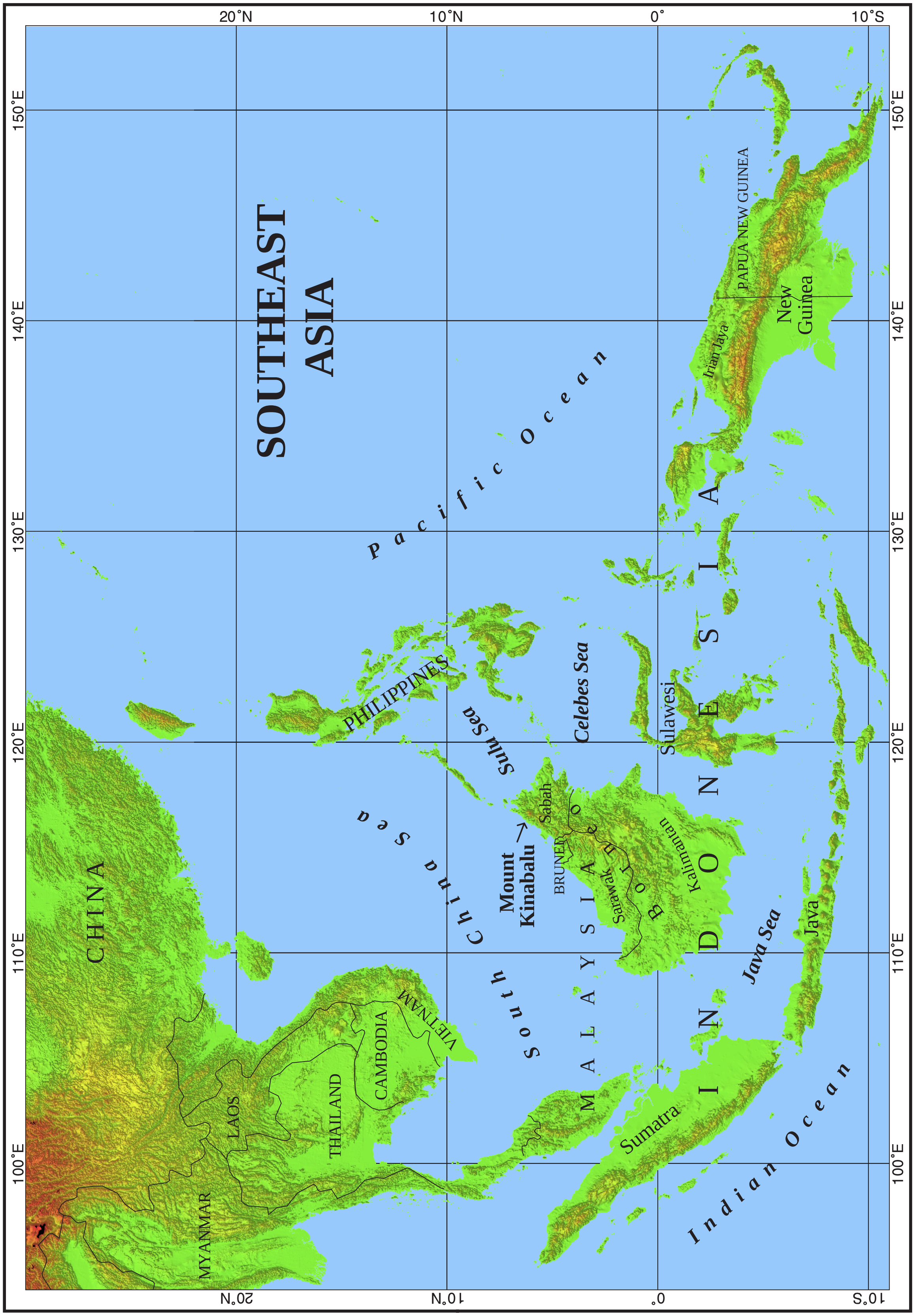
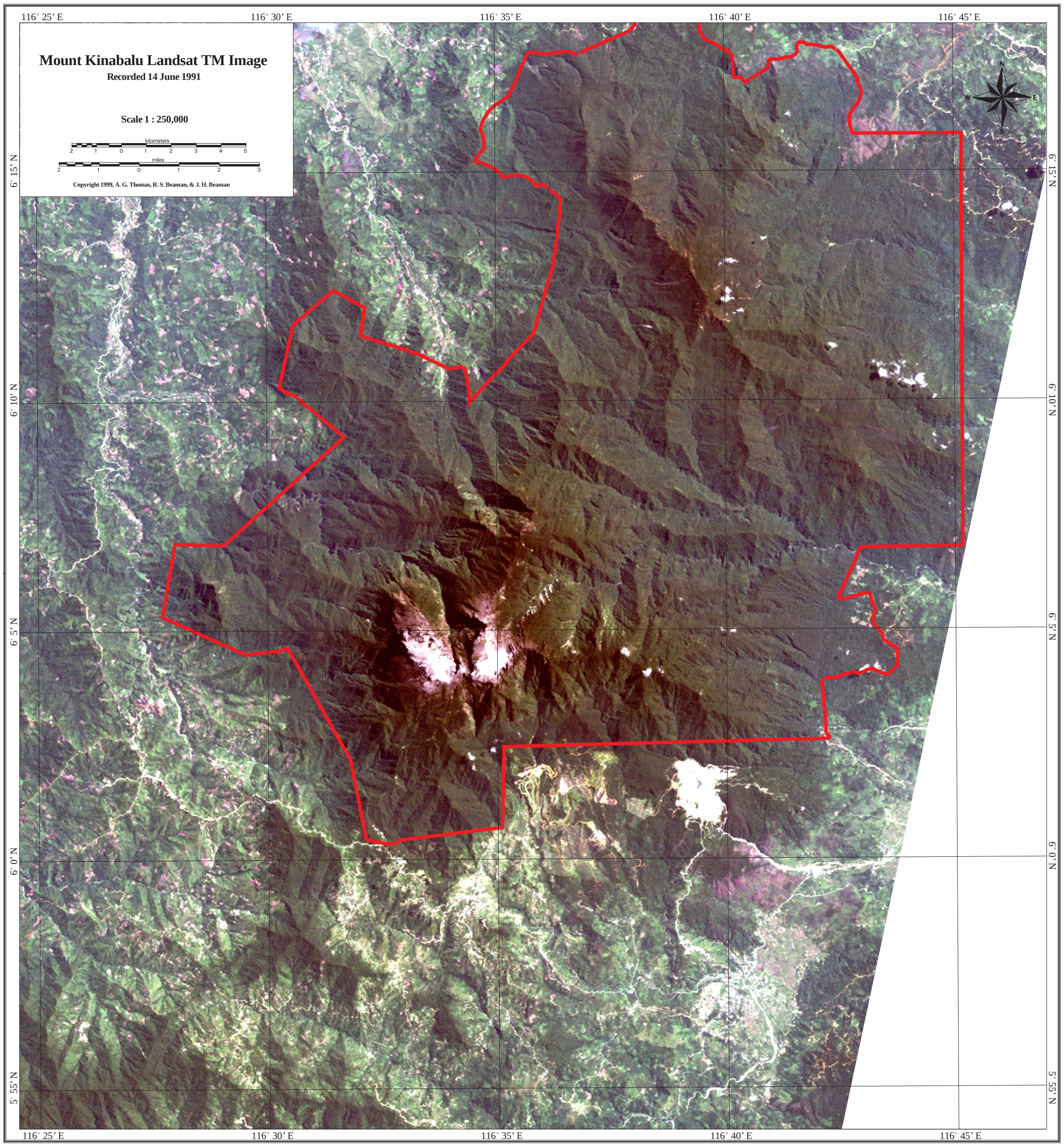

SOUTHEAST ASIA
CHINA
MYANMAR
LAOS
THAILAND
CAMBODIA
VIETNAM
PHILIPPINES
MALAYSIA
INDONESIA
BRUNEI
Sabah
Sarawak
Kalimantan
Borneo
Mount Kinabalu
Sumatra
Java
Sulawesi
Irian Jaya
PAPUA NEW GUINEA
New Guinea
South China Sea
Sulu Sea
Celebes Sea
Java Sea
Pacific Ocean
Indian Ocean
20°N
10°N
0°
10°S
100°E
110°E
120°E
130°E
140°E
150°E

Figure 1-3. Satellite image map of Mount Kinabalu, based on Landsat 5 Thematic Mapper data from 14 June 1991. Bands 3, 2, and 1 are shown applied to a red- green-blue (RGB) color model. Raw image data was rectified using digital elevation model (DEM) data and global positioning system (GPS) ground-control points. Original pixel values were maintained by this method, thus the image may be used in further analysis. The Kinabalu Park boundary is shown in red.


Mount Kinabalu Landsat TM Image
Recorded 14 June 1991
Scale 1 : 250,000
kilometers
2 1 0 1 2 3 4 5
miles
2 1 0 1 2 3
Copyright 1999, A. G. Thomas, R. S. Beaman, & J. H. Beaman
116° 25' E
116° 30' E
116° 35' E
116° 40' E
116° 45' E
6° 15' N
6° 10' N
6° 5' N
6° 0' N
5° 55' N

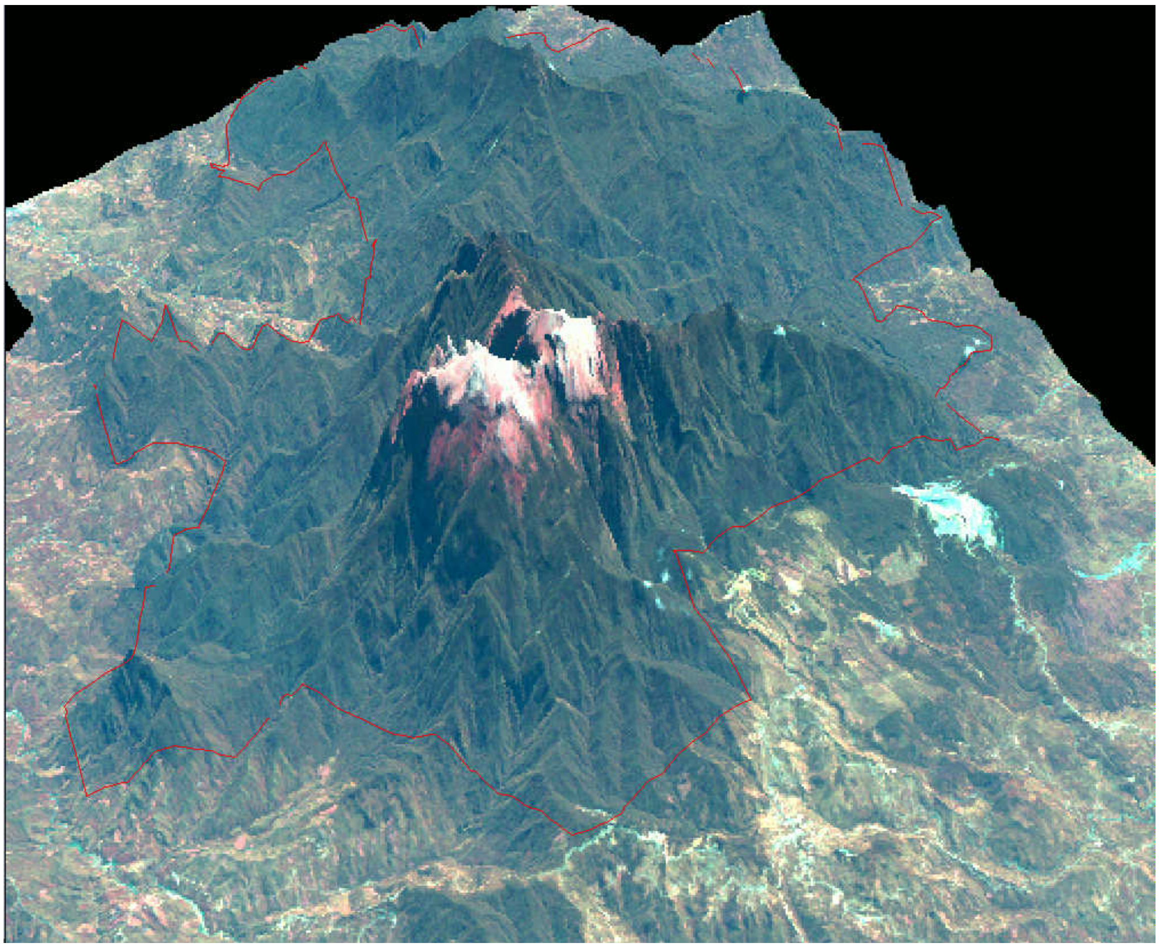


Figure 1-4. Drape of the Landsat TM image of Mount Kinabalu over the DEM, as seen from the northwest. This figure was produced using image bands 7, 2, 1. The Kinabalu Park boundary shown in red is an additional coverage. Black holes in the draped image are areas where surface visibility was miscalculated owing to three-dimensional surface-resolution limitations. The surface resolution is 50×50 m while the image resolution is 28.5×28.5 m.

Figure 1-5. Reduced scale (1:250,000) reproduction of Mount Kinabalu location map showing place names of kampungs, peaks, rivers and botanical collecting localities. The shaded relief map was produced by hill shading and color coding by elevation the digital elevation model (DEM).

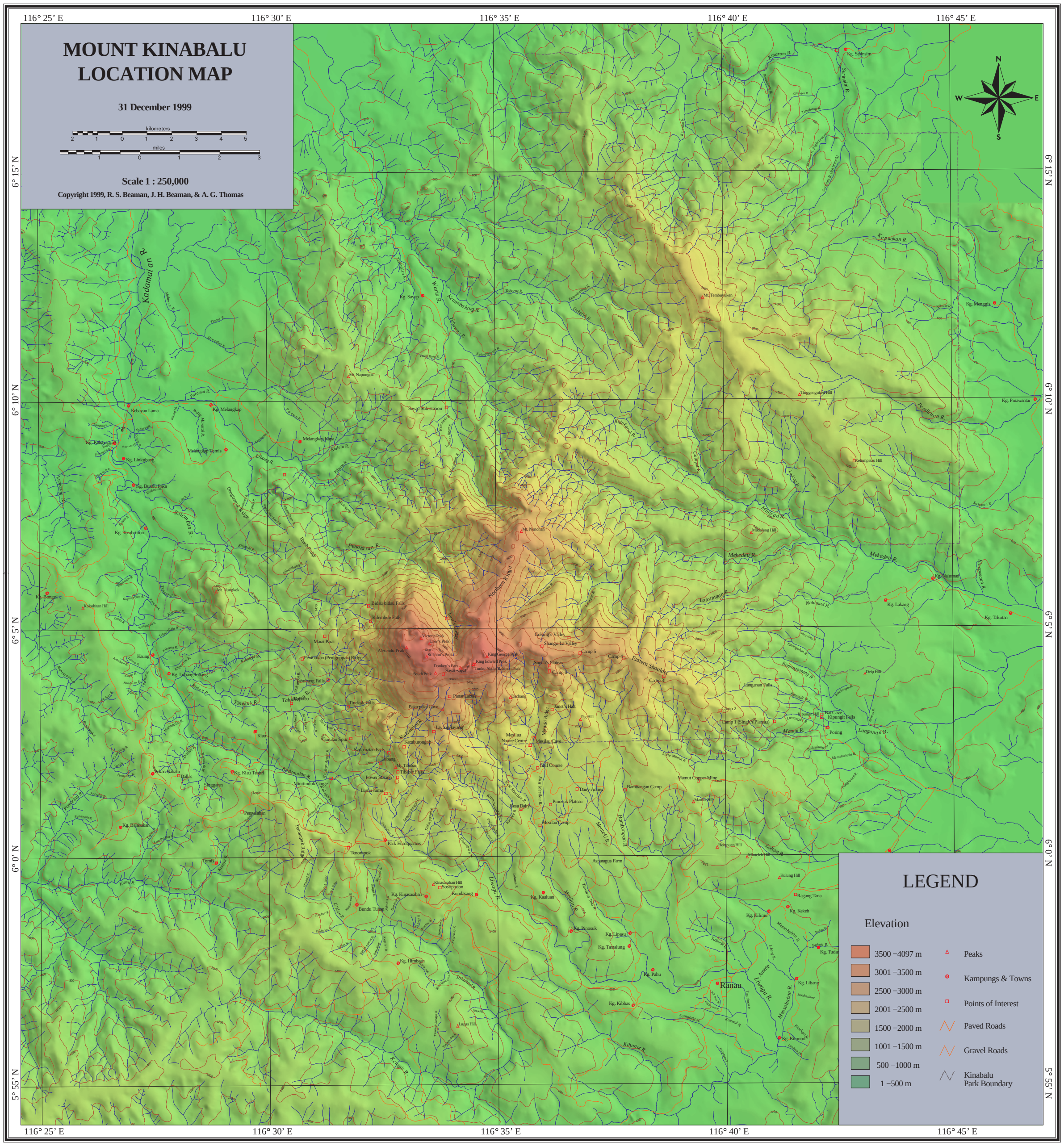

MOUNT KINABALU
LOCATION MAP
31 December 1999
kilometers
miles
Scale 1 : 250,000
Copyright 1999, R. S. Beaman, J. H. Beaman, & A. G. Thomas
116° 25' E
116° 30' E
116° 35' E
116° 40' E
116° 45' E
6° 15' N
6° 10' N
6° 5' N
6° 0' N
5° 55' N
N
S
E
W
Ranau
LEGEND
Elevation
3500 - 4097 m
3001 - 3500 m
2500 - 3000 m
2001 - 2500 m
1500 - 2000 m
1001 - 1500 m
500 - 1000 m
1 - 500 m
Peaks
Kampungs & Towns
Points of Interest
Paved Roads
Gravel Roads
Kinabalu
Park Boundary

Table 1-1. Species of *Elatostema* included in this study, their general distributions, and occurrence on ultramafic substrates. [1]Species occurs exclusively on ultramafic substrates. Undescribed species indicated by single quotes around the specific epithet.

Taxon	Ultramafic	Distribution
E. acuminatum	X	Kinabalu, Borneo, Java, India
E. `auriculatifolium'	X	Kinabalu
E. bulbothrix	X[1]	Kinabalu
E. `bullatum'		Kinabalu
E. `dallasense'		Kinabalu
E. `flavovirens'		Kinabalu
E. gibbsae		Kinabalu, Sabah
E. integrifolium		Himalayas
E. kabayense		Kinabalu, Sarawak
E. kinabaluense	X	Kinabalu
E. lineare	X	Kinabalu, Sabah
E. lithoneuron	X	Kinabalu
E. `maraiparaiense'	X	Kinabalu
E. pedicillatum	X[1]	Kinabalu
E. penibukanense	X	Kinabalu
E. `pinnatum'		Kinabalu
E. `purpurascens'		Kinabalu
E. rubrostipulatum		Kinabalu
E. `serpentinense'	X	Kinabalu
E. tenompokense	X	Kinabalu
E. thalictroides		Kinabalu, Sabah, Sarawak
E. variolaminosum		Kinabalu, Sarawak
E. vittatum	X	Kinabalu, Borneo
E. winkleri-huberti	X	Kinabalu, Sabah

CHAPTER 2
GEOGRAPHICAL INFORMATION SYSTEM

Development of a geographical information system (GIS) for Mount Kinabalu was originally conceived to augment the botanical inventory of Mount Kinabalu, with a location map and gazetteer, and as a basis for mapping species distributions. As the technology has improved, GIS has become much more than just a mapping tool; it forms a spatial framework for analysis of biological data. Though beyond the scope of this dissertation, we are developing GIS tools to (1) predict where species occur in unexplored areas based on occurrence in known localities, (2) develop diversity indices based on surface areas and elevation, and (3) identify ltramafic habitat islands as part of an effort to understand plant speciation patterns on Kinabalu. Identification of ultramafic outcrops is of particular interest because of the correlation between these outcrops and distribution of endemic species, particularly those hypothesized to have evolved on Kinabalu.

Coverages included in the Kinabalu GIS to date are topography, hydrography (rivers and streams), the Kinabalu Park boundary, ground-control points, a vegetation map published by Kitayama (1991), place names (toponyms) relating to specimen collections made since 1851 as well as by local collectors for the *Projek Etnobotani Kinabalu* (PEK), the Landsat TM image, and a digital elevation model (DEM) was developed from topographic coverages.

Predictions of where a taxon occurs in unexplored areas are useful in planning expeditions into areas such as the still unexplored north side of Mount Kinabalu.

Likewise, park management may use this type of data to target certain areas for protection. Predicting the occurrence of a particular taxon is based on knowing the characteristics of its habitat. Sheila Collenette (pers. comm.) probably was the first person to use remote sensing in this manner in her rediscovery of *Paphiopedilum rothschildianum* on Mount Kinabalu. Using black and white aerial photographs of Kinabalu she was able to recognize the *Casuarina s.l.* forests that are characteristic of many ultramafic areas. Site visits proved her technique worthwhile, because the rare slipper orchid, *P. rothschildianum,* had not been known from the wild in almost 70 years. The type collection had been (mischievously) attributed to New Guinea.

Remote sensing and GIS software (ERDAS Imagine and ESRI Arc/Info, respectively) provide image enhancement and classification techniques that make these sorts of predictions possible in a systematic way. Digital elevation models (DEMs) allow further refinement of predictive models by the inclusion of elevation, slope and aspect data. Diversity indices may also be enhanced by developing models to incorporate DEM data into the diversity index. How species diversity relates to habitat diversity and the spatial extent of certain plant communities is of particular interest on Mount Kinabalu, because of the high endemicity of species, particularly in ultramafic areas.

Satellite Imagery

The satellite image used extensively in this study is a Landsat 5 Thematic Mapper (TM) product, from an orbit ca. 700 km above the earth's surface. The image shown in Figure 1-3 is a quarter of a quarter scene, i.e., one-sixteenth of the total scene that covers 185 x 185 km. This image, recorded 14 June 1991, is one of only two cloud-free images available for the area, which is characterized by frequent and heavy cloud cover. The