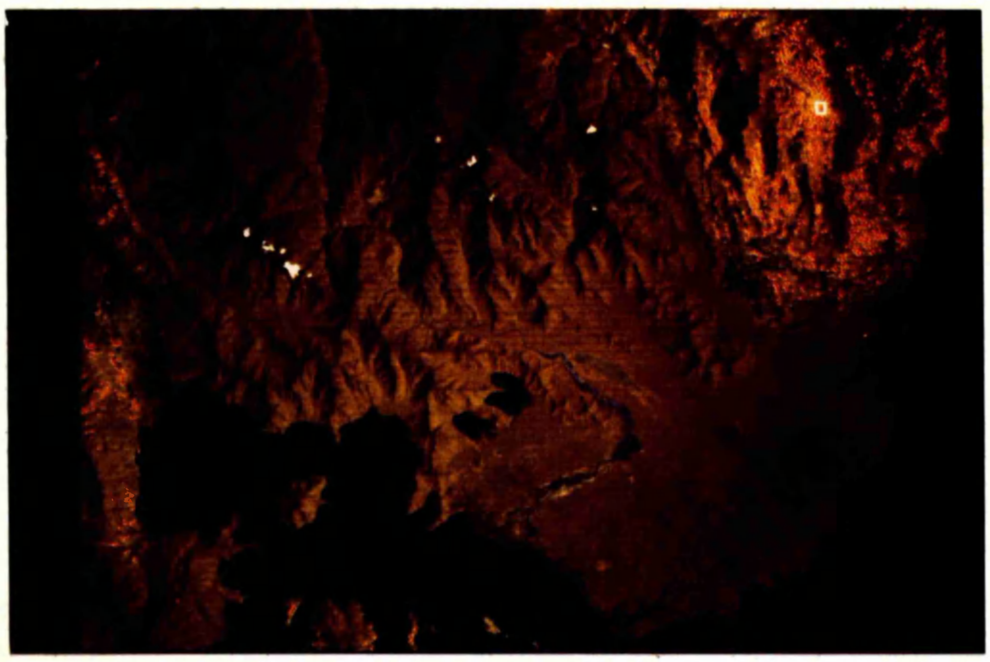
PHOTOGRAPH 8

PROCESSED IMAGE USED FOR FIELD CHECKING



PHOTOGRAPH 9

EXPERIMENTAL UNSUPERVISED CLASSIFICATION



0 10 20 30 KM

Cibachrome prints from 35mm transparencies of the CRT display - quick look hard copy. Although this type of hard copy is not geometrically accurate, the category differentiation is the same as the 70mm controlled negatives produced in the mechanical film writer directly from the digitally processed data .

With this display some experimental unsupervised classifications were tried out, in order to see how homogenous the ground cover reflectance was. An area of shifting cultivation and grassland in Tokala Atas was selected for this purpose. In addition an area of grassland/shifting cultivation was selected and classified. The result was displayed in an area in orange colour, to make it easily discernible from the subscene display, and is shown in PHOTOGRAPH 9 on page 79. Other classifications were attempted tentatively on the following areas: firstly on an area of upper montane forest to the north of the Ranu lakes. This classification was not particularly useful, as large areas of obviously different ground cover (eg coastal mangroves) were being falsely classified along with areas of hill forest. This included areas of mountain shadow, and some valley floors, and coastal areas.

Secondly, an area of valley floor was tentatively classified. The result of this classification was not satisfactory because a badly striped effect was classified and other areas were again falsely classified.

A sample window was then taken out of the subscene for further analysis and processing, as this would be the main area of field work, determined by the inaccessibility of the area and the lack of time for ground checking. The window extracted and displayed was of 86 x 86 pixels and covered the southern part of the proposed reserve. This southern part consists of the Morowali and Ula-Solato plains, including all the mangrove forest areas, the areas of shifting cultivation and grassland, and the area of swamp forest.

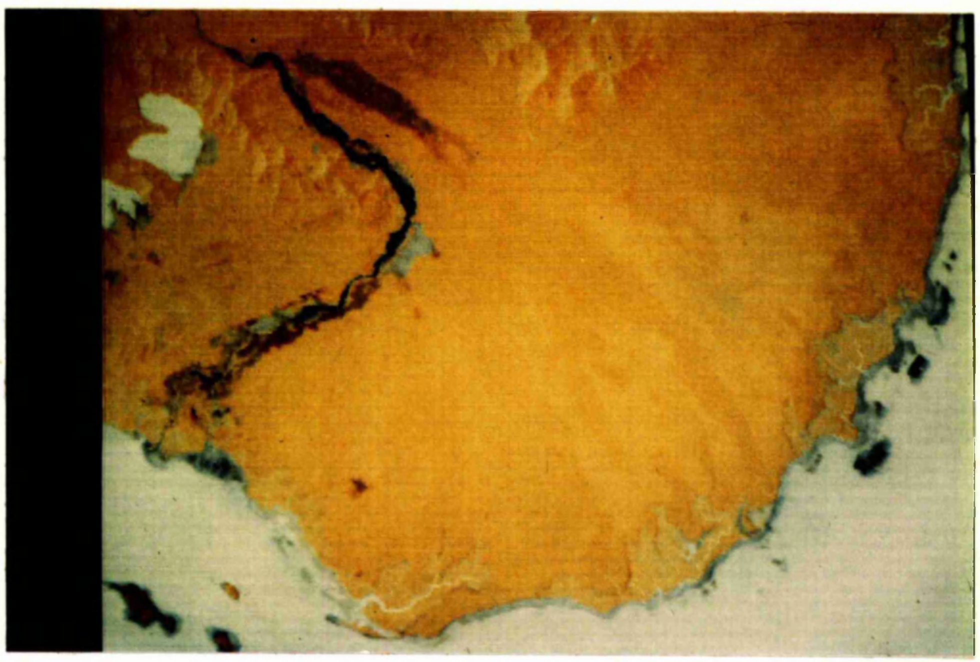
Band 7 was omitted because of bad striping, and a colour composite was made using 4 on green, 5 on blue and 6 on red. This produced quite a good result, and so a tentative classification was attempted on an area of homogeneous looking mangrove forest near the mouth of the Morowali river. In the event there proved to be significant differentiation within the mangrove areas and between the mangrove areas further north towards the Solato river.

Rotations in colour were tried next using first red/green than green/blue followed by red/blue. The result was useful and showed differentiation between ground cover types quite well. This image was also used for ground checking (Cibachrome enlargement from Ektachrome transparency taken off the CRT display) and is shown in PHOTOGRAPH 10 on page 82

The data processing of the satellite data prior to field work provided two Cibachrome prints; the use

PHOTOGRAPH 10

PROCESSED IMAGE USED FOR FIELD CHECKING



0 10 20 KM

of aerial photographs and ground checking of sample areas were to be the next steps.

4.3 Preliminary Classification

The preliminary vegetation/land cover classification was interpreted from the image shown in PHOTOGRAPH 10. This was a visual interpretation and was assisted by reference to the aerial photography. The land cover over the area was classified according to the vegetation classification proposed and outlined by Malingreau (1977), and is discussed in section 5. The preliminary vegetation classification is shown in FIG 8 on page 84.

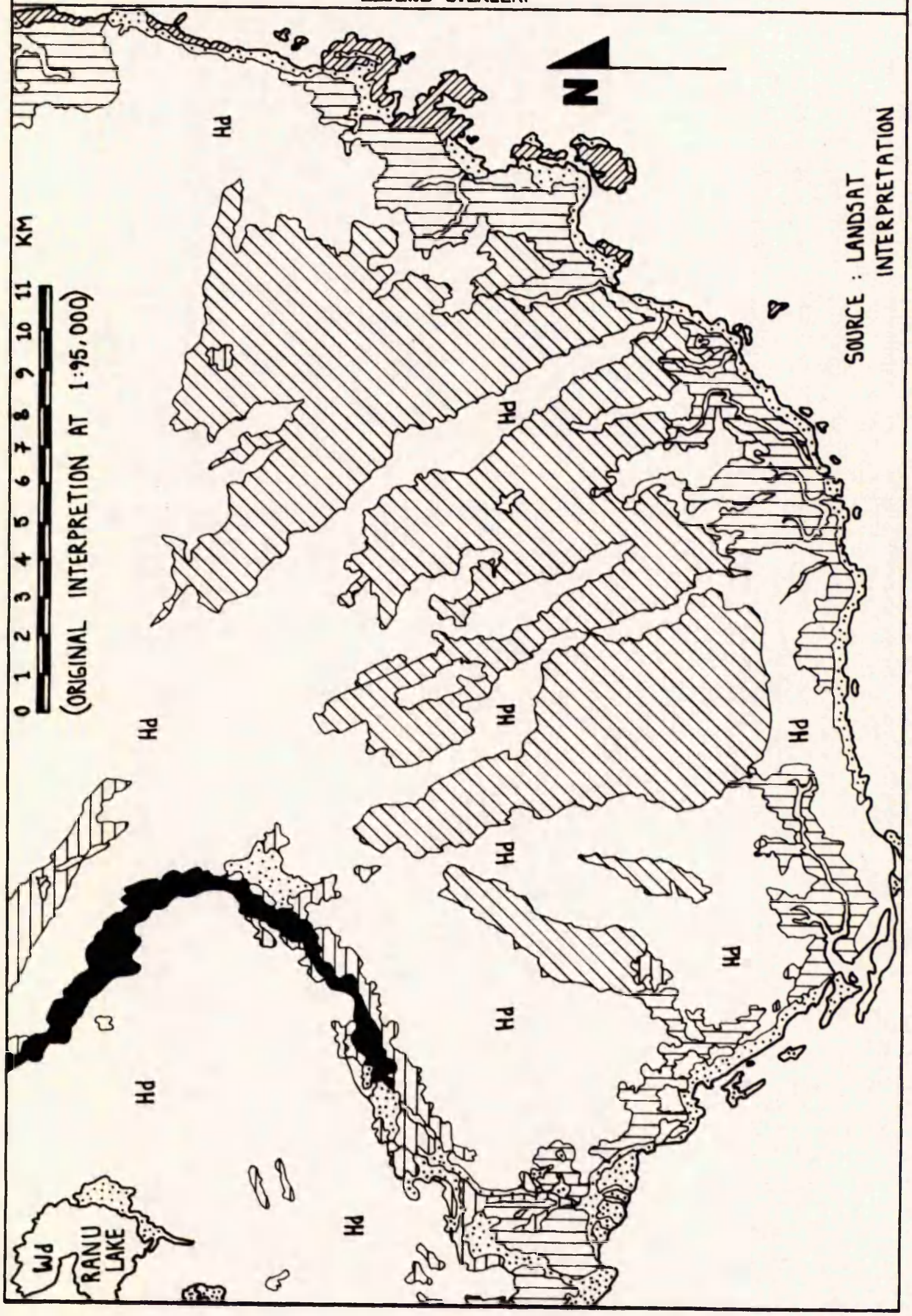
4.4. Ground Checking

With a non-geometrically corrected image in the field location is always a problem, particularly in remote areas of dense jungle and mangrove forest. Because of this, inaccessibility and a time constraint, it was not possible to use any sort of random sampling frame. Ground checking was carried out on a transect basis, utilizing where possible old transect lines which had been cut by a mining company for mineral exploration. These old transect lines had been accurately plotted by theodolite traverse by the mining company, and so location was not a problem along these lines. FIG 9 on page 86 shows the location of transect lines which

FIG 8

PRELIMINARY VEGETATION CLASSIFICATION

LEGEND OVERLEAF



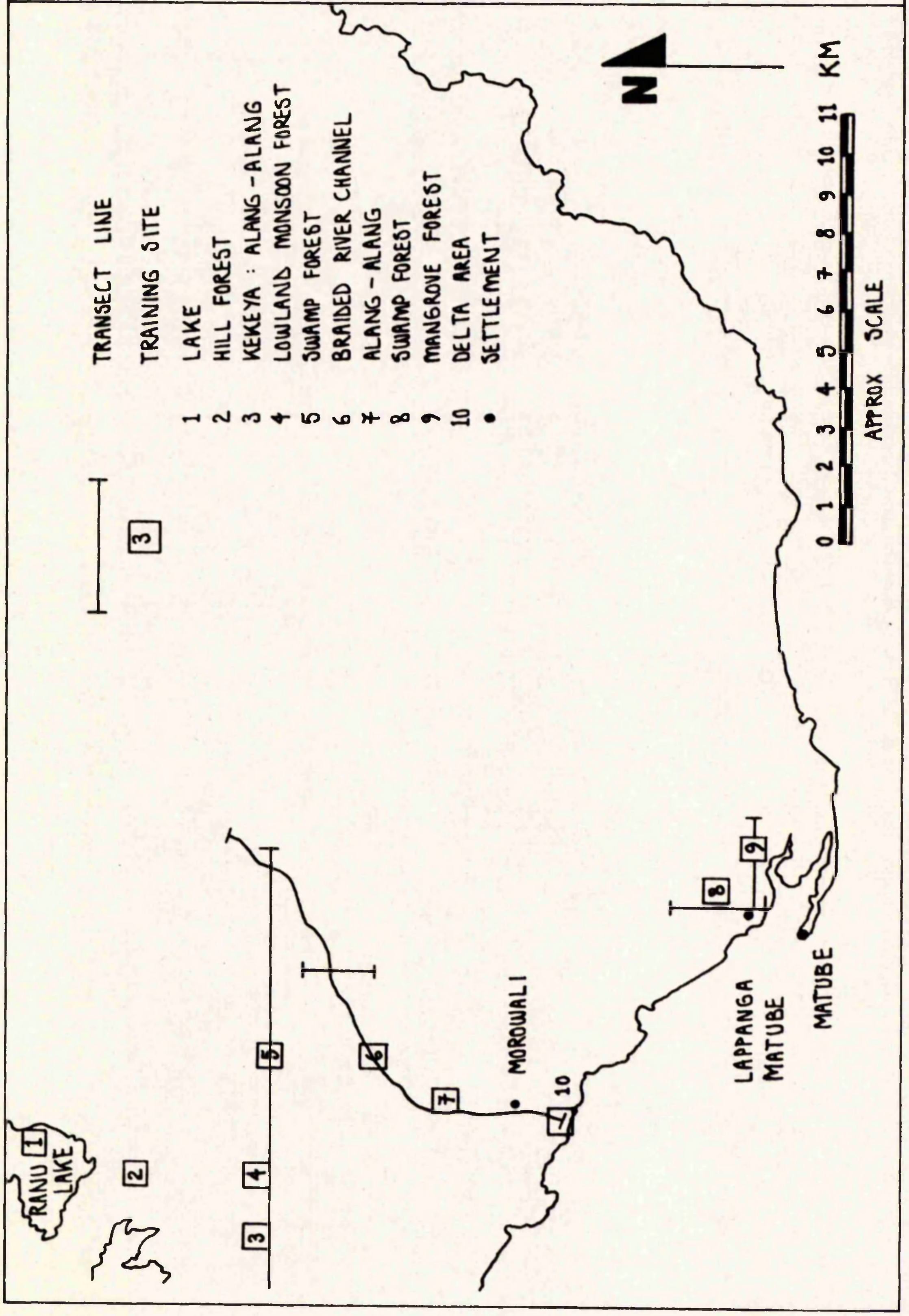
LEGEND FOR FIG 8
PRELIMINARY VEGETATION CLASSIFICATION

N

CLASS	SYMBOL	
MANGROVE FOREST HUTAN PAYAU		Hm
SWAMP FOREST HUTAN RAWA		Hs
COASTAL SAND ~ BEACHES ~ DUNES		Dk
CORAL		
GRASS PLAINS AND SHIFTING CULTIVATION ALANG - ALANG		GA/La
RIVERBANK VEGETATION WITH <u>CASUARINA</u> <u>EQUISETIFOLIA</u> HYDROPHYLOUS FOREST		Hg
LAKE DANAU	Wd	Wd
DRY DECIDUOUS FOREST ~ LOWLAND MONSOON FOREST HUTAN MUSIM	Hd	Hd

FIG 9

LOCATION OF TRANSECT LINES AND TRAINING SITES



were used for ground checking and the training sites used for experimental supervised classification.

The first transect line for ground checking was chosen in the Matube area of the Morowali Plain near to Tanjung Bea. This was chosen because it follows one of the old P T Indochrome transect lines, and thus had been located accurately. The transect line passes through, first lowland monsoon forest, then swamp forest, then mangrove forest, then areas of sand and mud and a village area of shifting cultivation and grassland with sparse settlements. The area under consideration can best be seen in FIG 10 on page 88 which shows the vegetation/ land cover in this area as interpreted from aerial photographs after field checks.

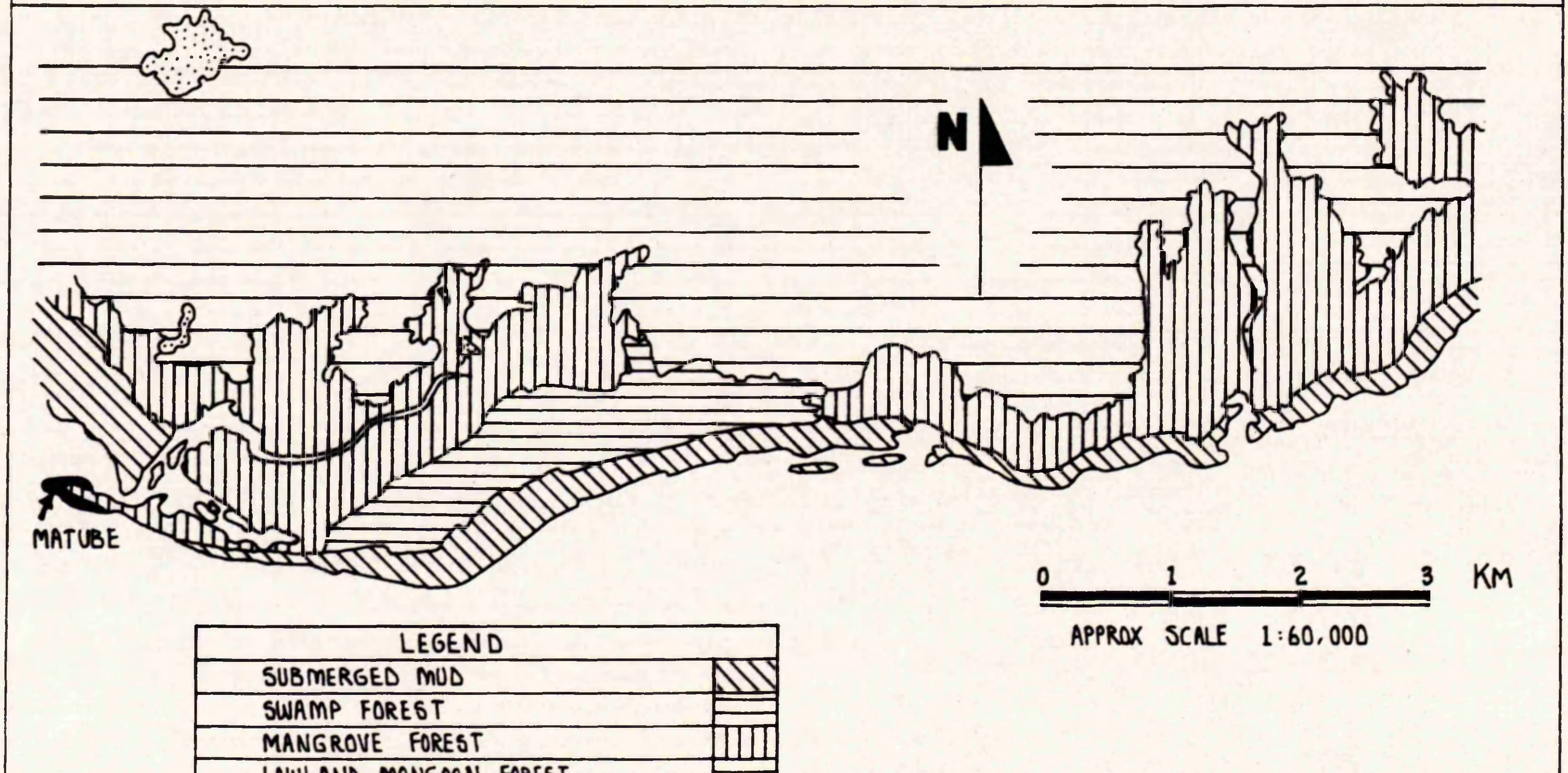
Vegetation types which the transect passes through are illustrated in the following PHOTOGRAPHS: No 11 on page 89 lowland monsoon forest; No 12 on page 90 swamp forest; No 13 on page 91 mangrove forest; No 14 on page 91 village/shifting cultivation (Lappanga Matube).

Lappange Matube

The first transect was due north from the re-settlement village of Lappanga Matube. This passed through the mangrove forest, shifting cultivation and into lowland monsoon forest. Checks on the species dominancy were made every 200 m on a 10 m quadrat basis. This was made accurate by reference to the survey pegs that the mining company had left at 100 m intervals.

FIG 10

VEGETATION MAP OF THE MATUBE AREA



SOORCE : AIR PHOTOGRAPH INTERPRETATION

PHOTOGRAPH 11

LOWLAND MONSOON FOREST

PHOTOGRAPH 12

SWAMP FOREST

PHOTOGRAPH 13

MANGROVE FOREST

PHOTOGRAPH 14

LAPPANGA MATUBE

Starting at the coastal area the mangroves were dominated by Rhizophora, R. Mucronata and Sonneratia alba. Moving inland the dominancy changed to a mixed Rhizophora and Bruguiera zone. Further away from the coast this zone developed into a drier zone with Lumnitzera and Acrostichum aureum and Pandanus and Casuarina Equisetifolia dominance, with an abundance of ferns on the ground level. The area of mangroves was established as a training site for future supervised computer classification. FIG 9 on page 86 shows all the transect lines and training sites used in the ground checking.

The areas of shifting cultivation were limited in area and consisted of rice ladang and other subsistence crops (sweet potatoes, bananas). Grassland areas consisted of alang-alang grassland (Imperata cylindrica).

Casuarina Equisetifolia is again found along the edge of the alang-alang areas in abundance and in places virtually in complete dominance. The monsoon forest areas which followed the shifting cultivation area were dominated by Shorea and Dipterocarpus and Vatica, followed by Pangium and Diospyros mixed evenly. Along areas of small inlets and tributary streams Casuarina Equisetifolia dominated.

The second transect taken from Lappanga Matube was due east from the village area, and passed through swamp forest into mangrove forest, and some areas of coastal submerged mud and sand.

The swamp forest was mostly dominated by Calophyllum and Pandanus. Some Casuarina Equisetifolia was also noted in this area. From the swamp area there is a transition zone into the mangrove forest with Pandanus and Casuarina Equisetifolia. In the mangrove area the coastal zonation is similar to that encountered in the southern part of the first transect, due north from the village of Lappanga Matube. There were also areas along the coast with submerged mud and sandbanks.

The data collected from the transects were plotted on the preliminary vegetation map (FIG 8 on page 84 A few minor corrections were necessary, but approximately 90 per cent of the original classification was accurate. Because it was not possible to use a random sample frame of any kind, statistical accuracy levels could not be computed.

Morowali river area

PHOTOGRAPH 2 on page 69 shows part of an aerial photograph of the Morowali river delta area.

With this it was possible to locate a small area in which to conduct a detailed ground check, involving as many different vegetation/ground cover types as possible within one area. The area chosen was also to serve as a training site for future supervised computer classification.

The area of the Morowali river delta was selected to facilitate ground checking along the Morowali river inland, where large areas of grassland exist. No transect lines were in existence in the area and it was not possible to cut paths over the distances required. A transect was taken along the riverbank inland following an old Dutch track, which runs from Morowali to Tokala Atas. This passed through submerged sand and mud, mangrove forest, areas of shifting cultivation and grassland, lowland monsoon forest and swamp forest.

In the delta area the mud was exposed in parts and sand was submerged up to two feet in places. On reaching the coast, the mangrove formation was again similar to the two previously mentioned. This held true with the exception of Casuarina Equisetifolia which was distributed as large fully grown trees and areas of seedlings. Seasonal flooding could possible account for this distribution. Around riverbank areas Casuarina Equisetifolia was in full dominance, growing on the sandy, braided inter-channel areas. PHOTOGRAPH 15 on page95 shows braided channel areas along the Morowali river.

The areas of grassland were dominated by alang-alang (Imperata cylindrica) with only small areas of rice ladang and sparsely located settlements. A transect of 2km   ength was made perpendicular to the river channel at one point (see FIG 9 for location), from the lowland monsoon forest, through alang-alang and Casuarina Equisetifolia dominated vegetation.

PHOTOGRAPH 15

BRAIDED CHANNEL OF THE
MOROWALI RIVER 8KM UPSTREAM

PHOTOGRAPH 16 on page 97 shows this area, with cobble-beds extending away from the river bank.

A transect due west from the Morowali river was taken through the lowland monsoon forest and swamp forest areas. In the monsoon forest the dominancy was fairly consistent, being: Dipterocarpus, Shorea and Vatica with an even distribution of Diospyros and Pangium. Along the river bank areas Dillenia was noted, along with Casuarina Equisetifolia. Dillenia and Casuarina Equisetifolia were also found in abundance along the alang-alang edges of the lowland monsoon forest.

In the swamp forest areas the dominancy was mainly Pandanus and Calophyllum. A training site was established in this swamp forest area for future supervised classification.

Ranu Rivermouth Area

A brief survey was carried out in the mangroves at the mouth of the Ranu river, to test for similarities with areas already surveyed. The formation turned out to be very similar to the previously mentioned formations at Lappanga Matube and Morowali, with the exception that Sonneratia alba was absent. This was due to the formation being younger and less well developed.

Kekeya Surrounds

The area of alang-alang grassland at Kekeya was

PHOTOGRAPH 16

COBBLE BEDS ALONG THE MOROWALI RIVER

identified as a training site for future supervised computer classification. PHOTOGRAPH 17 on page 99 shows the Kekeya clearing. The clearing is dominated by alang-alang with no shifting cultivation, but sparsely distributed shrubs and bushes.

An area of hill forest was also visited near to the Kekeya clearing. The main species in the hill forest were Pangium, Shorea and Diospyros. It was noted that the diameter of trees was generally larger (60-70 cm generally) than in the lowland monsoon forest.

4.5 Conclusions

Although the methodology discussed in the preceding section has proved to be reasonably accurate when checked with existing maps, the method of ground checking could be modified. The use of light aircraft at low altitude taking 35 mm photographs at timed intervals along plotted transects, would have greatly improved the accuracy of the ground checking. Such a technique would facilitate the checking of even the most remote areas.

Final computer processing was carried out after the ground checking, and is described in detail in Chapter 5.

No overall quantitative assessment of the accuracy of the survey was made, but comparison of the classification with the available aerial photography, and ground

PHOTOGRAPH 17

KEKEYA CLEARING

checking led to the conclusion that the overall classification accuracy was somewhere in the region of 85 per cent. Some areas of misclassification of forest types were noted and corrected after ground checking. These areas tended to be where the incidence of terrain shadow was pronounced.

The speed at which surveys of this type can be performed demonstrates the usefulness of Landsat data for the rapid survey of large areas when limited detail with respect to vegetation type and structure is acceptable.

CHAPTER FIVE

FINAL COMPUTER PROCESSING OF THE IMAGERY

Introduction

After the field work had been completed, the final computer processing of the imagery was carried out, once again on the IDP 3000 facility at RAE Farnborough.

The areas located and noted in the field as training sites (FIG 9 on page86) were classified one by one in order to attempt to produce a computer classified map.

Supervised Computer Classification

Starting with the entire scene displayed on the CRT, a window of 86 x 86 pixels was extracted and displayed in place of the entire scene. This window covered the southern part of the proposed Morowali reserve. Bands 4, 5, and 7 were used in a standard colour composite, using blue, green and red respectively. Rotations in colour were applied to this using first red/green then green/blue followed by red/blue. As had been discovered during the processing prior to field work, this manipulation provided fairly good differentiation between the different ground cover types.

The supervised classification was applied by moving a cursor to the required area and size. The area of hill forest near the Kekeya clearing was classified first.

This classification was not particularly useful, as large areas of different ground cover were also classified as being the same. These were mainly coastal mangroves, but also included mountain shadow areas.

Second an area of alang-alang grassland at Kekeya was classified (PHOTOGRAPH 17 on page 99). This produced another false classification which included areas of upper montane forest. The differentiation of the clearing, and other grassland areas, was better on the processed imagery than with the classifiction applied.

The area of mangrove forest at Lappanga Matube which had been identified as a future training site was then classified. This produced quite severe 'computer confusion', and showed vast areas of hill forest and mountain shadow as being the same as the magrove forest. This was because the mean radiance values of the mangrove areas and of the hill shadow areas were very similar in all four spectral bands.

Because of this unsuccessful supervised classification it was decided to interpret the final map from the processed imagery without the computer classifications applied. This was the procedure adopted for the preliminary vegetation classification.

The same procedure was followed for the northern part of the Morowali reserve. However, without any ground checks in the northern area, and with the knowledge of the problems of automatic computer classification in such areas, the processing was completed more quickly.

The processed imagery was then transferred through a mechanical film writer onto 70mm controlled negatives of bands 4, 5 and 7.

5.3 Colour Additive Enlarging and Printing of the Hard Copy

The 70mm controlled negatives produced after the computer processing were enlarged in the Spembly colour additive enlarging system at RAE Farnborough.

This is a standard colour additive enlarging system with three colour enlargers specially adapted for this purpose. The central enlarger is moved up to the required height, to reach the required scale. The side enlargers are then raised to the required height to match the scale. The negatives are inserted into the enlargers, bands 4, 5 and 7 from left to right for convenience. Blue is then projected through band 4, green through band 5 and red through band 7.

The centre enlarger is used as the control for registering the other two enlargers. This is achieved by switching on the centre enlarger and first the left enlarger. The left hand enlarger is then adjusted along the X axis and the Y axis, and a third rotation adjustment, by the use of the micrometer adjustment screws, until the required accuracy of registration is achieved. The procedure is then repeated with the right hand enlarger.

Following the accurate registration of all three bands onto the baseboard, exposure tests are taken. After determining the correct exposure, with colour brilliance set on full, the colour balance is manipulated to achieve the required balance and a balance on the grey scale wedge alongside the image. Printing is then carried out onto Cibachrome paper and processed in the normal Cibachrome process. The results of this are shown in PHOTOGRAPHS 18 and 19 on page 105.

From the same controlled 70mm negatives, black and white enlargements were produced to the scale of 1:100,000. Contact prints are shown in PHOTOGRAPHS 20, 21 and 22 (northern area) on page 106 and 23, 24 and 25 (southern area) on page 107.

5.4 <u>Final Interpretation and Classification</u>

The final interpretation was carried out at the final scale of 1:100,000 on the black and white prints, utilizing all three bands.

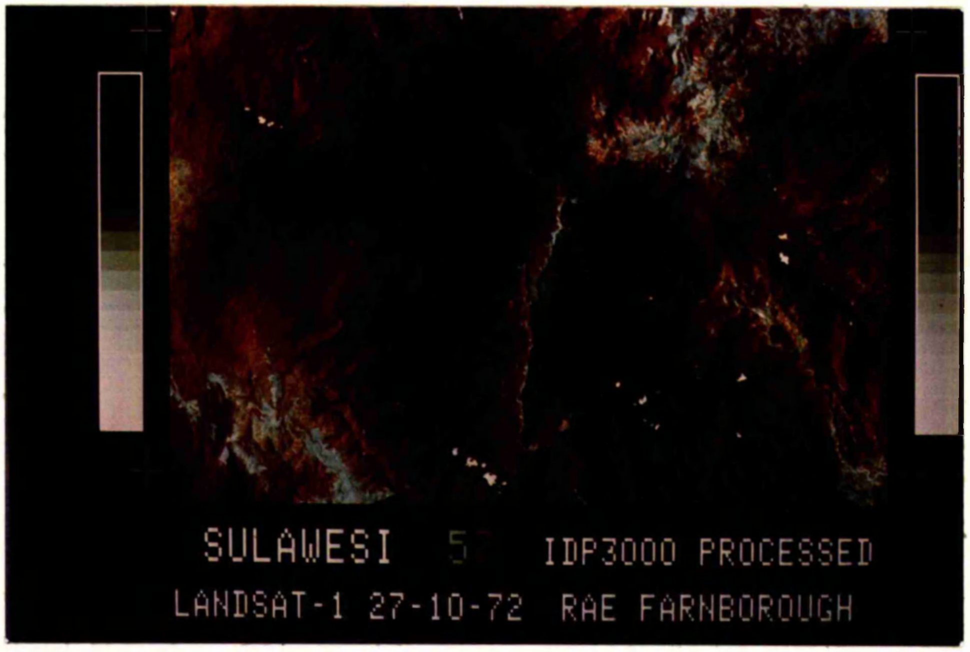
Band 7 was used to delineate the coastal and lake bounaries. The mangrove areas were also delineated on band 7 and a combination of band 7 and band 5 was used to delineate the swamp forest areas. The interpretation was carried out on a transparent plastic sheet which was transferred from one band to another to gain all the information.

Band 4 was especially useful for the grassland

PHOTOGRAPH 18

COLOUR ADDITIVE CIBACHROME PRINT

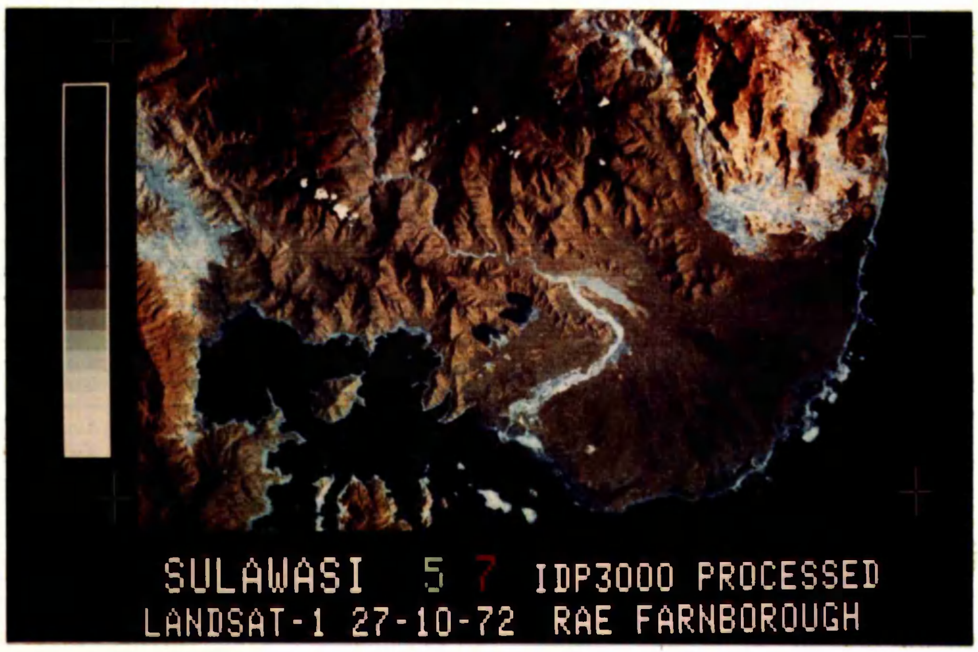
NORTHERN AREA



PHOTOGRAPH 19

COLOUR ADDITIVE CIBACHROME PRINT

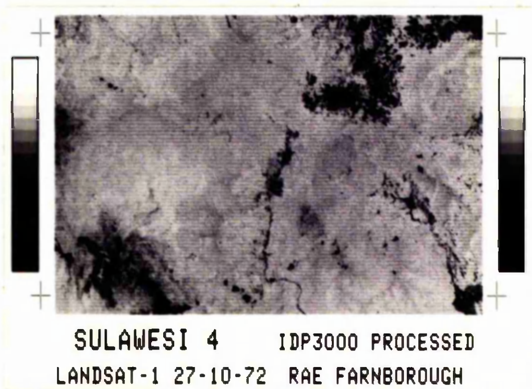
SOUTHERN AREA

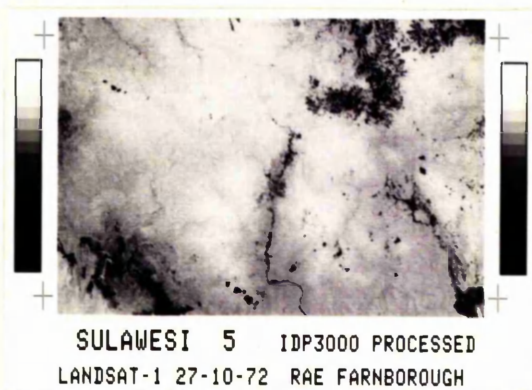


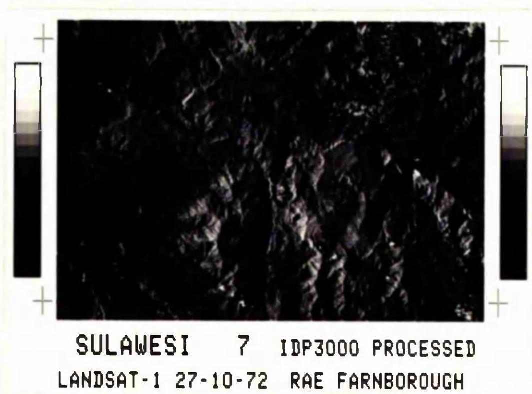
0 10 20 30 KM

PHOTOGRAPHS 20, 21, 22

CONTROLLED 70mm USED FOR ENLARGEMENT TO
1:100,000 SCALE - NORTHERN AREA BANDS 4, 5, AND 7



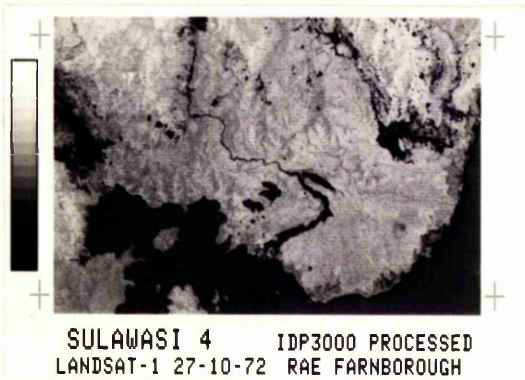




0 25 50 KM

PHOTOGRAPHS 23, 24, 25

CONTROLLED 70mm USED FOR ENLARGEMENT TO
1:100,000 SCALE - SOUTHERN AREA BANDS 4, 5, AND 7



0 25 50 KM

and shifting cultivation areas. Band 5 was used for delineating the areas of coastal coral and sand and mud deposits. Band 5 was also used for delineating the areas of hill and mountain forest, as the relief was less apparent and the separations were good.

PHOTOGRAPH 26 on page 109 shows the final vegetation map, a copy of which is inside the back cover. Certain differences in areas delineated may be apparent between the preliminary vegetation classification and the final map. The main cause of this discrepancy was the improved quality and the enlarged scale of the imagery used for the final interpretation, and the corrections which were applied following ground checking.

The map adds to the list of maps available for this area, and presents what is believed to be the most accurate of its kind to date, because of the quality and scale of the digitally processed remotely sensed data, and the extent of ground checking.

5.5 The Vegetation Classification

The vegetation classification employed was one proposed by Malingreau (1977). The classification was a land cover/ land use classification proposed for use with remotely sensed data in Indonesia. This classification was adopted because a uniform land use classification presents many advantages, especially in a country like Indonesia where numerous land resources surveys were being carried

PHOTOGRAPH 26

VEGETATION MAP OF THE MOROWALI AREA

out. An important consequence of the adoption of a uniform land use legend is that it will facilitate the introduction of standardised land evaluation procedures (FAO, 1976), because as indicated by Vink (1975), "land use surveys are of fundamental importance for land development planning. Only when all aspects of the present situation are known, can further developmental plans be made."

There is no ideal classification of land cover/ land use which will satisfy the needs of all surveyors. Each of them has particular features of interest which will emphasise some details more than others. It is, therefore, very important to establish a standard strategy for approaching the problems of developing a land use classification. As indicated by Simonett (1974), "Such a strategy should permit each researcher the latitude to organize and classify land use data in accordance with his needs and at the same time maintain some degree of compatibility".

The framework for land cover/land use classification presented in Malingreau's paper can be used at levels ranging from a broad reconnaissance land resources survey scale 1:50,000 to a semi-detailed reconnaissance one 1:100,000 - 1:50,000. More detailed surveys would require further subdivision of some lower catergories. An important advantage of an hierarchic classification is that classes can easily be aggregated under the heading of a higher ranking category. This is especially useful for a general (regional or national) compilation purposes performed as the base for more detailed local inventories.

The use of remote sensors for collecting land cover/land use data has also some bearing on the classification adopted. A first requirement which is sometimes put forward is that the classes should be consistently identifiable on the imagery to be interpreted.

The hierarchical nature of Malingreau's proposed scheme offers noteworthy advantages for image interpretation; indeed if in a specific instance a feature cannot be identified at a given level it can be placed in a category immediately above or higher, at which level it is easier to recognize. This procedure helps to avoid blanks or misclassifications. For example, if it cannot be decided whether an area is under intermittent or under permanent field crop cultivation, it can be placed, pending field check or further analysis, in the upland crop category which is relatively easy to identify. Generally speaking the classes of a higher level are more easy to identify and delineate than those of a lower level, on any type of imagery.

The Proposed Classification of Land Cover/Land Use for Indonesia

The classification consists of two parts:

1. A hierarchic listing of the classes with a connotative symbol (letter symbols are used, although numerals may

present advantages for computer processing).

2. A short description giving the extent of the class, its characteristics and prominent features.

The highest level of categorization mainly refers to the type of land cover and the lower level refers more to the types of land utilization. The classification is elaborated more for some land cover/land use classes than for others; this is because Malingreau considered them more important as agricultural resources.

Two additional columns are added to the classification; they give respectively the nature of land cover (S) associated with the units (S for soil, W for water and V for vegetation), and an indication of the permanent (P) or transient (T) nature of their spectral characteristics. These latter parameters are of importance when selecting the most appropriate platform/image type and date of acquisition for the inventory of specific classes. The land cover/land use classification is shown in TABLE 4, on page 113 TABLE 5 on page 119 shows definitions of land cover/land use classes.

TABLE 4

LAND COVER/LAND USE CLASSIFICATION

Symbols	Classes		Possible land cover W water S Soil B vegetation	Permanent (P) transient (T) spectral Characteristics
W	1. Water			
Wt	1.1. Water bodies			
Wk	1.1.1. Pond	kolam	W/-/-	P
Wd	1.1.2. Lake	danau	W/-/-	P
Wp	1.1.3 Reservoir	persediaan air	W/-/-	P/T
Wi	1.1.4 Fish pond			
Wik	1.1.4.1. Fresh water	kolam	W/-/-	P/T
Wit	1.1.4.2. Brackish water	tambak	W/-/-	P/T
Wb	1.1.5. Coastal formations bays and estuaries		W/-/-	P
Ws	1.2. Water courses			
Ws	1.2.1. Stream (drainage network)	sungai	W/-/-	P/T
Wc	1.2.2. Irrigation and drainage canals	saluran	W/-/-	P/T
V	2. Vegetated area			
Vc	2.1. Cultivated area		W/S/V	P/T
Vcp	2.1.1. Permanently cultivated area		W/S/V	P/T
S	2.1.1.1. Sawah		W/S/V	T

TABLE 4

LAND COVER/LAND USE CLASSIFICATION

Symbols	Classes	Possible land cover W water S Soil B vegetation	Permanent (P) transient (T) spectral Characteristics
Si	2.1.1.1.1. Irrigated *sawah pengairan*	W/S/V	T
Si2	a. Continuous rice	W/-/V	T
Sip	b. 1 crop of rice + palawija	W/S/V	T
Sil	c. 1 crop of rice + fallow	W/S/V	T
Sic	d. Sugar cane producing area	W/S/V	T
Sr	2.1.1.1.2. Rainfed *sawah tadah hujan*	W/S/V	T
Srp	a. 1 crop of rice + palawija	W/S/V	T
Srl	b. 1 crop of rice + fallow	W/S/V	T
Sp	2.1.1.1.3 Tidal rice *pasang surut*	W/-/V	T
U	2.1.1.2. Upland crops-rainfed *tanah kering*	-/S/V	T
Ut	2.1.1.2.1 Field crops *tegalan*	-/S/V	T

TABLE 4

LAND COVER/LAND USE CLASSIFICATION

Symbols	Classes	Possible land cover W water S Soil B vegetation	Permanent (P) transient (T) spectral Characteristics
Ut	2.1.1.2.2. Mixed garden <u>kebun campuran</u>	-/-/V	P
Us	2.1.1.2.3. Horticulture <u>kebun sayur</u>	-/S/V	T
Ui	2.1.1.2.4. Intermittent cultivation	-/S/V	T
P	2.1.1.3. Homestead garden	-/-/V	P
	<u>pekarangan</u>		P
E	2.1.1.4. Estates <u>perkebunan</u>		
	2.1.1.4.1 Tree crops	-/-/V	P
Er	a. rubber <u>karet</u>	-/-/V	P
Ek	b. coconut <u>kelaoa</u>	-/-/V	P
Ec	c. coffee <u>kopi</u>	-/-/V	P
Eo	d. oil palm <u>kelapa sawit</u>	-/-/V	P
	e. others (ie. fruit trees)	-/-/V	P
	2.1.1.4.2. Bush and other crops	-/S/V	P/T
Et	a. tea <u>teh</u>	-/-/V	P
Eb	b. tobacco <u>tembakau</u>	-/S/V	P/T
	c. others		

TABLE 4

LAND COVER/LAND USE CLASSIFICATION

Symbols	Classes	Possible land cover W water S Soil B vegetation	Permanent (P) transient (T) spectral Characteristics
H_E	2.1.1.5. Small holdings of any of the above commercial crop	-/S/V	P/T
Gf	2.1.1.6. Forest garden	-/-/V	P
L	2.1.2. Shifting cultivation area ladang	-/-/V	P/T
Lh	2.1.2.1. in forest cover	-/-/V	P/T
La	2.1.2.2. in grass cover alang-alang	-/-/V	P/T
H	2.2. Non cultivated area	W/S/V	P/T
	2.2.1. Forest (closed forest)		
Hc	2.2.1.1. Climatic forest	-/-/V	P
	2.2.1.1.1. High altitude forest	-/-/V	P
H_I	a. Tropical rain forest hutan primer	-/-/V	P
Hd	b. Dry deciduous forest hutan musim	-/-/V	P
Hb	c. Bamboo	-/-/V	P
	2.2.1.1.2. Low altitude forest hutan gambus		

TABLE 4

LAND COVER/LAND USE CLASSIFICATION

Symbols	Classes		Possible land cover W water S Soil B vegetation	Permanent (P) transient (T) spectral Characteristics
He	2.2.1.2. Edaphic forest			
Hs	a. Inland swamp forest		-/-/W	P
		hutan rawa		
Hm	b. Tidal forest		-/-/V	P
		hutan payau		
Hg	c. Riparian forest (forest gallery)		-/-/V	P
B	2.2.2. Shrub	semak	-/-/V	P
G	2.2.3. Grass	rumput	-/-/V	T
	2.2.3.2. Dry conditions		-/-/V	T
G_A	a. alang-alang	alang-alang	-/-/V	T
G_g	b. Rangeland (other grass)			
	2.2.3.2. Wet conditions		W/-/V	T
Gr	a. Coastal marshes	rawa	W/-/V	T
	b. Upland marshed	rawa	W/-/V	T
	2.2.4. Mixed forest-bush-grass (secondary growth/ forest)		W/-/V	T
Bm	2.2.4.1 Climatic formation		-/-/V	P
		belukar		

TABLE 4

LAND COVER/LAND USE CLASSIFICATION

Symbols	Classes		Possible land cover W water S Soil B vegetation	Permanent (P) transient (T) spectral Characteristics
Br	2.2.4.2 Edaphic formation (swamp/marshes)	rawa	W/-/V	P
H_p	2.2.5. Forest plantaion	hutan produksi	-/-/V	T(?)
Hpj	a. teak	jati	-/-/V	T(?)
Hpp	b. pinus	pinus	-/-/V	P
	c. others			
	3. Non vegetated, non cultivated area			
Dk	3.1. Barren land (eroded area)	daerah kritik	-/S/V	T
	3.2. Coastal sand beaches, dunes		-/S/-	P
	3.3. Bare rock (outcrops)		Rock	P
	3.4. Lava flow	lahar	Rock/S	P
	4. Settlement and built-up area			
Ko	4.1. Town	kota		
Kp	4.2. Village	kampung		
	4.3. Communication network			
	4.4. Airport			
	4.5. Others			

TABLE 5

DEFINITIONS OF LAND COVER/LAND USE CLASSES

Wk	Pond	:a small body of water which is usually located near settlements and used for fish rearing and / or domestic water supply.
Wd	Lake	:an extensive sheet of water enclosed by land, occupying a hollow in the earth surface.
Wp	Reservoir	:impounded body of water or controlled lake in which water is collected and stored. Single or multipurpose (irrigation, flow control, hydroelectric, etc).
Wi	Fish pond	:body of water managed for fish production: - fresh water (kolam): inland - brackish (tambak): coastal
Wb	Bays and estuaries	:inlets or arms of sea extending inland.
Vc	Cultivated area	:area managed for the production of food and/or fibre. As much confusion sometimes arises in the definition of patterns associated with multiple croppings, some definitions are given in TABLE 6 on page 130.

TABLE 5

DEFINITIONS OF LAND COVER/LAND USE CLASSES

Vcp	Permanently cultivated		:area occupied year long (it may not be supporting a crop during part of the year, ie. dry season).
S	Sawah		:cultivated area with level fields surrounded by bunds and supporting at least one crop of rice in the rotation. The fields are flooded from transplant to a few weeks before harvest (wetland rice).
Si	Irrigated sawah		:sawah in which the fields are artificially supplied with water and producing: 1*
		Si2	:at least two crops of rice per year or five in two years. 2*
		Sip	:one crop of irrigated rice during the rainy season followed by a secondary crop - generally not irrigated - (palawija) at the beginning of the dry season (ie. cassava, legumes, corn, tobacco etc.). 3*

TABLE 5

DEFINITIONS OF LAND COVER/LAND USE CLASSES

1* in years of normal water availability conditions.

2* further subdivision may refer to the type of irrigation system (teknis, setangah teknis, pedesaan).

3* additional information regarding the type of irrigation system (ie. shallow wells) or the particular farming practices (ie. interplanting) may be included in subclasses.

Si1	:one crop of irrigated rice during the rainy season and no crop until the next rainy season (dry season fallow). 4*
Sic	:sugar cane growing area. Although the lay out of the fields is different than for rice crop this unit is usually included in the 'sawah' group because sugar cane is traditionally grown on a non-permanent basis in the rice producing area of the lowlands.

4* it may happen that these units Si2, Sip and Si1 are found together over a small area; the adoption of one cropping pattern or another are indeed very much

TABLE 5

DEFINITIONS OF LAND COVER/LAND USE CLASSES

Condition by water availability at the field level. Distances to secondary and tertiary canals are often determinant.

Sp	Tidal rice (*pasang surut*)	: sawah in coastal marshy lowlands drained at low tide through a system of canals and one way gates. Rice is produced during the rainy season; secondary crops are grown before or after (pineapple, cassava, etc.).
U	Upland crop area	:area occupied by rainfed crops on the original topography or on benched slopes. A very large variety of crops and farming systems found in this group makes difficult a detailed subdivision. The four following classes only have been retained; they provide a framework for more detailed analysis..
Ut	Field crops (*tegalan*)	:grain, root or fiber crops grown in open fields (benched or not) Fallows are rare and only for short terms.

TABLE 5

DEFINITIONS AND LAND COVER/LAND USE CLASSES

		Seasonality is controlled by the rainfall pattern (and/or by labour availability). Trees and bushes, if any, are confined to the edges of the fields. Rice (paddy - gogo), tobacco, beans Cassava, maize groundnuts, etc. are grown.
Uk	Mixed garden (kebun campuran)	:fields occupied by field crops, mixed with trees and bush crops (often fruits); the ground coverage by the upper storey is not more than 30 percent.
Us	Horticultural production area (kebun sayur)	:vegetable producing area in the uplands. Cabbage, shallots, garlic, carrots, etc. are common (may include medicinal plants).
Ui	Intermittent cultivation	:system of cultivation characterized by the presence during the rotation of short term fallows in an otherwise permanently occupied area. Field crops are found in this unit in association with grass and low scrubs in the fallows.

TABLE 5

DEFINITIONS OF LAND COVER/LAND USE CLASSES

P	Homestead gardens (*pekarangan*)	:garden compound surrounding the houses and covered with a dense close canopy mainly composed of fruit trees; the understorey often consists of low growing shade tolerant plants. When the distinction is difficult between this unit and UK (mixed garden) the density of cover and the presence of dwellings should be used as discriminating criteria.
E	Estate (*perkebunan*)	:commercial tree, bush or field crop plantation; the unit is generally pure (mono culture). Further sub-division refers to the crop type.
H	Small holding	:of the same crops as under E; privately owned plots; often mixed cropping.
Gf	Forest garden	:intermediate stage between forest and mixed garden cover during the progressive replacement of forest species by fruit trees and palms and the establishment of fields crops in the clearings.

TABLE 5

DEFINITIONS OF LAND COVER/LAND USE CLASSES

S	Shifting cultivation: (ladang)	system of cultivation involving cutting/burning of natural vegetation (forest, shrub or grass) and an alternation between a short period (3-4 years) during which field crops occupy the clearings and a lengthy period (10-20 years) during which the soil is rested and the land left to natural re-growth (secondary forest, belukar or grass)
	Non cultivated area	:includes forestry.
Hc	Climatic forest	:climatic climax (final and stable plant community of a developmental series at equilibrium with the general climate).
HI	Primary forest	:(tropical evergreen forest), high altitude, undisturbed dense forest on various topographic settings; sempervirens, closed canopy, distinct stories, numerous epiphytes. Includes Araucaria, Dypterocarpeae, Podocarpeae, Pinus, Agathis forest, etc

TABLE 5

DEFINITIONS OF LAND COVER/LAND USE CLASSES

Hd	Dry deciduous	:monsoon forest. The dominant species are deciduous (dry season). The understorey may be sempervirens. The density of cover is lower than the primary forest. Species: Teak, Eucalyptus, etc.
Hb	Bamboo forest	:in natural state mainly in Sulawesi.
He	Edaphic forest	:forest formation whose compos-ition and structure is mainly determined by an extreme physical condition of the substratum (often soil moisture).
Hs	Swamp forest	:inland swamp forest with large number of species (fresh water).
Hm	Tidal forest	:brackish water coastal forest (Avicenia, Rhizophora, etc.). includes mangrove formation, Nipah.
Hg	Riparian forest or forest gallery	:hydrophylous forest alongside rivers and frequent inundated terrain.
B	Shrub	:or scrub, bush. Shrubby formations are composed of low woody plants often interspersed with trees and

TABLE 5

DEFINITIONS OF LAND COVER/LAND USE CLASSES

		grass; they can be found in wet or dry conditions. Often indicates that human activities have or are taking place in the original tree formation.
G	Grass	:in dry conditions, alang-alang is the most common. Other herbaceous formations are found in grazing areas of eastern islands. In wet conditions: grass, sedges are found in edaphic formations in coastal or upland marshes.
Bm	Mixed forest-bush-grass	:foramtions of secondary re-growths at various stages after the burning, cultivation of the forest land or the selective cutting of the forest itself. The distinction is so far not clear between the formation called belukar (thicket) and secondary forest (hutan sekindar). A phyto-ecological classification seems to be more appropriate than a structural one for distinguishing between the various formations.

TABLE 5

DEFINITIONS OF LAND COVER/LAND USE CLASSES

Hp	Forest plantation	:commercial exploitation of reforestation projects. Many species.
Dk	Barren land	:area devoid of vegetation because of erosion; soil or bed rock apparent. A possible sub-division within this category pertains to the degree of erosion.
	Coastal sand beaches	:sloping accumulation of sand and gravel usually devoid of vegetation.
	Sand dunes	:accumulation of sand of eolian origin; covered with grass or low bush, planted with coconuts or devoid of vegetation.
	Lahar	:land slide or mudflow of pyroclastic material on the flank of a volcano. Depending upon age of the formation, the land cover/land use can range from irrigated sawah to bare rock. Often: shrub, grass.

TABLE 5

DEFINITIONS OF LAND COVER/LAND USE CLASSES

K	Settlement and built-up areas	: administrative criteria (population) are often used for town and village. Discrimination criteria more appropriate for air photo interpretation and of more significant ecological value could be based on the relative proportion between built-up and vegetation (pekarangan) areas.

TABLE 6

A FEW DEFINITIONS RELATED TO MULTIPLE CROPPING

Multiple cropping	:the intensification of cropping in time and space dimension. Growing two or more crops on the same field in a year.
Sequential cropping	:growing two or more crops in sequence (time dimension) per year. The succeeding crop is planted after the preceeding one is harvested. Farmer manages only one crop at a time. - successive crops are of the same species. - successive crops are of different species. - the second crop is the re-growth (ratoon) of the preceeding one (frequent in sugar cane, sometimes with rain-fed rice).
Intercropping	:growing two or more crops sumultaneously on the same field. Crop intensification is in both time and space dimension. Farmer manages more than one crop at a time in the same field.

TABLE 6

A FEW DEFINITIONS RELATED TO MULTIPLE CROPPING

- mixed intercropping: growing two or more crops simultaneously without distinct row arrangement (many combinations in ladang); row intercropping: growing two or more crops simultaneously where one or more are planted in rows.
- relay intercropping: growing two or more crops simultaneously during part of the life of the first crop.

5.6 Conclusions

Following the collection of scientific data during the multicisciplinary expedition, the Morowali area was declared a Nature Reserve and a management plan was prepared by the World Wildlife Fund (WWF, 1980), with the support of the International Union for the Conservation of Nature and Natural Resources.

The WWF management plan considers the Morowali area to be of high conservation value because:

"1. It includes one of the few remaining extensive areas of lowland alluvial forest in Sulawesi.

2. There are no other large reserves protecting forest types which grow on basic or ultrabasic rocks. Although the forest types growing on basic and ultrabasic rocks are impoverished and low in species diversity, they are nevertheless of conservation value as a distinct natural ecosystem.

3. There are no other large reserves protecting forest types which grow on limestone. The small areas of protected forest at Soroako in Sulawesi Tenggara are also on limestones and ultrabasics, but have been extensively disturbed by human activities (Balgooy, 1979).

4. It is unusual in containing five distinct ecosystems and hence a great diversity of flora and fauna.

5. It is the home of a large number of endemic species of mammals and birds of specific interest.

6. Protection of the upper watersheds of the Sumara and Ula-Solato rivers will safeguard the water supply for agricultural development in the alluvial plains.

7. Protection of the coastline with its extensive mangroves will prevent land erosion and further silting of coral reefs and fishery grounds offshore." (WWF, 1980).

"Most of the reserve is remote, mountainous and inaccessible. Outside visitors are rare and the area is in little demand for any large scale commercial exploitation", but "the continued presence of 4,000 Wana swidden cultivators and 1,200 coastal villagers within the reserve, and the continued collection of rotan and damar are seen as being clearly incompatible with the area's status" (WWF, 1980).

"The enforcement of the reserve regulations would:

1. Force the displacement of more than 5,000 people from their homes and leave them with no means of livelihood.

2. Deny many people from surrounding villages a major source of their income". (WWF, 1980).

It is suggested that the coastal people, who have been resident in the villages of Morowali and Lappanga for only two years, be assisted to move elsewhere, where there would be greater scope for the provision of land and facilities for cultivation". However, this course of action is considered to be neither possible nor desirable for the 4,000 Wana people within the reserve. For many of the Wana's moving would mean leaving their traditional homelands and abandoning the only way of life they know". "It is therefore proposed that these people should be allowed to remain on condition that they practise their traditional forms of agriculture". (WWF, 1980).

The goals of the management plan are the conservation of Morowali's unique diversity of undisturbed ecosystems and the protection of lowland agricultural water supply, and the principal aims can be outlined as follows:

"1. Protection of the variety of natural habitats and scenery in as undisturbed state as possible.

2. Preservation of viable populations of wild animals and plants of particular interest or rarity.

3. Protection of watersheds.

4. To safeguard the ancestral lands of the Wana people.

5. Use of the reserve for tourism, recreation and research in ways which benefit the local people and do not threaten the other values of the reserve." (WWF, 1980).

Revision of boundaries is suggested, "to include the mangroves at the mouth of the Sumara river, the whole of Gn. Tambusisi, the headwaters of the Morowali and Sumara rivers, the upper slopes of Gn. Tokala, and the islands Tokobae and Tomori. These extensions of the proposed area are made to :1. Protect the largest mangrove forest in the area ; 2. Protect two important watersheds and a wealth of valuable habitat on the slopes of Gn. Tambusisi and the upper slopes of Gn. Tokala, and ; 3. Protect the forested islands of the bay which add so much to the scenery and wildness of the reserve". (WWF, 1980).

REFERENCES

Balgooy, M M J van, A report to the Directorate of Nature Conservation on a visit to Sulawesi.
1979

Baltaxe, R, Pilot project on tropical forest cover monitoring: project implementation; methodology, results and conclusions. UN 32/6. 1102-75-005 Project report No 4 FAO, Rome.
1980

Baltaxe, R, (ed), The application of Landsat to tropical forest surveys. Forest resources division. Forest Dept, FAO, Rome.
1980

Bina, R T, Jara, R S, Lorenzo, E N and de Jesus, Jr, B R, Mangrove inventory of the Philippines using Landsat multispectral data and the Image-100 system. NRMC Research monograph. No 2 series of 1978.
1978

Central Planning Consultancy, Lithology and Groundwater potential of Sulawesi. Land and water resources report. Directorate general of water resources development.
1979

Central Planning Consultancy, The water resources and potentially irrigable land of the province of central Sulawesi. Directorate of planning and programming. Directorate general of water resources development.
1979

Danjoy, W A, and Sadowski, F G, Use of Landsat data in the study of forest classification in the tropical jungle. Proc. 12th International Symposium Remote Sensing of environment, ERIM, Ann Arbor.
1978

Davis, W A, and Peet, F G, A method of smoothing digital
1977 thematic maps. <u>Remote Sensing of Environment</u>, 6, pp45-49.

Disperati, A A, and Keech, M A, The value of using SLAR,
1978 satellite imagery and aerial photography for a forest survey in the Amazon basin, in Collins, W G, and Van Genderen, J L, (eds) <u>Remote Sensing applications in Developing Countries</u>, pp51-55, Remote Sensing Society, London.

ERIM, Bangladesh training programme in the processing
1979 of Landsat digital data for land accretion, Boro rice inventory and forest applications. <u>Bangladesh Landsat Centre and Environmental Research Institute of Michigan</u>. Final report.

FAO, A Framework for land evaluation. <u>Soils bulletin</u>
1976 <u>32</u>. FAO, Rome.

FAO, <u>Forest resources in the Asia and Far East region</u>.
1976 FAO, Rome.

FAO, Report on a preliminary visit to Morowali, Central
1978 Sulawesi. Based on work of Van der Zon, A P M, and Yaya Mulyana, 1978. <u>FAO Report No FO/INS/73/013</u>.

FAO/UNDP, <u>Nature Conservation and Wildlife management</u>,
1977 <u>Indonesia</u>. Interim report. FO:DP/INS/013. FAO/UNDP, Rome.

FAO/UNDP, <u>Proposed Lore Kalamanta National Park manage-</u>
1977 <u>ment plan</u>. 1978/79 - 1980/81. Nature Conservation and Wildlife management project of the FAO.

FAO/UNDP, 1978 Proposed Gunung Gede - Pangrango NationalPark management project. INS/73/013. FAO, Rome.

FAO/UNDP, 1979 Nature conservation and wildlife management Indonesia. Terminal report. FO:DP/INS73/013. FAO/UNDP, Rome.

Geobol, 1978 Mapa de copertura y uso actual de la tierra (Bolivia). Memoria explicativa: Serie sen sores remotas. Z. La Paz, Bolivia.

Gomez-Pompa, A, Vasquez-Yanes, C, and Guevara, S, The 1972 tropical rain forest: A non-renewable resource, Science 177 pp762-65.

Helsop-Harrison, J, Genetic resource conservation: The 1974 end and the means. Journal of the Royal Society of Arts. 1974. pp157-69.

Kalensky, Z, Darmoyuwono, K, Potts, T F, and Michino, 1978 T, Thematic map of Lombok island from Landsat computer compatible tapes. Proc. 12th International Symposium Remote Sensing of Environment, ERIM, Ann Arbor, pp1349-65.

Keech, M A, Disperati, A A, and Ganzel, O, The 1978 delineation of Araucaria angustifolia in the forests of southern Brazil using satellite imagery, in Hildebrant, G, and Boehnel, H J, (eds), Proc. International Symposium Remote Sensing for Observation and inventory of Earth Resources, Freiburg. pp1805-11.

Kemp, R H, Burley, J, Keilding, H, and Nikles, D G,
1972 International co-operation in the exploration, conservation and development of sub-tropical and tropical forest gene resources. 7th World forestry congress. 71. Beunos Aires, Argentina.

Lachowski, H M, Dietrich, D L, Umali, R, Aquino, E,
1979 and Basa, V, Landsat assisted forest land-cover assessment of the Philippine islands. Photogrammetric Engineering and Remote Sensing. 45. pp1387-91.

Lamb, D, Conservation and management of tropical rain
1977 forest: A Dilemma of development in Papua New Guinea, Environmental Conservation. 4,2. pp121-29.

Malingreau, J P, A proposed land cover/land use
1977 classification and its use with remote sensing data in Indonesia. The Indonesian Journal of Geography. 7, 33. pp5-27.

Medhaven, Unni, Computer classification using Landsat
1978 data in two areas of tropical forest in India. Proc. 12th International Symposium Remote Sensing of Environment, ERIM, Ann Arbor, pp1471-80.

Miller,L D, Nvalchawee, K, and Tom, C, Shifting
1978 cultivation in the forests of northern Thailand, in Williams, D L, and Miller, L D, (eds), 1978. Monitoring forest canopy around the world with digital analysis of Landsat imagery.

Morain, S A, and Klankamsorn, B, Forest mapping and
1978 inventory techniques through visual analysis of Landsat imagery: examples from Thailand. Proc. 12th International Symposium Remote Sensing of Environment. ERIM, Ann Arbor, pp417-26.

Newell, R E, The Amazon forest and atmospheric general
1971 circulation, in Man's impact on the climate, (ed) by Mathews, W H, Kellog, W W, and Robinson, G D, Cambridge, Mass, Mit, Press.

Nossier, M K, Palestino, C U B, and Batista, G T,
1975 Mapeamento de vegetacao natural dos estatos de minas gerais e do espirito snato atraves de imagens MSS do ERTS-1. Report INPE-G17-LAFE, San Jose dos Campos.

Pereira, H C, Land-use and water resources in Temperate
1973 and Tropical Climates, Cambridge, University Press.

Poore, M E D, Problems in the classification of tropical
1963 rain forest, Journal of Tropical geography, 17, pp12-19.

Poore, M E D, The values of tropical moist forest
1976 ecosystems and environmental consequences of their removal. Unasylva, 28. Nos 112-113. pp127-144.

Richardson, W, and Gleason, J M, Multispectral
1975 processing based on groups of resolution elements, ERIM, Ann Arbor, Report No 109600-18-F.

Sheda, M D, Dry deciduous forests on Landsat imagery.
1977 Indian National Remote Sensing technical report. 0705, NRSA. Secunderabad, Andrah Pradesh.

Shimabukuro, Y E, Hernandez, P F, Koffer, N F, and
1978 Chen, S C, Automatic classification of re-forested Pinus spp. and Eucalyptus spp. in Mogi-Guacu, S P, Brazil, using Landsat data. Proc. 12th International Symposium Remote Sensing of Environment, ERIM, Ann Arbor, pp2091-2100.

Simonett, D S, Quantitative data extraction and
1974 analysis of remote sensor images in Estes, and Senger, Remote Sensing techniques for environmental analysis, Hamilton Publishing Company, pp51-82.

Siripong, A, Murai, S, Matsouka, R, Tateishi, R, and
1979 Okuda, T, Studying the physiognomic feature, the distribution of suspended sediment, tin mine and mangrove forest in the Pang-Nga area utilising Landsat MSS CCT data. Marine Science department, Chulalongkorn University, Bangkok.

Sommer, A, Attempt at an assessment of the World's
1976 tropical moist forests, Unasylva, 28, Nos 112-113, pp5-26.

Stott, P A, Tropical rain forest in recent ecological
1978 thought: the re-assessment of a non-renewable resource, in Progress in Physical geography, 2, No 1, pp80-98.

UNESCO, 1973 Conservation of natural areas and the genetic material they may contain. Expert panel 8: final report, MAB report series 12, Morges, Switzerland.

UNESCO, 1974 Task force on: criteria and guidelines for the choice and establishment of biosphere reserves. Final report. MAB report series 22, Morges, Switzerland.

Vink, A P A, 1975 Land use in advancing agriculture. Springer, Berlin.

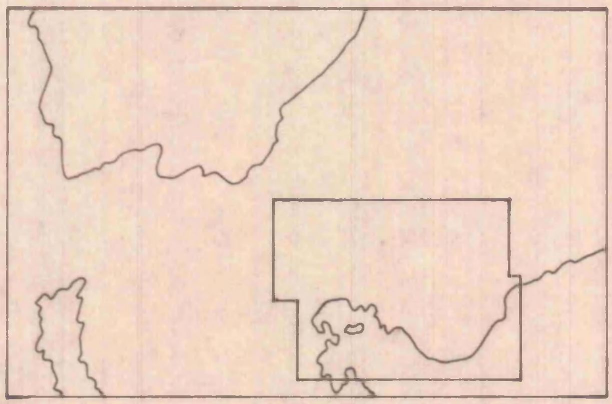
Whitmore, T C, 1975 Tropical rain forest of the far east. Oxford, Clarendon Press.

Williams, D L, and Coiner, J C, 1975 Utilization of Landsat imagery for mapping vegetation on the millionth scale. Proc. NASA Earth Resources Survey Symposium, NASA, Houston, Texas, pp53-65.

WWF, 1980 Morowali Nature Reserve: A plan for conservation. WWF/IUCNNR 1196 Gland, Switzerland.

Wyatt-Smith, J, 1950 Virgin jungle reserves. Malay forester. 13. p4. Kuala Lumpur.

LOCATION DIAGRAMS



Map compiled by R.M.Warwick-Smith. of the department of geography. School of Oriental and African Studies. University of London. Ground checking carried out by R.M.Warwick-Smith. assisted by Operation Drake during Jan–Mar 1980.

Source of data: Digitally processed Landsat 1 image.