

3. REMOTE SENSING

3.1 Rationale of remote sensing approach

The combination of deeply-weathered soils, moderate to steep slopes and high rainfall associated with tropical storms (cyclones), makes the Fiji islands very susceptible to landsliding. Although the islands are thinly populated with villages and towns located mainly around the coast, scattered communities occur throughout the islands, and development is taking place at a growing rate. In 1980, cyclone Wally caused devastation over a small area of the Serua Hills in southern Viti Levu. Other cyclones regularly cause destruction and loss of life. Whilst rainfall is clearly the most important triggering event, the extent to which other controls are important is uncertain. There is a clear need to provide regional scale hazard zonation and risk maps for much of the country, both for planning new developments and infrastructure, and for establishing preparedness and mitigation procedures for vulnerable areas and populations.

Fiji has an estimated land area of 18 330 km² with the main centres of population on the two main islands of Viti Levu and Vanua Levu. Geotechnical investigations by the Mineral Resources Department have provided some valuable information on the nature of the ground conditions that result in landsliding (Lawson 1993: see section 2.5). However, field survey work is slow and expensive, and cannot be regarded as an approach that, by itself, is capable of covering the large areas at risk in any realizable time frame. For the foreseeable future it is probable that hazard studies will be limited to specific investigations associated with major infrastructural developments and construction, such as the transportation corridor for the proposed Namosi copper mine.

If national coverage is to be achieved, it is therefore important that a method is developed that can provide small-scale regional maps quickly and at low-cost. Such provisional maps can serve to identify areas most susceptible to landslide events and the main risks to life and property. The use of remote sensing, combined with other existing data, is a practical approach potentially capable of achieving these coverage requirements. The need, therefore, is to determine how such data may be used, and to develop an operational methodology. The output from such an analysis will initially be a landslide inventory map showing the distribution of past landslides of different ages. However, although a type of hazard map, this is merely a record of past events and says little about locations where past slides have not occurred but which may be potentially at risk. The main purpose of the present pilot study is to determine whether the landslide inventory can be used to identify basic relationships with the geology, relief etc that can be used to rank the hazard more generally both within the area of the photointerpretation and beyond.

3.2 Data types, availability and acquisition

Given the relatively small land area concerned, and the scale of most landslides, the immediate requirement is for sub-regional hazard maps at a scale of around 1:100 000. Although Landsat Thematic Mapper (TM) imagery was provided by the Fiji-German Inventory Project (a forestry land cover project), no direct use was made of this; for most purposes, the 30 m ground resolution and maximum working scale of 1:50 000 is not appropriate to mapping landslides in Fiji. The use of SPOT Panchromatic imagery (10 m

resolution and working scales up to 1:15 000) is a possibility but was not available to the current project. A general problem is that all types of visible-to-infrared remote sensing data (including aerial photographs) suffer from the presence of persistent cloud cover in this tropical island situation. SPOT data has the potential for stereoscopic coverage but this requires two cloud-free overpasses on separate dates making acquisition of suitable data still more unlikely. It was finally decided to concentrate all efforts on the interpretation of conventional stereoscopic aerial photographs. These have a number of general advantages including large scale, high spatial resolution, stereoscopic coverage, low cost, ease of availability and the need of only modest equipment for their interpretation.

Various dates and scales of photographs are available for Fiji. In theory, useful information relating to individual cyclone events could be obtained by interpreting several generations of photographs for the same area. For example, such an approach could help indicate landslides which were active and others which had apparently become stable. However, for the purposes of this pilot study it was decided to use only the 1990 Agricultural Census photography. This is uniformly high-quality photography with a nominal (average) scale of 1:16 000. This scale is adequate to resolve even relatively small landslide events whilst not too large to be able to observe larger terrain features that developed as a result of landsliding over a period of time.

A major advantage of aerial photographs is stereoscopic viewing which significantly assists the interpretation and understanding of terrain features. Disadvantages at the regional scale include the large quantities of photographs needed to cover an area, the slowness of the interpretation and the difficulty of accurately transferring the information to a planimetric base map.

Aerial photographs are readily and cheaply available for Fiji, and can be ordered from the Lands Department offices in Suva.

3.3 Interpretation of aerial photographs

3.3.1 Techniques

Various types of stereoscope are available for photointerpretation, but the most convenient for systematic desk-based work is a mirror stereoscope, preferably with a parallel-motion attachment which allows roaming across the photograph pair. The mirror stereoscope enables the geologist to view the complete 'stereo model' (the area of overlap between adjacent photographs) at low magnification, or selected parts at higher magnification using a binocular attachment. It provides an appropriate working arrangement for the manual plotting of interpreted features onto a translucent overlay attached to one of the photographs.

Problems associated with the use of aerial photographs include relief-related distortions and scale variations. Relief distortions arise as a result of variations in land surface elevation across the photograph (in the same way that a tall building occurring at the edge of an aerial photograph would appear to be 'falling over'). Thus, the top of a hill will be displaced laterally outwards relative to its true, or planimetric, position. Scale changes are mainly the result of variations in flying height above the *ground surface*; thus at a constant flying altitude (i.e. above *sea level*), photo scale will change with the changing elevation of the land

surface. Both these factors make it difficult and slow to accurately transfer interpreted information to a base-map. For most photogeological work, alternate photographs in a 'run' are used for annotating the interpretation (making use of the stereo overlap on either side of the central one). However, because relief distortions increase towards the photo margins, it is more accurate to use only the central portion of *every* photograph along a flight line. Even then, the subsequent transfer of interpreted information to a base map can prove difficult in areas of significant topography. In south east Viti Levu this was generally a significant, though not a major, problem.

The interpreted information was transferred to a base map using a Plan Variograph. This instrument uses a lens system to project an image of the interpreted overlay at adjusted scale onto a translucent printed map base. In this case, the map base used was 1:25 000 scale separate of the drainage network, again obtained from the Fiji Lands department. By adjusting the magnification, the projected image was matched to the map (using drainage lines also marked on the photointerpretation for reference), and the information plotted. Where such an instrument is not available, the interpreted overlay for each photograph can be reduced using a photocopier. Given the final scale of plotting or analysis, this method will still provide sufficient accuracy. Other approaches to data transfer are possible provided that appropriate computer systems exist. These include the raster scanning of the interpretation overlay (onto which the map coordinates of recognizable points have been added), and the subsequent warping and merging of the digital images to fit the base map.

3.3.2 Geological interpretation and terrain classification

Aerial photography can provide information on old and recent landslides, faults and fractures ('lineaments'), bedding and other lithological structures, recent erosional/depositional processes, habitation (including cultivation), infrastructure and roads. In the present study, the aerial photographs were used to identify landslides, lineaments, and roads although useful information relating to various development activities potentially related, or relevant, to landsliding is also evident.

The interpretation of landslides is not difficult but requires some training and experience, and an understanding of landslide mechanisms and morphology. Figure 2.4 shows the form of 'typical' landslides and Figures 3.1 to 3.3 how these appear on the aerial photographs. Since the emphasis of the project was on *rapid* techniques, the 'level' or 'detail' of interpretation is important. Ideally, the experienced interpreter should be able to interpret a stereo model (photo pair) in about an hour or so, depending on the scale and complexity. Much more time than this suggests a higher level of detail than is required.

In order to develop a scheme for mapping landslides, an initial field inspection was carried out of several areas in south east Viti Levu, and the results verified in the field with an engineering geologist from the MRD. The field appearance of typical landslides is illustrated in Figures 1.2 and 2.7 to 2.12. Based on this orientation study, a simplified scheme of terrain and landslide classification was developed for the interpretation of the main study area.



Figure 3.1 Aerial photograph (41/012) of the coastal Waivuna region, Serua Hills, showing abundant 'young' landslides between locations a and b. Many landslides of 'transitional' age occur in deforested slopes SSW from locality c, towards the main Suva-Nadi highway.

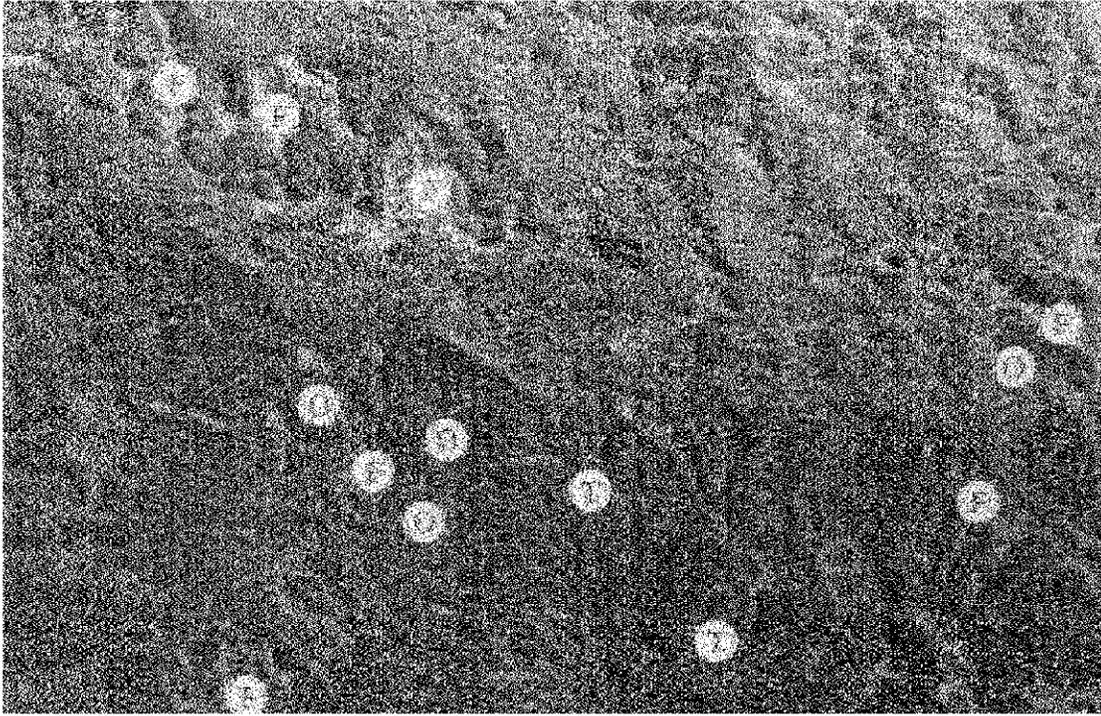


Figure 3.2 Classic appearance of landscape features due to landsliding shown on aerial photograph 39/142, 6 km NNW of Yarawa. 'Young' landslides (F) initiate new drainage, and also occur within 'transitional' (T) and 'old' (O) landslides.

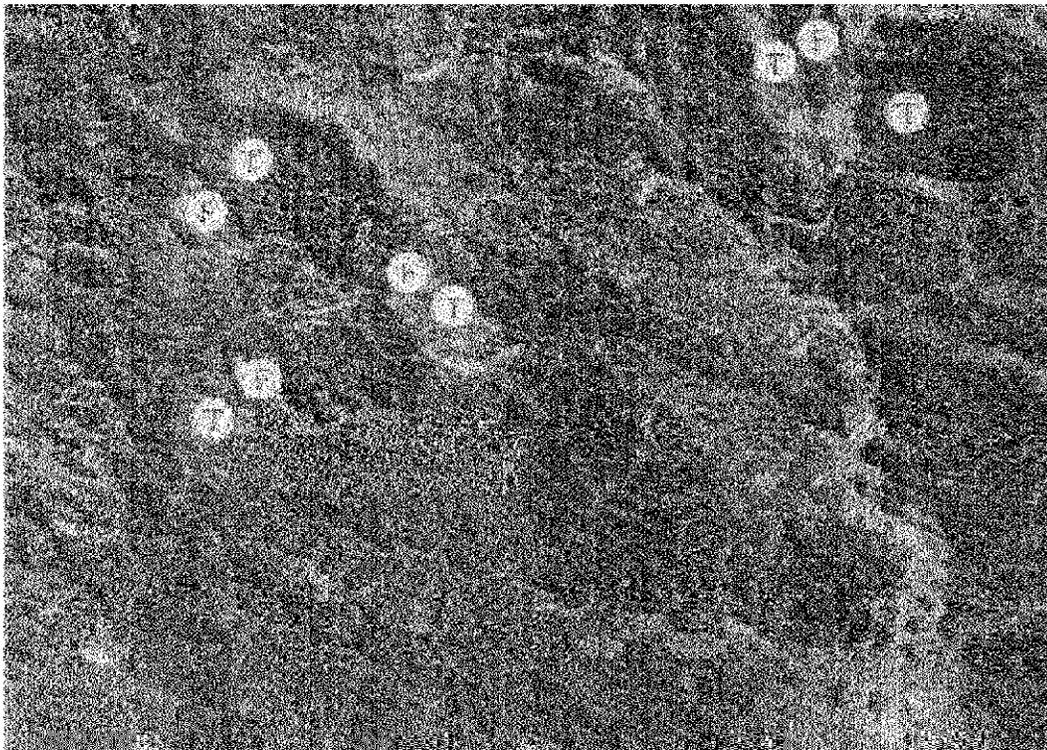


Figure 3.3 Aerial photograph (40/102) showing 'young' (F) landslide scars within particularly revegetated, 'transitional' (T) landslides, 2 km NW of Yarawa.