Updating Maps of Climax Vegetation Cover with Landsat MSS Data in Queensland, Australia

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ABSTRACT: Maps defining climax vegetation cover are available for large areas of rural Australia. However, limited data are available on current land-cover patterns. Landsat MSS data were used to update existing climax cover maps for an area on the fringe of the wheat belt in southern Queensland. The updating task proved difficult because modified communities frequently resembled climax vegetation; remaining climax vegetation was heterogeneous in terms of structure; and large scale anomalies were apparent in the existing climax cover maps. To cope with these difficulties, a combination of masking (image stratification), which restricted analysis to within class variability, and unsupervised classification, which allowed such variation to be sorted, was utilized. The research demonstrates that mapping land cover from Landsat and updating existing maps of land cover may have little in common. Specific approaches must be developed to address the problems inherent in the latter task.

INTRODUCTION

The utility of Landsat MSS data for land-cover mapping is well established for environments around the globe. Often, however, Landsat MSS data have been used as the primary data source. That is, satellite imagery has provided base data for previously unmapped areas or has not been related to other maps. In such cases the success of the exercise is judged against ground truth information directly related to the image. Where updating of existing maps is involved, another dimension is incorporated as Landsat MSS data must be compared not only with what is *on* the ground but also with what the existing map suggests *should* be on the ground. Unless it can be taken for granted that existing maps are accurate, updating tasks may be far more involved than would be expected at face value.

The land-use potential of large areas of Australia has been assessed using the land systems approach (Christian, 1958; Christian and Stewart, 1968). This work has been largely conducted by the Commonwealth Scientific and Industrial Research Organization (CSIRO) and State Departments of Primary Industries (DPI). Land systems, which form the primary map units of these studies, comprise patterns of similar landform, soil, and vegetation (Mabbutt, 1968; Mitchell, 1973). Land system reports may include vegetation and soil maps in addition to the land systems maps, although variation in unit boundaries across such maps is usually minor. Separate land-cover maps may be extrapolated by amalgamating vegetation units into cover classes (e.g., forest woodland, open woodland).

Land systems represent climax vegetation, and cover maps derived from them will reflect "...land-cover patterns that existed prior to European settlement" (Douglas, 1979, p.238). In contrast to approaches used by the U.S. Department of Agriculture Forest Service (Buttery, 1978), where modified as well as initial ecoclasses are mapped, little attention has been paid to the distribution of current land cover in Australia.

The regionalization inherent in the land systems map, or derivatives of it (e.g., land-cover maps), would appear suited to the resolution capabilities of Landsat MSS data (e.g., Justice and Townshend, 1981; Townshend, 1981). However, Australian based research that has tested this compatibility has met with mixed success (e.g., Story *et al.*, 1976; Jupp *et al.*, 1979; Robinove, 1979; Kacker, 1980; Hill and Hornibrook, 1981; Kelly, 1984). Some problems encountered, such as disagreement over the location and extent of specific land systems, particularly those that have been modified by land-use activities, could reasonably be attributed to land system maps rather than to the Landsat data. As well, generalization is a common feature of all regional scale land-cover maps and restricts their use as base maps for change detection (Campbell, 1983). The subjectivity inherent in the land systems approach to land-cover assessment is well established (e.g., Robinove, 1979; Thomas *et al.*, 1980; Laut and Paine, 1982), being related largely to the pattern recognition phase and extrapolation of point samples to mapped areas.

In a recent paper Hill and Kelly (1986) demonstrated that Landsat MSS data were capable of providing a reliable assessment of the distribution of climax and disturbed vegetation communities in the marginal wheat lands of southern, inland Queensland. The research involved updating climax cover maps derived from the land systems approach. While the existing maps guided the analysis and interpretation process, their use also presented a suite of problems. The aim of the current paper is to highlight the problems encountered and discuss the approach adopted to overcome them.

STUDY AREA AND BASE DATA

Research was conducted in an area of approximately 6000 km^2 on the western fringe of the winter wheat belt in southern, inland Queensland (Figure 1). The site, located in Waggamba Shire, is semi-arid, receiving on average between 500 and 600 mm of rainfall per year. Mean maximum temperature for the three summer months is 33°C with a mean minimum temperature for the three winter months of 6°C. Significant changes in land use have occurred over the past 20 years, mirroring a transition from predominantly sheep grazing to grain production with sheep and/or cattle, a process that is continuing. In association with this change in the agricultural system, large areas of timbered country have been cleared or partly cleared.

The study area lies along the eastern edge of the land systems map from the Lands of the Balonne-Maronoa study (CSIRO, 1974). This publication provided the 1:500 000 map base. Land-cover classes were taken from the Condamine-Maronoa Composite of Vegetation (1:1 250 000) which generalizes the vegetation communities of the land systems map into cover categories (DPI, 1980). Three climax cover types were demarcated:

- *Open Forest*: The predominant vegetation community is belah (*Casuarina cristata*) and brigalow (*Acacia harpophylla*) open forest. Projective foliage cover of the canopy is less than 70 percent but greater than 30 percent with canopy height often exceeding 20 metres. Topography is flat to undulating. The clay soils are associated with gilgai microrelief (patterns of uneven natural depressions) in many areas. Areas of bendee (*A. catenulata*) forest (>70 percent canopy coverage) occur in the northwest on hilly terrain having shallow, stony red earths.
- *Woodland*: Woodland communities (10 to 30 percent canopy cov-

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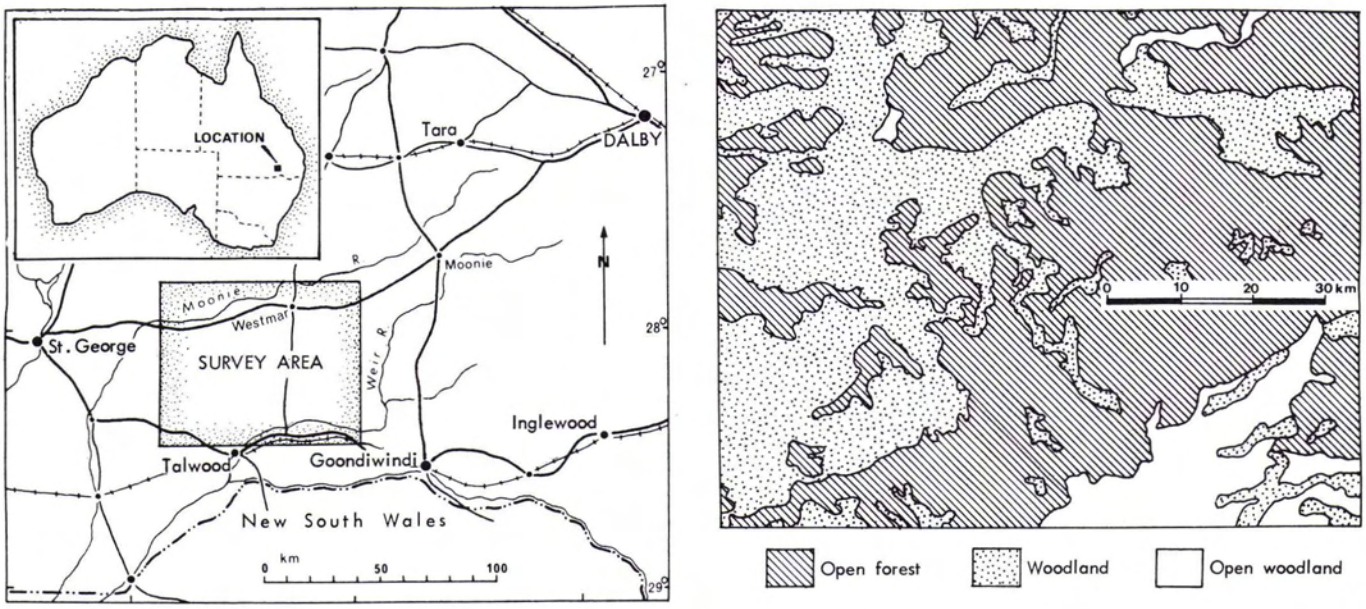

FIG. 1. Location of study area and distribution of climax cover types.

erage) are generally located on flat to undulating terrain having solodic soils or red earths. They are dominated by poplar box (*Eucalyptus populnea*) or poplar box with brigalow, mulga (*A. aneura*) or ironbark (*E. crebra*).

- *Open Woodland*: Coolibah (*E. microtheca*) open woodland (<10 percent canopy coverage) dominates this cover type which is found on heavy grey clays of the floodplains of the Macintyre and Weir Rivers in the south and the Moonie River in the north.

THE UPDATING TASK AND METHODS

The image classification task involved defining three vegetation communities (open forest, woodland, and open woodland) that remained in the climax state (remaining) and those that have undergone modification (e.g., have been removed). The Landsat MSS scene used was recorded on 12 September 1981. Image processing was conducted on the Department of Mapping and Surveying, Comtal Vision 1/20 system. Black-and-white aerial photography (1:25 000 scale) from 1982 was available to guide interpretation and accuracy assessment.

Early attempts at classification using the usual single-step approach, that identifies all classes of interest in one processing of the image (e.g., Campbell, 1983), revealed four major problems:

- *Similarity between modified (high cover) and climax (low cover) vegetation.* Partial clearing of forest and woodland has resulted in vegetation communities that were of similar structure to climax woodland and open woodland, respectively. In spectral terms, these communities were indistinguishable from the respective climax classes making classification of, for example, climax woodland across the entire study area impracticable. An indication of the type of problem involved with modified, high cover communities resembling climax communities of lower cover status is given by Figure 2.
- *Degree of modification of Climax Vegetation.* Modified vegetation communities within each map category were often similar, in terms of canopy coverage criteria, to climax communities (Figure 3). This complicated the task of identifying climax and modified vegetation communities. The woodland and open woodland classes presented special problems in this regard.
- *Cover type variation.* Within each climax vegetation class variations in species composition, structure, and canopy cover were present (Figure 4). Each classification category therefore comprised a range of target types.
- *Map anomalies.* The major problem encountered in this research derived from anomalies evident in the existing cover maps. For undisturbed communities, in each of the three cover types, there were large apparent errors. Open forest, for example, was often called woodland (10 to 30 percent coverage); woodland was shown as open forest (30 to 70 percent coverage); and in some cases areas shown as open woodland (<10 percent coverage) proved to be of open forest or woodland status (Figure 5). Cover status *per se* was therefore an inappropriate indicator of climax communities in some instances. The major anomalies occurred in open forest and woodland. Cross-reference to the 1960's aerial photography utilized to produce a climax vegetation map did not indicate that any of the anomalies identified in the remaining climax vegetation were due to changes in the stands over the intervening 20-year period.

To cope with these problems, a separate image was created for each of the climax cover classes. This strategy was designed to confine image classification to within-class variability and remove the confusion associated with between-class similarities. Stratification of the data into three images was achieved by applying masking techniques. The map boundaries were registered to the image to define the masks. The graphics of the image processing system generated each mask by assigning the value of zero to all pixels outside the map areas of interest and an arbitrary value greater than zero (e.g., 255) to pixels within the relevant map boundary. This binary band (image channel) acted as an initial filter in the classification phase.

Within each mask an unsupervised spatial-spectral clustering algorithm, AMOEBA (Bryant, 1979), was used to identify homogeneous classes in the Landsat data. Given the range of vegetation communities involved (e.g., points 2, 3, and 4 above), use of supervised classification techniques was inappropriate. The image smoothing resulting from the context (spatial) aspect of AMOEBA was appropriate to the production of map products at the regional scale. Reference to aerial photography guided the allocation process whereby the output clusters were amalgamated to provide the two classes of interest (climax and modified) within each of the three masks. Aerial photography was also employed to assess the accuracy of the results obtained by using a stratified random sample of 1432 points. A confusion matrix was generated for accuracy assessment.

RESULTS

The Landsat-based assessment of the study area indicated that 11, 54, and 14 percent of open forest, woodland, and open woodland, respectively, remained in the climax state. Accuracy of the classification (Table 1) was above 80 percent for each of the six classes defined. Overall mapping was 95 percent correct (Hill and Kelly, 1986).

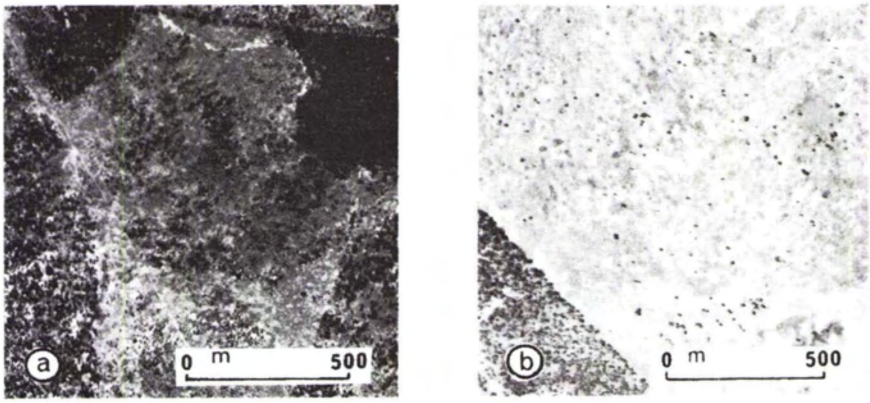

FIG. 2. Modified high cover communities often resembled climax communities of lower cover status, for example: (a) This area was originally belah and brigalow open forest. Much of it has been modified to woodland or open woodland status. (b) This area was originally poplar box woodland. Most of the woodland has been modified to open woodland status.

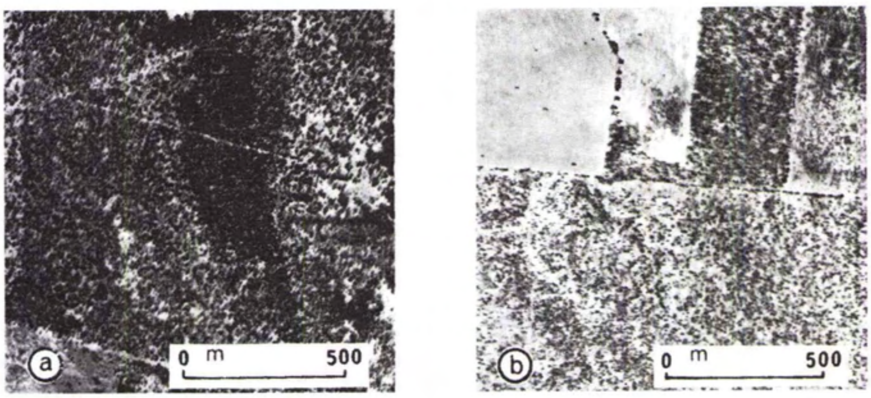

FIG. 3. Degree of modification for climax classes influenced classification, for example: (a) This area was originally climax belah and brigalow open forest. Despite partial clearing, some modified areas are still of open forest status (>30 percent cover). (b) This area was originally poplar box woodland. Despite partial clearing, some areas (e.g., bottom half of photograph) are still of woodland status (>10 percent cover).

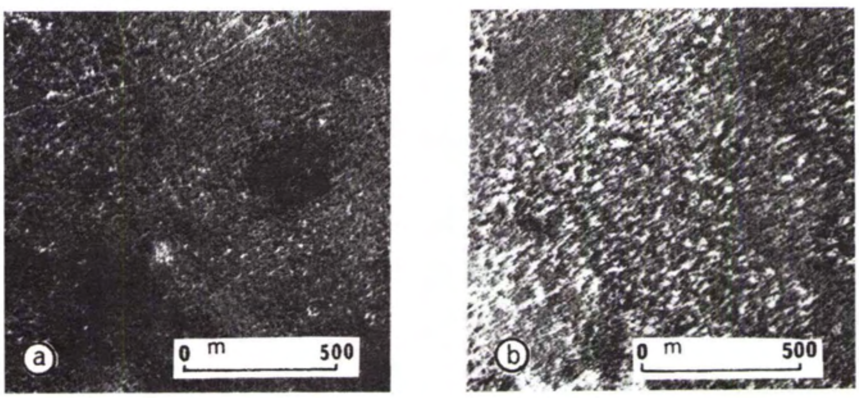

FIG. 4. Within the climax categories a range of communities and structures were evident, for example: (a) open forest; and (b) woodland.

The major sources of error were related to the problems outlined previously.

- In the open forest category (omission) some undisturbed communities that were of woodland status were classified as removed. As the spectral signatures of these areas were indistinguishable from open forest that had been modified to similar coverage condition, the problem could not be resolved.
- For reasons similar to these cited above, the reverse occurred for the woodland category (commission) where some disturbed communities could not be separated from climax stands.
- As expected, separating climax open woodland from areas where

TABLE 1. ACCURACY ASSESSMENT FOR THE LANDSAT CLASSIFICATION

Land Cover	Sample Size	Percent Omissions	Percent Commissions	Mapping Accuracy
Open Forest		15	4	81
Modified Open Forest	789	2	5	94
Woodland		3	8	90
Modified Woodland	446	9	3	89
Open Woodland		10	4	87
Modified Open Woodland	197	4	9	88

development had made a substantial impact presented some difficulties. No pattern of error was identified.

CONCLUSIONS

The current research demonstrates that mapping land cover and updating existing maps of land cover from Landsat MSS data present the analyst with often quite different problems. Availability of the climax cover map and acceptance of its boundaries and vegetation categories as the entities to be updated necessitated an approach to image processing that would not have been followed if the exercise had been to produce a land-cover map of the study area.

Restricting image analysis to within each map class illustrates this point. For example, it was necessary to identify remaining climax woodland and separate this from woodland derived from partial clearing of open forest. Although such stands were of similar land-cover status (i.e., woodland), land cover as such was not of primary interest given the character of the updating task. Similarly, within each map category there was the problem of separating climax stands from modified stands that exhibited similar canopy coverage status. As the primary role of the mapping exercise was to update existing maps, which are widely accepted as base line data for resource assessment and analysis purposes, classification on the basis of land-cover condition alone was inappropriate if the integrity of the existing cover map was to be maintained.

Inaccuracies in the climax cover map provided another dimension to be considered. The reliability of existing maps should not be accepted without question in any remote sensing application. In the present case, however, the aim was not to revise the boundaries of the original map, but to monitor change within them. Therefore, the contradictions between climax status and its surrogate, projective canopy coverage, were a major problem. Mapping unmodified (climax) vegetation, even if it was incorrectly classified in terms of coverage criteria on the existing map, took precedence over mapping land cover.

If the view is taken that maps of current land cover are necessary and that these are most useful if used in conjunction with existing maps of climax land cover, then this latter data source must form an integral part of the mapping program. In the present case this was achieved through masking, which removed the need to consider between cover type similarities. Use of an unsupervised classifier simplified the identification of the separate vegetation communities which comprised each cover type. This sequence of analysis demonstrates an approach to solving the types of problems encountered in updating a cover map derived from the land systems approach.

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REFERENCES

Bryant, J., 1979. On the Clustering of Multidimensional Pictorial Data. *Patten Recognition*, Vol. 11, pp. 115–126.

Buttery, R.F., 1978. Modified Ecoclass — A Forest Service Method for Classifying Ecosystems. *Proceedings National Workshop on Integrated Inventories of Renewable National Resources*, Tuscon, Arizona.

Campbell, J.B., 1983. *Mapping the Land: Aerial Imagery for Land Use Information*. Association of American Geographers, Washington, D.C.

Christian, C.S., 1958. The Concept of Land Unit and Land Systems. *Proceedings 9th Pacific Science Congress*, Vol. 20, pp. 74–81.

Christian, C.S., and G.A. Stewart, 1968. Methodology of Integrated Survey. *Aerial Surveys and Integrated Studies*, UNESCO, Paris, pp. 233–280.

C.S.I.R.O., 1974. *Lands of the Balonne — Maronoa Area, Queensland*. Land Research Series, No. 34, Commonwealth Scientific and Industrial Research Organization, Melbourne.

Douglas, J.S., 1979. The Use of Remote Sensing to Map and Monitor the Natural Resources of South Australia. *Landsat 79: Proceedings 1st Australasian Remote Sensing Conference*, Sydney, 22–25 May, pp. 237–242.

D.P.I., 1980. *Waggamba Shire Handbook*, Department of Primary Industries, Brisbane.

Hacker, R.B., 1980. Prospects for Satellite Applications in Australian Rangelands, *Tropical Grasslands*, Vol. 14, pp. 288–295.

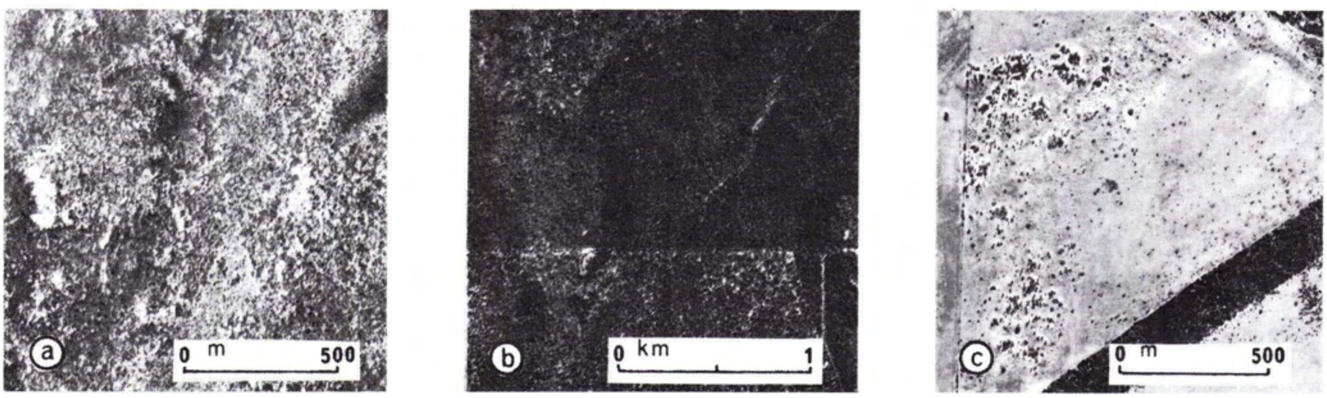

FIG. 5. Classification anomalies were present in the climax cover maps, for example: (a) This area is shown as climax bendee forest (>70 percent cover) but most of it is technically of woodland status (10 to 30 percent cover). (b) This area is shown as bull oak and popular box woodland (10 to 30 percent cover) but most of it is of open forest status (>70 percent cover). This is the case even for partially cleared areas (e.g., bottom section of photograph). (c) This area is shown as coolibah open woodland. However, the remnant strip of climax vegetation is of open forest status (30 to 70 percent cover).

Hill, G.J.E., and M.J. Hornibrook, 1981. Use of Landsat Data for Forest Classification in the Granite and Traprock Area of Queensland. *Landsat 81: Proceedings 2nd Australasian Remote Sensing Conference*, Canberra, 31 Aug.–4 Sep., pp. 2.12.1–2.12.5.

Hill, G.J.E., and G.D. Kelly, 1986. Integrating Landsat and Land Systems for Cover Maps in Southern Inland Queensland. *Australian Geographical Studies*. Vol. 24, pp. 235–243.

Jupp, D.L., E.M. Adomeit, P.M. Austin, P. Furlonger, and K.R. Mayo, 1979. The Separability of Landcover Classes on the South Coast of New South Wales. *Landsat 79: Proceedings 1st Australasian Remote Sensing Conference*, Syndey, 22–25 May, pp. 49–80.

Justice, C.O., and J.R.G. Townshend, 1981. *The Use of Landsat Data for Land Cover Inventories of Mediterranean Lands, Terrain Analysis and Remote Sensing*, edited by J.R.G. Townshend, George Allen and Unwin, pp. 133–153.

Kelly, G.D., 1984. Manual Versus Digital Analysis of Landsat Data for Landsat Mapping. *Landsat 84: Proceedings 3rd Australasian Remote Sensing Conference*, Gold Coast, 21–25 May, pp. 535–540.

Laut, P., and T.A. Paine, 1982. A Step Towards an Objective Procedure for Land Classification and Mapping. *Applied Geography*, No. 2, pp. 109–126.

Mabbutt, J.A., 1968. *Review of Concepts of Land Classification Land Evaluation*, edited by G.A. Stewart, Macmillan, pp. 11–28.

Mitchell, C.W., 1973. *Land Evaluation*, Longman, London.

Robinove, C.J., 1979. *Integrated Terrain Mapping with Digital Landsat Images in Queensland, Australia*. USGS Professional Paper No. 1102.

Story, R., G.A. Yapp, and A.T. Dunn, 1976. Landsat Patterns Considered in Relation to Resource Surveys. *Remote Sensing of Environment*, Vol. 4, pp. 281–303.

Thomas, J.L., V.M. Benning, and R.L. Bennetts, 1980. Land-use Application of Landsat. *New Zealand Agricultural Science*, Vol. 14, pp. 169–184.

Townshend, J.R.G., 1981. Chapter 5, Regionalization of Terrain and Remotely Sensed Data, in *Terrain Analysis and Remote Sensing*, edited by J.R.G. Townshend, George Allen and Unwin, pp. 109–132.

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