I. TITLE OF REPORT: A Methodology for Small Scale Rural Land Use Mapping in Semi-Arid Developing Countries Using Orbital Imagery. Part IV: Review of Land Use Surveys using orbital imagery outside of the U.S.A.

II. PRINCIPAL INVESTIGATOR: Dr. J.L. van Genderen

III. AUTHORS OF REPORT: Genderen, J.L. van and Lock, B.F.

IV. ADDRESS OF ORGANIZATION: Fairey Surveys Ltd., Reform Maidenhead, Berkshire, SL6 8BU, England

V. DATE REPORT WRITTEN: April 1976

VI. EREP INVESTIGATION NO: SR 9686

VII. NASA TECHNICAL MONITOR: Mr. Martin L.Miller, Code TF6, NASA, Johnson Space Center, Houston, Texas 77058, U.S.A.

SUMMARY OF SIGNIFICANT RESULTS

Outside of the U.S.A., various attempts have been made to investigate the feasibility of utilizing orbital MSS imagery in the production of small scale land use maps. Overall, the review has found that these studies are not as elaborate or extensive in their scope as the U.S.A. ones, and generally, the non U.S. investigators have employed unsophisticated and less expensive techniques. A representative range of studies is presented to demonstrate the approaches and trends dealing with reprocessing, interpretation, classification, sampling and ground truth procedures. Only those workers involved with visual techniques are discussed.

(All references quoted can be found in bibliography of final contractors report.

(E76-10492) A METHODOLOGY FOR SMALL SCALE RURAL LAND USE MAPPING IN SEMI-ARID DEVELOPING COUNTRIES USING ORBITAL IMAGERY. PART 4: REVIEW OF LAND USE SURVEYS USING ORBITAL (Fairey Surveys Ltd., Maidenhead G3/43

N76-31636
HC $3.50
Unclas
00492

3.3. REVIEW OF RELEVANT RESEARCH IN OTHER COUNTRIES

3.3.1. INTRODUCTION

Outside of the United States various attempts have been made to investigate the feasibility of utilizing LANDSAT MSS imagery in the production of small scale land use maps. Overall, they have not been as elaborate or extensive in their scope and have generally employed unsophisticated and less expensive techniques. As far as can be determined no comprehensive reports of non-United States research ~~has~~ have been published. However, this review is not intended to provide an exhaustive cover of investigations. Instead, a representative range of studies will be presented in an attempt to demonstrate the approaches and trends that have been considered dealing mainly with pre-processing, interpretation, classification sampling and ground truth procedures. Only those workers involved with visual techniques are discussed.

3.3.3. THE NETHERLANDS

Several studies utilizing LANDSAT imagery in developing countries have been carried out by members of I.T.C., Enschede, Holland. Among them, Rijnberg and van der Broek (1975) have made use of LANDSAT data in a preliminary soil survey and land suitability classification of a portion of S.W. Sudan to determine areas suitable for mechanised rain-fed farming. The imagery was used for basic data collection in this remote area where no aerial photographs or reliable maps exist and has also provided a basis for future planning. Preliminary investigations were also undertaken in a range of associated studies including mapping existing land use. Imagery consisted of black and white prints of each spectral band at 1:1,000,000 scale, 70 mm dia positives of the same bands and dates as well as an ozalith print at 1:250,000 of band 7 for one date and a colour composite of the same date and scale. Four unstated "landscapes" were determined but identification was mainly based on geomorphological features and vegetation patterns. The authors maintain that the use of imagery obtained at different times of the year should be considered especially with regard to

the use of colour composites as they believe that "the fine differences in colour express fine differences in ecosystems". They consider that "these spectral properties show to full advantage when soil moisture differences become critical, at some point in the early stage of the dry season". Another aspect that the investigators considered was the possibility of extrapolating "the value of a particular colour at a specific position, to the same colour somewhere else". They claim, in a subjective manner, that this was apparently possible to a large extent and that this technique assisted in the r pid preparation of the interpretation map. Also, comparison with some recently acquired aerial photographs indicated that the interpretation of the imagery had been comparatively successful.

3.3.3. SOUTH AFRICA

The Department of Planning, Pretoria has assessed the value of LANDSAT imagery in urban and regional land use mapping and inventoriz tion for planning purposes using unsophisticated techniques (la Grange et al, 1973). Clearest images were obtained using a stereoscope with 6X magnification on black and white positive prints (1:1,000,000) of bands 5 and 7 with band 6 as a "good control". Band 4 was difficult to interpret. The type and intensity of agriculture was clearly distinguished and irrigated as well as intensive and extensive dry land cultivations were identified. The investigators concluded that the LANDSAT imagery could make a significant contribution to regional land use mapping. No indication of any attempt to verify the interpretations by field checking was made.

Other researchers (Malan et al, 1974) have experimented with the production of inexpensive 1:500,000 false colour photolithographic prints of LANDSAT imagery which have been used to a limited extent in agricultural land use and planning studies. According to the researchers, the quality of the products have been consistently good and easy to interpret with limited training.

A later and very pertinent investigation by Little and Scotney (1974), Department of Agriculture, Natal Provincial Administration has also considered

the utility of LANDSAT imagery for producing land use maps using unsophisticated techniques. The research was designed to develop and test methods that could be used to record and monitor land use change and provide a basis for future land management programmes. The authors assert that due to the high cost and the time required using conventional methods and materials previous land use surveys in Natal had been unco-ordinated and patchy and that there was a distinct need for a standardised land classification scheme. Their arguments followed closely those that were preferred by Anderson and Place (1971) but they did not establish a basic set of criteria that the system should meet. Their classification system contained three levels, viz.

Level 1 - to serve broad regional requirements

Level 2 - to contain information needed for sub-regional needs

Level 3 - to key-in with the current town planning classification in Natal which records detailed building and land use.

These categories were designated by an alphabetic and colour coding system. Overall, the classification places more emphasis on urban and built-up land than the U.S.G.S. Circular 671 classification (Anderson et al, 1974) (see Table) and includes Transport, Recreation, Industry, Commerce and Extractive Industries at Level 1 (see Table).

The major interpretation technique considered was the use of various combinations of colour transparencies made by the diazo process. The resolution of the transparencies were examined at various scales from 1:1,000,000 to 1:100,000 and the researchers decided that the most suitable scale for land use detection was 1:250,000 which permitted the identification of all Level 1 categories and some Level 2. The interpreters had little experience with LANDSAT imagery but they had first hand knowledge of the area and claim that they had little difficulty adjusting to the new format. Additional detailed information from previous land use surveys carried out in 1954 and 1972 was available and used as the major method for establishing ground truth. A limited amount of field inspection was undertaken.

The investigators concluded that the date of acquisition of the imagery played an important part in the interpretation procedure and they stated that more detail could be extracted if the imagery could be obtained during different seasons. They stress that, in order to produce accurate land use maps, the interpreter should have detailed knowledge of the area and should have sufficient base maps and aerial photographs to accurately locate data. Furthermore, they believe that the diazo transparencies extend the range of interpretation and has great potential. However, this view is not shared by Viljoen and Viljoen (1975) who assert that although, in theory, diazo colour composites should be as good as photographic composites, in practice their image definition is poorer.

3.3.4. SPAIN

An attempt has been made by Spanish researchers to utilize LANDSAT data in identifying large areas of citrus groves and rice groves in the Valencia region of Eastern Spain (de Sagredo and Salinas, 1973). The basic methodology involved the delimitation of all the citrus trees and rice fields in the test sites on Natural Topographic Maps at a scale of 1:50,000 using ground truth information obtained from aerial photographs and a recent Citrus Trees Census. These plots were then reduced to various scales ranging from 1:100,000 to 1:400,000 and then compared with enlargements of imagery from each spectral band of the Landsat imagery. Preliminary results indicated that once their simple techniques became operational the imagery could be used in the production of a small scale land use map to supersede the existing one that was published in 1958.

3.3.5. SWEDEN

Researchers in Sweden have examined the possible uses of LANDSAT 1 data for environmental studies especially water quality studies and land use mapping (Hellden and Olsson, 1976). In previous research, they established pre-processing and interpretation methods involving traditional visual techniques and "an objective evaluation of the grey tones" which have allowed them to differentiate up to 18 different land use categories.

TABLE : LAND USE CLASSIFICATION (Little and Scotney, 1974)

LEVEL 1 (Regional)		LEVEL 2 (Sub-Regional)		
LAND USE	CODE	LAND USE	CODE	COLOUR
Agriculture	A	Dryland arable and grassland	Ac	738
		Sugar cane	As	
		Irrigated arable land	Aw	
		Pineapples	Aa	
		High intensity crops (veg.)	At	
		Inactive agriculture	Ai	
		Fibre crops (sisal, phorium)	Af	
		Orchards	Ao	737
		Vineyards	Av	
		Veld (grassland)	Ap	51
		Veld (karoo bush)	Ap	57
		Veld (bush thicket)	Ap	740
		Bantu farming	Ab	As above
Forestry	F	Pine plantation	Fp	41
		Wattle plantation	Fw	
		Gum plantation	Fg	
		Poplar plantation	Fm	
		Jungle	Fj	
Water Resources	W	Natural ponds, lakes, pans	Wn	740
		Artificially impounded water	Wc	
		Streams and rivers	Ws	
		Marine waters	Wm	
		Wooded wetlands (swamps)	Ww	735 / 740
		Vlei	Wb	
Commerce	C	Central business district	Cu	746
		Shopping centres	Cc	
		Strip development (commercial)	Cs	
		Tourist resorts	Cr	
		Hotels and motels	Ch	

TABLE : (continued) LAND USE CLASSIFICATION

LEVEL 1 (Regional)		LEVEL 2 (Sub-Regional)		
LAND USE	CODE	LAND USE	CODE	COLOUR
Residential Use	R	High density housing	Rh	745
		Medium density housing	Rm	
		Low density housing	Rl	
		Strip development (Housing)	Rs	
		Ribbon development (housing)	Rd	
		Rural hamlet	Rr	
		Agricultural plots and holdings	Rp	
		Bantu housing (townships)	Rb	
		Bantu housing (kraals)	Rk	
		Bantu Housing (compounds)	Rc	
Industry	I	Heavy industry	Ih	752
		Light industry	If	
Recreation	O	Outdoor recreation	Or	739
		Game reserve	Og	
		National park	On	
Extractive Industry	E	Underground mining	Eu	746 / 752
		Stone quarry	Eq	
		Sand and gravel pits	Es	
		Opencast mining	Em	
Public Areas	P	Public and semi-public areas	P	744
Transport	T	Roads and major interchanges	Th	734
		Railway facilities	Tr	1740 / 747
		Airports	Ta	1740 / 747
		Harbours	Ts	744
		Communications and utilities9	Tt	
Natural Rock and Sand	N	Exposed rock (sparse veg.)	Nt	735 / 746
		Dune sand (nil vegetation)	Ns	735
		Erosion	X	

Their latest investigation has involved the production of a 12-category land use map of the County of Kronoberg, Southern Sweden involving 27 map sheets at a scale 1:50,000 based on black and white diapositives of the four spectral bands of ~~Landsat~~ LANDSAT imagery at a scale of 1:1,000,000. Pre-processing included partial enlargements by means of an Additive Colour Viewer to produce false colour composite pictures of bands 4 (green), band 5 (blue) and band 7 (red). Detailed interpretation using a Stereoautograph ~~B & S~~ BBS permitted further enlargement up to 6 times with the aid of a connected pantograph. Additional enlargement of selected areas (up to 15 times) was carried out with an Interpretoscope. One of the major controls on the level of interpretation was the spatial resolution of the recorded Landsat imagery and that certain objects could dominate the recorded spectral response and lead to misinterpretations.

The 12 land use categories included gravel pits, fields, pastures, spruce forest, pine forest, deciduous forest, mixed forest, meadow land, lakes, bogs, marshes and built-up areas but it has not been stated whether the classification was developed specifically for this area or whether it was adapted from existing systems or whether any attempt had been made to standardise the classification system. Ground truth was carried out but few details of the method adopted have been presented. The authors claim that preliminary results indicate that the accuracy of the majority of land use categories exceeds 85%. Also a partial check has been made possible by comparing the final map with a beech forest inventory carried out in 1967-68 and results of a preliminary check have been described as satisfactory.

3.3.6. UNITED KINGDOM

The probability of using orbital imagery for land use mapping in the United Kingdom has attracted a certain amount of attention and investigations have ranged from the application of fully computerised techniques which have plotted corrected MSS data directly onto film (Smith, 1975) to

less sophisticated techniques. However, most of the research has concentrated on other countries. This may have been due to a variety of factors including the availability of research funds and the fact that the United Kingdom is not particularly suitable for the use of MSS data due to the frequent cloud cover, complex land use patterns and small field sizes. Also, several large scale national land use surveys have been carried out in the past (Coleman, 1961) and, at present, a national land use survey of the developed areas of England and Wales is being undertaken using vertical aerial photography (van Genderen and Smith, 1975). Furthermore, the United Kingdom has an extensive coverage of large scale topographic maps, thematic maps, vertical aerial photographs and statistical services.

However, Breyeton and White (1975) have considered the use of LANDSAT 1 imagery in land use mapping in hydrological studies as the nature of the land use can have considerable effect on many hydrological parameters, eg. evaporation, soil moisture content, run-off, etc.. Therefore, the provision of up-to-date information on the amount and type of land use changes could be very beneficial in their studies. Unfortunately, they have found that although LANDSAT imagery offered synoptic overviews and repetitive cover, one major drawback for United Kingdom studies has been the strong likelihood of cloud cover that either totally obscured areas or created haze problems. On the frames that they selected certain land use categories were easily detected, eg. urban areas, water bodies, and woodland but areas with detailed land use and vegetation patterns caused problems in interpretation. Rural land use was classified into four broad types, viz. intensive arable areas, extensive pastures and common land, mixed farming areas and woodlands. No deliberate attempt was made to incorporate or employ any existing land use classification system and the establishment of ground truth information was not discussed. Most of the interpretation was undertaken using black and white photographic prints and colour composites at scales of 1:1,000,000 and 1:500,000 as well

as a multi-spectral viewer. They conclude that ~~Landsat~~ LANDSAT imagery is only useful for detecting the broader features of geology, water movement and land use, especially if imagery from different seasons is available and that this type of imagery would have more value in arid countries where the collection of the imagery is not affected so much by atmospheric conditions.

A group of researchers at the University of Bristol in association with the Ministry of Agriculture have carried out a series of investigations to establish ground truth procedures for sen or testing and/or calibration and for estimating the accuracy of remote-sensing analysis (Curtis and Hooper, 1974). From their studies, they have demonstrated that the notion of a ground truth site varies according to the user's objective and the size of the study area. They have suggested that the allocation of sample plots can be mad statistically more efficient if the area can be stratified into relatively homogeneous areas (e.g. grassland)" and the number of sample plots can then be estimated by "the method of proportional allocation". The size of the sample plot should be determined by "the study objectives, statistical considerations, cale of phenomena and time factors" as well as the total area covered by each frame. Another important aspect of their studies involved a consideration of the type of data that can be collected in land classification and agricultural land-use studies. The main factors investigated were the time of observation, crop height, crop colour, perspective, soil exposure, agricultural treatments but the researchers pointed out that the range of ground data that should be collected depends on the nature of the region and its soil, relief and climatic characteristics. In general, they believe that four types of data are required if multi-purpose investigations are to be performed, viz. site morphology, crop/vegetation cover characteristics, cultivation/husbandry features and soil surface conditions.

A later study (Williams and Curtis, 1975) has extended the field studies to include seasonal and diurnal variations of many of the previously mentioned factors using a mobile ground multi-spectral data collection system and automatic recording systems that can be left running for several weeks at a time. Also, the conventional quadratting procedures used in the previous study to measure percentage crop cover was found to be too slow and new photographic quadratting techniques are being developed. However, no details of this new sampling procedure have been presented.

One of the most interesting and detailed U.K. studies has been presented by a group of researchers at University of Reading who have attempted to evaluate LANDSAT 1 MSS imagery for erosion studies, land use analysis and woodland detection within Basilicata Province, Southern Italy (Justice, Williams, Townshend and Savigear, 1976). With regard to land use, their provisional results indicate that the identification of woodland can be carried out successfully in upland areas but other types of land use especially in lowland areas are more difficult to detect. The researchers suggest that the use of texture as well as tone can provide useful results. Initial pre-processing included the preparation of enlarged prints of selected areas from each channel of the original imagery from LANDSAT 1 at scales of 1:500,000, 1:250,000 and 1:90,000 and colour composites were produced using the Diazo process and a Fairey Additive Viewer. Also, uncontrolled airphoto mosaics were compiled at 1:90,000 and 1:60,000 The data were then studied using a wide variety of interpretation techniques ranging from stereoscopes and an Interpretoscope to the use of a Fairey Additive Viewer and a Video Processing Unit. Ground truth information was collected on reconnaissance traverses in the form of general landform descriptions, vegetation and land use and ground-level photographic records. The researchers attempted "to collect information which was relatively time-independent" as the MSS data was recorded in August and November, 1972 and the field work was carried out

in March-April, 1975. No detailed description of the actual sampling procedures that were adopted has been presented but "sample areas were chosen according to preliminary pre-field tone-textural division of the LANDSAT imagery and from revisions made during the initial reconnaissance". However, the authors stated that the land use within the selected sample areas was mapped at 1:25,000 onto a topographic base and at 1:32,000 onto air-photo bases. In addition, detailed records of environmental parameters were made at "chosen sample sites within the sample areas using a site sampling card system".

The effects of scale and seasonality on the imagery were initially considered at a scale of 1:500,000 and different amounts and types of environmental information were obtained. The researchers believe that the small scale MSS imagery can be valuable as a coordinating agent for information from many different sources and provide a data source when aerial photography is unavailable as well as permitting "extrapolation from one area to another to be made with more confidence". However, they claim that these factors have limited use in regional planning and that information at much larger scales is required. Therefore, their investigations have been directed towards the interpretation of imagery at much larger scales by first looking at the delineation of woodland from other land use and secondly by attempting to distinguish different types of land use in more complex landscapes. They found that the delineation of woodland in upland areas depended on the time of the year when the imagery was recorded. On the lower areas of the test site difficulties arose when trying to distinguish between areas of evergreen pines, shrubs, olives and oranges on band 5 imagery but maquis could be distinguished from orchards and pines among a colour composite (bands 4, 5 and 7).

In the study of the more complex land use areas a six category land use classification system based on information derived from field data and aerial photographs. It appears that no attempt was made to adapt the land use categories to an existing scheme. The classification appears to have been

developed to accom[illegible] the land use existing within the par[illegible]ular area and the map "ser[illegible] the ground data with which to assess the LANDSAT imagery". The [illegible]ers found that "from a subjective visual a[illegible]lysis of the November LA[illegible]ery, the degree of tonal contrast and vari[illegible]ion and thereby p[illegible] declined in the order 5, [illegible], 7 and 4 and c[illegible]m[illegible] in the analysis". More detailed ob[illegible] of the imagery for each land u[illegible] ding Unit in five sele[illegible]d [illegible]eas[illegible]reas. [illegible]nd [illegible]e classified satisfactorily bu[illegible]our gro[illegible]ps of [illegible]sing tonal slices, vi[illegible]. bare clay land[illegible], gul[illegible]ough grazing, olive gro[illegible]es and evergre[illegible]ion in the latter class could be obtaine[illegible]alysis of the August imagery was not as [illegible]nd to be the most useful but the ease of ana[illegible] November imagery, viz. bands [illegible], [illegible] and 7. T[illegible]nterpretation of the land use patterns reco[illegible]nced by the effect of slope on land use, [illegible] imagery was recorded and the spatial resolut[illegible] in that it is doubtful whether LANDSAT imagery [illegible] ensive land use maps for the whole region mainly [illegible] between the coar[illegible] spatial resolution of the imagery and [illegible] land use patterns in certain parts of the test [illegible]er, thi[illegible] difficult to criticise objectively as t[illegible] do not di[illegible]y state the actual scale of the proposed comprehens[illegible].

An earlier study at the Department of Geography, University of Reading (Townshend, et al, 1974) compared the capabilities of LANDSAT 1 and SKYLARK Earth-Resources rocket for resource surveying in Central Argentina. Crop surveying uses the only land use aspect considered in the investigation and a direct comparison between the imagery obtained from the two platforms could not be carried out due to the different dates of data acquisition and

the lack of suitable ground truth information. The authors point out that SKYLARK has several distinct advantages, viz. greater control over the time of imagery acquisition, better spatial resolution and comparatively low cost but the advantages of repetitive monitoring and data storage facilities offered by the LANDSAT multi-spectral scanner make it more amenable for use in crop surveys.

Other groups of U.K. researchers have been active in investigating the extend to which LANDSAT imagery can be utilized in land resource surveys in developing countries by employing low cost techniques. King and Blair Rains (1974) have compared LANDSAT-1 imagery with pan-chromatic aerial photography for use in land resource surveys and considered the Rift Valley Lakes Basin, Ethiopia as a test site. They believe that the LANDSAT imagery is a "significant aid to map production in areas where the present map coverage is poor, but its scale is too small for detailed analysis". However, the latter criticism may have been caused by the researchers as they restricted themselves to a narrow selection of MSS imagery. They stated that "apart from some enlargements to 1:500,000 and 1:250,000, most of the analysis was undertaken using black and white paper prints at 1:1,000,000" and separate bands were compared using a mirror stereoscope. No mention of optical enlargement was made. In addition, they considered a colour composite of one frame and "coloured translumencies (ammonia paper)" - diano? - of each band of another frame but they did not state the scales. They conclude, from their observations, that because of its synoptic overview, repetitive cover and especially its low cost, LANDSAT imagery can be useful in land resource surveys" but only as an additional tool to the available aerial photography".

Hunting Surveys and Professor Shackleton, University of Leeds have examined the potential of LANDSAT imagery for mapping a variety of natural resources including soils and land forms, vegetation and land use in addition to their primary task of using the imagery to revise the geological map of Ethiopia (White, 1974). The investigators assert that

"single channel black and white imagery is not satisfactory for mapping vegetation and land use in Ethiopia". They believe that spectral colour comparison is essential and they used false colour prints and a multi-spectral viewer in their studies. Although the investigation with respect to land use was only exploratory, the researchers believe that "it appears to be perfectly feasible to map out the major vegetation formation and land usage". No attempt was made to develop an overall land use classification scheme or to describe ground truth procedures but some field checking of initial interpretations was carried by making "a few traverses by Land Rover". The researchers made a generalized conclusion by stating that "different subjects, however, require different levels of supporting ground information and also different formats of imagery" but do not offer any detailed advice. However, they do stress that they agree with other investigators that LANDSAT imagery, due to its synoptic overview can be an "excellent first-stage approach to the surveys necessary for development and management" as well as the monitoring of dynamic situations.

3.3.7. U.N. FOOD AND AGRICULTURE ORGANISATION

Howard (1974) has presented a general report on the F.A.O.'s investigations in applying LANDSAT imagery in a range of projects in developing countries including Morocco, Ethiopia and Sudan. He states that initially the imagery was used to provide synoptic views as an aid to regional surveys but this interest has extended to the use of re-constituted ~~re-constructed~~ false colour imagery and computer-generated false colour mosaics and large scale maps. Furthermore, he claims that the LANDSAT imagery can be used to provide a very wide range of valuable data including thematic maps at a scale of 1:250,000 which provide background information for areas that have previously been unmapped and could also assist in monitoring landscape changes. In particular, he is very enthusiastic about the role of orbital imagery in integrated surveys of land use and natural resources and stresses that "the potential

contribution of satellite imagery to integrated surveys in developing countries is only beginning to be appreciated". Overall, the article pursues the concept that geomorphology should be the central component in integrated surveys and, consequently, it does not offer any concrete guidance for the production of small-scale land use maps, per se, other than some indirect comments on pre-processing and interpretation.

3.3.8. VENEZUELA

Conventional photo-interpretation techniques have been applied to LANDSAT imagery in a study of the Valencia Lake Basin region, Venezuela (Salas et al, 1974). Common instruments, viz, a magnifying glass and microfilm reader were used to identify tonal contrasts on colour composites and bands 5 and 7 (presumably black and white paper prints) at scales ranging from 1:1,000,000 to 1:100,000. Basically, the project was designed to assess the use of aerial photographic interpretation techniques to determine the amount of human intervention on the natural landscape. A two level vegetation/land use classification system was developed with the first level being determined by classifying "toning groups by aggregating tonal similarities to micro-relief units and sociological aspect of vegetation". At the second level, the tonal characteristics derived at the first level were sub-divided into more detailed vegetation and land use sub-classifications. Ground truth procedure involved the use of panchromatic photographs at scales of 1:50,000 and 1:25,000 and field checking. The authors used a sampling technique to determine and map the degree of human intervention and to define more precisely the vegetation borders and agricultural types.

3.3.9. SUMMARY

In a similar manner to the investigations in the United States, researchers in other parts of the world have tended to concentrate on only a few of the stages involved in producing small scale rural land use maps from LANDSAT imagery. Some have presented interesting statements on various pre-processing techniques (Little and Scotney, 1974; King and

Blair Rains, 1974; Justice et al, 1976; Rijnberg and van der Broek, 1975). Other aspects including factors that have influenced the interpretation of the MSS imagery and the gathering of satisfactory ground truth information have also been considered (Curtis and Hooper, 1974; Williams and Curtis, 1975; Justice et al, 1976). Apparently the problem of standardisation of land use classification schemes has not concerned most of the investigators who appear to have adapted existing local schemes or they have devised their own scheme to fit their research objectives. However, Little and Scotney (1974) have proposed a classification scheme in an attempt to standardise land use mapping in Natal, South Africa (see Table). It is probably the most interesting classification that has been developed outside of the United States. Unfortunately, it does not have the general flexibility offered by U.S.G.S. Circular 671 (Anderson, 1974) (see Table).

Most of the investigators have praised the synoptic overview, the monitoring capabilities and the rapid collection of dat offered by the LANDSAT multi-spectral scanning system. Also, they have considered many of the factors that caused concern with the U.S. researchers including the selection of a satisfactory final map scale (Howard, 1974; Little and Scotney, 1974; King and Blair Rains, 1974) and the correct selection of spectral bands (Justice et al, 1976; la Grange et al, 1973; de Sagredo and Salas, 1977; Salas et al, 1974). The problems caused by the time of acquisition of the imagery also concerned some researchers (Brexton and White, 1975; Justice et al, 1976; Rijnberg and van der Broek, 1975) and Little and Scotney (1974) emphasised that the interpreter should have a good knowledge of the region being studied.

3.4. GENERAL SUMMARY

This chapter has shown that, although there has been many detailed studies in various aspects of small scale land use surveys, there has been no satisfactory overall attempt, either in the United States or elsewhere, to bring together all the findings of the researchers. It is evident,

therefore, that the formulation of a methodology detailing all the stages of the preparation of the maps which would establish the general framework for the rapid and inexpensive production of this type of map could provide extremely valuable assistance to individuals or organisations wishing to produce small scale land use maps from LANDSAT imagery. If presented satisfactorily, the methodology should avert the necessity for detailed research and testing of the many different aspects involved in the production. However, before the methodology can be formulated a more detailed criticism of specific points emphasised by previously mentioned researchers will be considered in the next chapter under the categories of pre-processing, interpretation, classification and ground truth. In addition, a range of relevant comments presented by workers in other areas of research will be investigated and then, in the following chapter, a number of techniques ~~and~~ will be evaluated before the detailed methodology is presented.