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I. TITLE OF REPORT: A Methodology for Small Scale Rural Land Use Mapping in Semi-Arid Developing Countries using Orbital Imagery Part VI: A Low-Cost Method for land use mapping using simple visual techniques of interpretation.

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## SUMMARY OF SIGNIFICANT RESULTS

The paper describes a viable operational methodology for the rapid production of small scale rural land use maps of semi-arid developing countries from LANDSAT multispectral orbital imagery using inexpensive and unsophisticated techniques. It was found that colour composite transparencies and monocular magnification provided the best base for land use interpretation. New methods for determining optimum sample sizes and analyzing interpretation accuracy levels were developed. All stages of the methodology were assessed, in the operational sense, during the production of a 1:250,000 rural land use map of Murcia Province, South-East Spain.



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# INTRODUCTION

The major aim of this research project was to develop a viable methodology for producing small scale rural land use maps in semi-arid developing countries using imagery obtained from orbital multi-spectral scanners (MSS). At present no such methodology is available, and it was felt that there was an urgent need for a detailed description of all the stages involved in the production of small scale land use maps using MSS data, similar to the methodologies that have been developed for use with conventional aerial photography.

Until the 1960's, detailed rural land use surveys have been mainly carried out in developed countries and land use maps have been produced for a range of purposes with a wide variety of scales and classifications. The primary purpose of these surveys has been to determine the spatial distribution of land use at a particular time. The resultant land use maps have provided planners with useful analytical tools for general or reconnaissance evaluations as well as establishing a permanent data base as part of a continual monitoring system of the landscape. These surveys have been carried out using time-consuming and often expensive methods involving the collection of information from various statistical agencies, field reports and vertical black and white panchromatic aerial photography (Kriesman, 1969).

With the emergence of many new independent nations since World War 11, the planning of their economic development policies has often necessitated the use of medium-small scale land use maps which have permitted broad overviews of regions and have provided the bases for more detailed and diverse investigations at larger scales. Also, with the ensuing changes in agricultural products and land management procedures, they have provided a system for establishing permanent and systematic records of landscape changes.

However, there have been problems in the production of these medium-small scale land use maps in both developing and developed countries mainly associated with the collection of base data (Thaman, 1974).

Although the development of techniques for collecting remotely sensed data has progressed very rapidly, many problems still persist in the utilisation of the information. They include the correct selection and calibration of sensors for specific purposes as well as an understanding of their design capabilities and functions. Also, the identification of image characteristics and the lack of clarity caused by the quality and resolution factors of the remotely sensed data have presented difficulties in the interpretation of land use at medium to small scales (Landgrebe, 1972). Seasonality or the time of imagery acquisition is another important factor that can affect the nature of the data collected (Owen-Jones, 1975).

Other problems include the lack of appropriate techniques for establishing ground truth using satisfactory sampling techniques (Kelly, 1970; Zonneveld, 1974; Allan, 1975), the lack of a proven and versatile land use classification scheme suitable for use with small scale imagery (Anderson, 1971; Anderson et al., 1972; Dodt and van der Zee, 1974) and the lack of adequate training for persons involved in interpreting this imagery(Nunnally, 1974). Also, the high costs incurred in using many of the computer based interpretation systems that have been evolving during the last two or three years will probably preclude their future use in many countries (Sweet et al., 1974; Lietzke & Stevenson, 1974).

It is apparent, therefore, that a detailed methodology for producing small scale rural land use maps from data obtained by remote sensing techniques could have immediate practical applications. The objective then, has been to produce a methodology that could be applied using relatively accessible equipment and materials, as many developing countries lack suitably qualified staff, technology and equipment. In addition, it appears that adequately tested automatic systems for interpreting land use patterns from orbital imagery will not be functional in the foreseeable future (Hempenius 1975; Savigear et al 1975). These systems need to incorporate spatial, spectral and temporal factors in order to interpret land use under a wide range of conditions and, although much research has been carried out, no completely successful system has been developed.

For a more detailed description of the methodology described in this paper, the reader is referred to Genderen, J.L. van and Lock, B.F. 1976 . That publication includes a critical evaluation of relevant remote sensing techniques that can be utilized in carrying out land use surveys, guidance on pre-processing procedures, selection of correct data bases, discussion of map scale selection, interpretation procedures, the development of suitable land use classification schemes, clarification of ground truth procedures, especially sampling methods and the production of the final land use map.

This methodology presents a basis from which medium-scale rural land use maps can be produced without resorting to exhaustive background research and training, or the use of expensive equipment and technologies.

# THE METHODOLOGY

The methodology has been divided into two stages, viz. pre-operational and operational. Basically, the pre-operational stage involves the careful selection of the appropriate interpretation techniques and imagery that may be used in the operational stage where the actual land use map is produced. All aspects of both stages are considered to be particularly relevant and to achieve optimum results in the final map, adequate attention must be paid to the planning, selection and preparation of imagery and techniques before the interpretation process commences.

In order to assist the detailed explanation of the proposed methodology, a diagrammetric representation of the whole procedure has been devised. Each main step has been numbered and further explanations and expanded diagrams have been presented (see Figure 1). Various alternatives are listed in several of these steps and it is possible for an investigator to select from these suggestions or he may adopt the recommended approval if he wishes.

The recommended route through the different steps in both the pre-operational and operational stages has been shown as a solid black line and several alternative routes have also been shown (see Figure 1).

## 1. Pre-Operational Stage

Planning: This initial phase of the methodology has been divided into two main steps which establish the basis for the whole mapping operation. The first step entails the detailed clarification of the purpose of the map and a statement of objectives that need to be fulfilled in order to produce the desired map. These, in turn, influence decisions that must be made about the most appropriate scale and detailed specifications of the final map. The framing of the objectives and the final mapping scale and specifications requires a careful consideration of possible imagery, base maps and other reference material. Once the objectives have been defined, standard pre-processed LANDSAT MSS imagery can then be selected and purchased from EROS Data Center or any authorised organisation. However, this step can provide difficulties for investigators unfamiliar with the different types of LANDSAT MSS imagery as it can be obtained at four different scales, in four different black and white positive or negative spectral bands and in transparency or paper print format. In addition, colour composites are available as transparencies or opaque prints at various scales (see Figure 3). Obviously, this wide choice could lead to much unwarranted expence if guidance is unobtainable, as imagery for each spectral band is not required in rural land use investigations. In addition, imagery should be selected so that the seasonal variations in vegetation cover can be utilised in the accurate delineation and identification of land use boundaries and categories.

The recommended standard pre-processed imagery of each LANDSAT MSS frame for rural land use mapping consists of one 1:1,000,000 false colour composite transparency, if available, or one each 1:1,000,000 black and white positive transparencies of bands 4,5 and 7 for producing colour composites by the diazo process. In addition, one 1:250,000 colour composite print or, if unavailable, one 1:250,000 paper print of band 5 are required.

Preparation:

This phase involves the procedures necessary to provide a satisfactory base for the detailed interpretation of the land use in the operational stage of mapping. The first step necessitates a preliminary interpretation of the purchased standard imagery in order to establish whether further "in-house" pre-processing is required. (Step 2, Figure 3). The quality of interpretation is not only affected by the quality and seasonality of the imagery but it is also a function of the interpreter's reference level, the collateral material available and the visual optical enhancement techniques that can be employed. Details of these aspects are summarised in Figure 4. Adequate care should be taken to ensure that the interpreter spends sufficient time in becoming familiar with the nature of the MSS imagery and the spectral responses of the region as the level of interpretation skill at this stage tends to influence the framing of the land use classification scheme, the selection of visual enhancement equipment and the type and amount of additional pre-processing. The familiarisation with the imagery should be achieved by considering relevant collateral data about the region as well as the methods used in acquiring and processing the LANDSAT MSS data.

Once the interpreter becomes accustomed to the imagery, a preliminary land use classification scheme can be evolved which should be as broad as possible within the limitations imposed by the final mapping scale, the image scale and resolution and the spectral responses of the vegetation cover (see Figure 5). In addition, it involves the integration of relevant collateral material, the interpreter's reference level and guidelines from other similar land use classification systems, especially the system outlined in the U.S. Geological Survey Circular 671. However, before the system is produced a set of criteria should be established which define the conditions which the system should meet. These criteria should reflect the scope of the mapping objectives and they should provide adequate guidelines for the development of a satisfactory classification system that will be appropriate for the region. Probably the best guidance with regard to the framing of criteria and designing of the structure of a land use classification system for use with LANDSAT MSS imagery can be obtained from U.S. Geological Survey Circular 671. This system basically consists of two levels of classification and both levels are based on a description of the land use which is expressed in terms of vegetation cover rather than an activity-oriented classification. Level 1 contains categories which express broader types of land use and it is more directly applicable for use with small scale orbital imagery. Level 2 categories are more detailed sub-classifications of Level 1 categories and they are designed for use with larger scale orbital and high altitude air imagery. Further details about this system are provided in Tables 1 and 2.

As a result of the assessment of the imagery during the preliminary interpretation step and the development of the initial classification system, any further pre-processing that can assist in the operational interpretation should be undertaken. Essentially, this involves photographic enhancement of the standard LANDSAT MSS imagery and available aerial photography, especially enlargements and/or the use of the diazo process to produce colour composites (see Figure 6). In addition, some other pre-processing to produce imagery in 35 mm. or 70 mm. slide formats for certain parts of the region may be carried out.

After considering all available techniques and imagery, those most appropriate for use in the operational stage of the map production may then be selected. The approach that was adopted in the production of the land use map or Murcia Province and the one that is recommended for future use in operational rural land use surveys utilising LANDSAT MSS imagery is outlined in Figure 7.

Several choices of imagery are available. Instead of the expensive standard colour composites, diazo colour prints of bands 4,5 and 7 of each frame can be made from the black and white positives and super-imposed to produce satisfactory colour composites. Also, an enlarged black and white positive print of band 5 at 1:250,000 could be used as an alternative to the standard opaque print of the colour composite at 1:250,000. In addition, other supplementary materials and equipment that may be used to assist interpretation include air photo mosaics at various scales, slides of portions of selected areas of LANDSAT MSS imagery for viewing with 35 mm. or 70 mm. projectors and relevant reports.

2. Operational Stage

The first major step in the operational stage consists of the detailed interpretation of the selected LANDSAT MSS imagery and the production of the preliminary rural land use map (step 7). In the detailed interpretation, colour is used as the main image interpretation element in the detection, recognition, delineation and classification of the different land use categories. The other interpretation elements e.g. shape, size, texture, site, etc. are all used to varying degrees depending on the type of land use being investigated. Again, the potential accuracy level depends on the interpreter's reference level with regard to his training in image interpretation, his knowledge of specific related subjects and his familiarity with the spectral characteristics of the LANDSAT MSS imagery. Colour composite transparencies of each frame at a scale of 1:1,000,000 (either standard or diazo) with rear illumination from a light table are initially viewed under monocular magnification to detect areas of similar colour. Then, when familiar with the colour and resolution characteristics, areas of similar land use are identified by extrapolating away from the colours of areas of known land use. These areas can be identified from various sources including relevant reports, topographic and thematic maps of parts of the region and air-photo interpretation of available aerial photographs or mosaics. The location of the similar areas can be facilitated by the use of a specially prepared transparent base map containing selected topographic data at a scale of 1:250,000.

Further enhancement to aid the interpretation of difficult areas can be achieved by other optical enhancement techniques,especially slide projectors, microfiche and micro-film readers which may be used to enlarge optically, imagery of certain portions of the region that require further investigation. Also, the spectral responses recorded on imagery acquired during different seasons (multi-date imagery) should be viewed as an additional aid in clarifying boundaries and categories.

Once the interpretation has been completed the boundaries and categories can be transferred to a transparent base map from the 1:250,000 colour composite print or black and white enlargement of band 5. In this case, the recommended base map scale should be the same as the print containing the interpreted data, i.e. 1:250,000 and it should contain sufficient information to permit the location of land use boundaries in the field.

Other aspects involved in the preparation of the preliminary land use map include the determination of the minimum size of the area of categories that should be mapped. The generally accepted minimum size, based on a map scale of 1:250,000, is approximately 25 hectares (60 acres) which represents an area of 4 sq mm. on the map. As a consequence, areas of land use smaller than this size should be absorbed within the surrounding category unless there are certain circumstances which necessitate their inclusion on the map. For example, certain areas of irrigated land may have special significance and may be easily identified and mapped. Then, appropriate symbols and colours for each category should be added to the map to enable easy identification of areas in the field. Finally, the map should be checked for omissions in the interpretation phase and in the process of transferring data to the base map.

This can be achieved by first overlaying the transparent map onto the 1:250,000 print used in the interpretation and then systematically checking within each graticule of a selected grid system e.g. 1:50,000 topographic map system.

ESTABLISHMENT OF GROUND TRUTH (Step 8)

The next step in the operation is one that is occassionally omitted from the overall mapping procedure (see Figure 1). It involves the establishment of ground truth or, in other words, it enables the accuracy of the interpretation of the land use from LANDSAT MSS to be assessed and, consequently, should form an important part of the mapping operation. The suggested method can be divided into three parts, viz: the sampling strategy, field data collection and the analysis of data (see Figure 9).

In the sampling strategy phase, a stratified random sampling technique has been found to be the most appropriate method available and stratification is achieved by using the different categories of the land use classification system. The number of points for each category is obtained by consulting Tables 3, 4 and 5 which indicate the appropriate number of sample points required for the prescribed interpretation accuracy level. In practice, the optimum sample size is obtained by adding several more sites to the value derived from the tables as certain factors, e.g. bad weather and prohibited access may prevent detail at certain sites from being recorded. Random sampling is then carried out over the whole area using co-ordinates generated from random number tables. These points are then plotted onto the preliminary land use map which overlays millimetre graph paper. Thus, the inter-sections of lines on this graph paper represent the centres of 250 m. squares on the ground. When the desired optimum number of points has been reached for a particular category no more random points are added to the list for that category. Ideally, random sampling continues until the optimum number is reached for each category. However, in practice, the areal distribution and coverage of some categories may be too small to permit the generation of enough random points.

Field data collection requires careful planning to make certain that the appropriate data are collected as rapidly as possible and that the data will provide a satisfactory check on the level of interpretation as well as isolating possible reasons for mis-interpretation. This is best achieved in the field by using data collection sheet designed for rapid recording and easy analysis of appropriate information.

After all the sites have been visited, the data collection sheets should be analysed to determine whether the prescribed accuracy level of the interpretation of each land use category had been met. This can be achieved by referring back to Tables 3, 4 and 5. If the number of errors for a particular sample size at 90% accuracy level is too great (Table 5), then the 85% accuracy level may have to be accepted. (Table 4). If the errors are still too high either the accuracy level must be lowered further or the 85% level may be accepted with the knowledge that the probability of incorrect interpretations is going to be higher than the normally accepted 5% probability level.

Further investigation of the data collection sheets may permit subjective as well as statistical analyses of the types of interpretation errors that were made. If the accuracy level and reasons for mis-interpretation warrant it, then a reassessment of the mapping operation may be required. This could possibly mean a complete review of the mapping objectives and specifications if the results are particularly bad. Or, it could mean a review at other steps in the overall methodology indicated by alternative route (a) shown on Figure 1.

Correction of Preliminary Rural Land Use Map:

If the accuracy of interpretation as indicated by the ground truth investigation is accepted as sufficient, then corrections to the preliminary map can commence. Initially, any changes to the classification system should be carried out, i.e. any classification changes indicated by the field survey where certain categories should be collapsed due to the low interpretation accuracy at Level 2. The final classification system should then be devised with brief but adequate descriptions of each category and sub-category. Then, any specific queries noted on traverses or at sample sites should be checked on the imagery and relevant changes made to the map. This is particularly applicable to the location of boundaries between categories.

Final Map:

The production of the final map involves the presentation of the map in its completed state ready for application in the tasks for which it was designed. It entails the re-drawing of the corrected and generalised data shown on the preliminary map and it also includes the normal cartographic procedures of devising a satisfactory overall layout, the design of a legend incorporating the classification system, and the selection of lettering, symbols and colours. One suggestion regarding colours suitable for land use mapping with LANDSAT MSS imagery has been made by Paludan (1973). It is also outlined in Peterson (1975). The main aim of this colour scheme has been to make land use maps prepared from this data source as compatible as possible.

Once completed the final map can then be used as a final "colour rough" for colour printing or it may be used directly as the base map for further investigations within the region. An important addition to the final map should be a report detailing the purpose, objectives and specifications of the map as well as possible recommendations for potential map users. It should also include explanations of the various pre-processing, interpretation, classification and ground truth procedures adopted during the production of the map.

## CONCLUSIONS

The results of this study have shown that it is feasible to design a methodology that can provide suitable guidelines for the operational production of small scale rural land use maps of semi-arid developing regions from LANDSAT MSS imagery using inexpensive and unsophisticated techniques. The suggested methodology should provide immediate practical benefits to map-makers attempting to produce land use maps in countries with limited budgets and equipment. As the LANDSAT MSS imagery system permits regular synoptic coverage of the Earth's surface, it provides an ideal method for establishing a satisfactory data base and further monitoring of land use changes over large areas.

Initially, many pre-processing and interpretation techniques were considered and rejected on the grounds that they were inappropriate mainly due to the high cost of the imagery equipment or their inadequacy for use in the operational sense.

The suggested imagery and interpretation techniques consisting of colour composites and monocular magnification proved to be the simplest, fastest and most versatile method.

In order to maintain a standardised classification of land use, the criteria and hierachical structure presented in the U.S.G.S. Circular 671 were found to be acceptable as a general basis for researchers and organisations wishing to develop systems for their own regions. However, it should be stressed that these recommendations should only be used as guidelines for the development of an adequate system for a particular region.

As no satisfactory method could be located which provided directions for systematically analysing the results of the interpretation, a new scheme was devised and tested. This situation arises from the fact that the concept incorporates the probability of making incorrect interpretations at particular prescribed accuracy levels e.g. 85% or 90% for a certain number of errors e.g. 0,1,2,3 etc. for a particular sample size. This contrasts with the usual practice of expressing the interpretation errors as a percentage of a subjectively derived number of sample sites. Consequently, it is felt that this approach offers a more meaningful explanation of the interpretation accuracy level of the whole operation and within each category. Furthermore, it should prove to be very useful in other types of operational remote sensing projects where stringent specifications need to be met but, prior to this study it was not possible to check the accuracy of the work in any reliable, statistical manner.

In conclusion, it has been demonstrated that the proposed methodology can play an important role in providing a suitable link between the acquisition of the LANDSAT MSS data and its operational application in land use mapping using inexpensive techniques.

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BIBLIOGRAPHY

ALLAN, J.A. (1975). Land use in the Merida (Badajoz) region of Spain. An application of the LARS System 3 in a complex agricultural area using ERTS-1 imagery. Unpublished paper presented at the Second Annual General Conference of the Remote Sensing Society, National College of Agricultural Engineering, Silsoe, Bedfordshire, 9-11 Sept., 1975.

ANDERSON, J.R., HARDY, E.E. and ROACH, J.T. (1972). A land-use classification system for use with remote sensor data. Washington D.C., U.S. Geological Survey, Circular 671, 16 pp.

DODT, J. and ZEE, D. van der (1974). Identification of rural land-use types. I.T.C. Journal, 1974, 599-616

GENDEREN, J.L. VAN and LOCK, B.F. 1976: A Methodology for Producing Small Scale Rural Land Use Maps in Semi-Arid Developing Countries Using Orbital MSS Imagery. (Final Contractor's Report (NASA - CR), 270 pp

HEMPENIUS, S.A. (1975). Critical review of the status or remote sensing. Unpublished paper presented at 35th Photogrammetric Week, Oberkochen, W. Germany, 14 pp.

KELLY, B.W. (1970). Sampling and statistical problems. Remote sensing, with special reference to agriculture and forestry, Washington, D.C., National Academy of Sciences, 329-353.

KREISMAN, A.J. (1969). Land use surveys by aerial photographic methods. Physical resource investigations for economic development: a case book of OAS field experience in Latin America, Washington D.C., Organisation of American States, 277-305.

LANDGREBE, D. (1972). Systems approach to the use of remote sensing. International workshop on earth resources survey systems, Washington, D.C., NASA, vol. 1, 139-154 (NASA-SP-283-Vol-1).

LIETZKE, K.R. and STEVENSON, P.A. (1974). The economic value of remote sensing of earth resources from space: an ERTS overview and the value of continuity of service, vol. 6. Land Use, Pt. 1: Introduction and Overview. Princeton, N.J., Econ. Inc., 56 pp. (NASA-CR-141266; Rept-74-2002-10-Vol-6-Pt-1).

NUNNALLY, N.R. (1974). Interpreting land use from remote sensor imagery. Remote sensing: techniques for environmental analysis, ed. J.E. Estes and L.W. Senger, Santa Barbara, California, Hamilton Publishing Co., 167-187.

OWEN-JONES, E.S. (1975). Pattern classification of agricultural and non-agricultural areas. Remote sensing data processing, ed. J.L. van Genderen and W.G. Collins, Sheffield, University of Sheffield for Remote Sensing Society, 73-95.

PALUDAN, C.T.N. (1973). Research in remote sensing of land use. Huntsville, Marshall Space Flight Center, Environmental Applications Office.

PETERSON, R.A. (1975). Techniques for acquiring and employing ERTS-1 photographs for land-use mapping. Professional Geographer, 27, 221-227.

SAVIGEAR, R.A.G. et al. (1975). An approach to the evaluation of multi-spectral scanning systems. Multispectral scanning systems and their potential application to earth resources surveys, ed. R.A.G. Savigear, et al. Paris, ESRO, 7-50 (ESRO-CR-234).

SWEET, D.C., et. al. (1974). Multi-disciplinary applications of ERTS and SKYLAB data in Ohio. Procedures of the Ninth International Symposium On Remote Sensing of Environment, Ann Arbor, Environmental Research Institute of Michigan, 2093-2106.

THAMAN, R.R. (1974). Remote sensing of agricultural resources. Remote sensing: techniques for environmental analysis, ed. J.E. Estes and L.W. Senger, Santa Barbara, California, Hamilton Publishing Co., 189-223

ZONNEVELD, I.S. (1974). Aerial photography, remote sensing and ecology. I.T.C Journal, 1974, 553-560.

TABLE 1. LAND USE CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA (U.S. Geological Survey Circular 671; U.S. Department of the Interior, 1972)

Prepared by: J.R. Anderson, E.E. Hardy, J.T. Roach

| Level 1 | Level 2 |
|---|---|
| 1. Urban and Built-up Land | 1. Residential<br>2. Commercial Services<br>3. Industrial<br>4. Extractive<br>5. Transportation, Communications, and Utilities<br>6. Institutional<br>7. Strip and Clustered Settlement<br>8. Mixed<br>9. Open and Other |
| 2. Agricultural Land | 1. Cropland and Pasture<br>2. Orchards, Groves, Bush Fruits, Vineyards, and Horticultural Areas<br>3. Feeding Operations<br>4. Other |
| 3. Rangeland | 1. Grass<br>2. Savannas (Palmetto Priaries)<br>3. Chaparral<br>4. Desert Shrub |
| 4. Forest Land | 1. Deciduous<br>2. Evergreen (Coniferous and Other)<br>3. Mixed |
| 5. Water | 1. Streams and Waterways<br>2. Lakes<br>3. Reservoirs<br>4. Bays and Estuaries<br>5. Other |
| 6. Unforested Wetland | 1. Vegetated<br>2. Bare |
| 7. Barren Land | 1. Salt Flats<br>2. Beaches<br>3. Sand other than Beaches<br>4. Bare Exposed Rock<br>5. Other |
| 8. Tundra | |
| 9. Permanent Snow and Ice Fields | |

TABLE 2. TENTATIVELY PROPOSED REVISIONS FOR A LAND USE

CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA
(U.S.G.S. Circular 671)

Prepared by: James R. Anderson, Chief Geographer,
U.S. Geological Survey; October, 1973

| Level 1 | Level 2 |
|---|---|
| 1. Urban and Built-up Land | 1. Residential<br>2. Commercial and Services (including institutional)<br>3. Industrial<br>4. Extractive (excluding strip mining, quarries, and gravel pits, etc.)<br>5. Transportation, Communications, and Utilities<br>6. Mixed (including strip and clustered settlement)<br>7. Open and Other |
| 2. Agricultural Land | 1. Cropland and Pasture<br>2. Orchards, Groves, Vineyards and Ornamental Horticultural Areas<br>3. Confined Feeding Operations<br>4. Other |
| 3. Forestland | 1. Deciduous<br>2. Evergreen (coniferous and others)<br>3. Mixed |
| 4. Wetland | 1. Forested<br>2. Non-forested |
| 5. Rangeland | 1. Herbaceous Range<br>2. Shrub-Brushland Range<br>3. Mixed |
| 6. Water | 1. Streams<br>2. Lakes<br>3. Reservoirs<br>4. Bays and Estuaries<br>5. Other |
| 7. Tundra | (Proposed level-2 categories are currently under study in Alaska and will be reported separately) |
| 8. Permanent Snow, Icefield, and Glaciers | (Proposed level-2 categories are currently under study in Alaska and will be reported weparately) |
| 9. Barren Land | 1. Salt Flats<br>2. Beaches (including mudflats)<br>3. Sandy Areas other than Beaches<br>4. Bare Exposed Rock<br>5. Strip mines, quarries, and gravel pits<br>6. Transitional Areas<br>7. Other |



(from Third ERTS Symposium, N.A.S.A., 1974, pp. 31-32)

TABLE 3

PROBABILITY OF SCORING NO ERRORS IN SAMPLES OF VARYING SIZES FROM A POPULATION WITH A RANGE OF REAL ERROR PROPORTIONS q

SAMPLE SIZE

specified interpretation accuracy

| q \ x | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 60 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| .99 | | | | | | | | | | | 0.5472 |
| .95 | | | | | | 0.2146 | 0.1661 | 0.1285 | 0.0994 | 0.0769 | 0.0461 |
| .90 | | | 0.2059 | 0.1216 | 0.0718 | 0.0424 | 0.0250 | 0.0148 | 0.0087 | 0.0052 | 0.0461 |
| .85 | | | 0.0874 | 0.0388 | 0.0172 | | | | | | |
| .80 | | 0.1074 | 0.0352 | | | | | | | | |
| .70 | 0.1681 | 0.0282 | | | | | | | | | |
| .60 | 0.0778 | | | | | | | | | | |
| .50 | 0.0313 | | | | | | | | | | |

——— stepped line indicates approximate .05 level of probability

TABLE 4

PROBABILITY OF SCORING ERRORS IN SAMPLES OF VARYING SIZES FROM A POPULATION WITH REAL ERROR PROPORTION OF 85%

i.e. THE SPECIFIED INTERPRETATION ACCURACY LEVEL IS 85%

| sample size \ number of errors (f) | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 15 | .0874 | | | | | |
| 20 | .0388 | .1368 | | | | |
| 25 | .0172 | .0759 | .1607 | | | |
| 30 | .0076 | .0404 | .1034 | | | |
| 35 | .0034 | .0209 | .0627 | .1218 | | |
| 40 | | | .0365 | .0816 | | |
| 45 | | | .0206 | .0520 | .0963 | |
| 50 | | | | .0319 | .0661 | .1072 |
| 55 | | | | .0189 | .0434 | .0781 |
| 60 | | | | | .0275 | .0544 |
| 65 | | | | | | .0365 |

TABLE 5

PROBABILITY OF SCORING ERRORS IN SAMPLES OF VARYING SIZES FROM A POPULATION WITH REAL ERROR PROPORTION OF 90%, i.e. THE SPECIFIED INTERPRETATION ACCURACY LEVEL IS 90%

| sample size \ number of errors (f) | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| 15 | .2059 | | | |
| 20 | .1216 | | | |
| 25 | .0718 | .1994 | | |
| 30 | .0424 | .1413 | | |
| 35 | .0250 | .0973 | | |
| 40 | | .0657 | | |
| 45 | | .0436 | .1067 | |
| 50 | | .0286 | .0779 | |
| 55 | | | .0558 | .1095 |
| 60 | | | .0393 | .0844 |
| 65 | | | | .0636 |
| 70 | | | | .0470 |

______ stepped line indicates approximate .05 level of probability

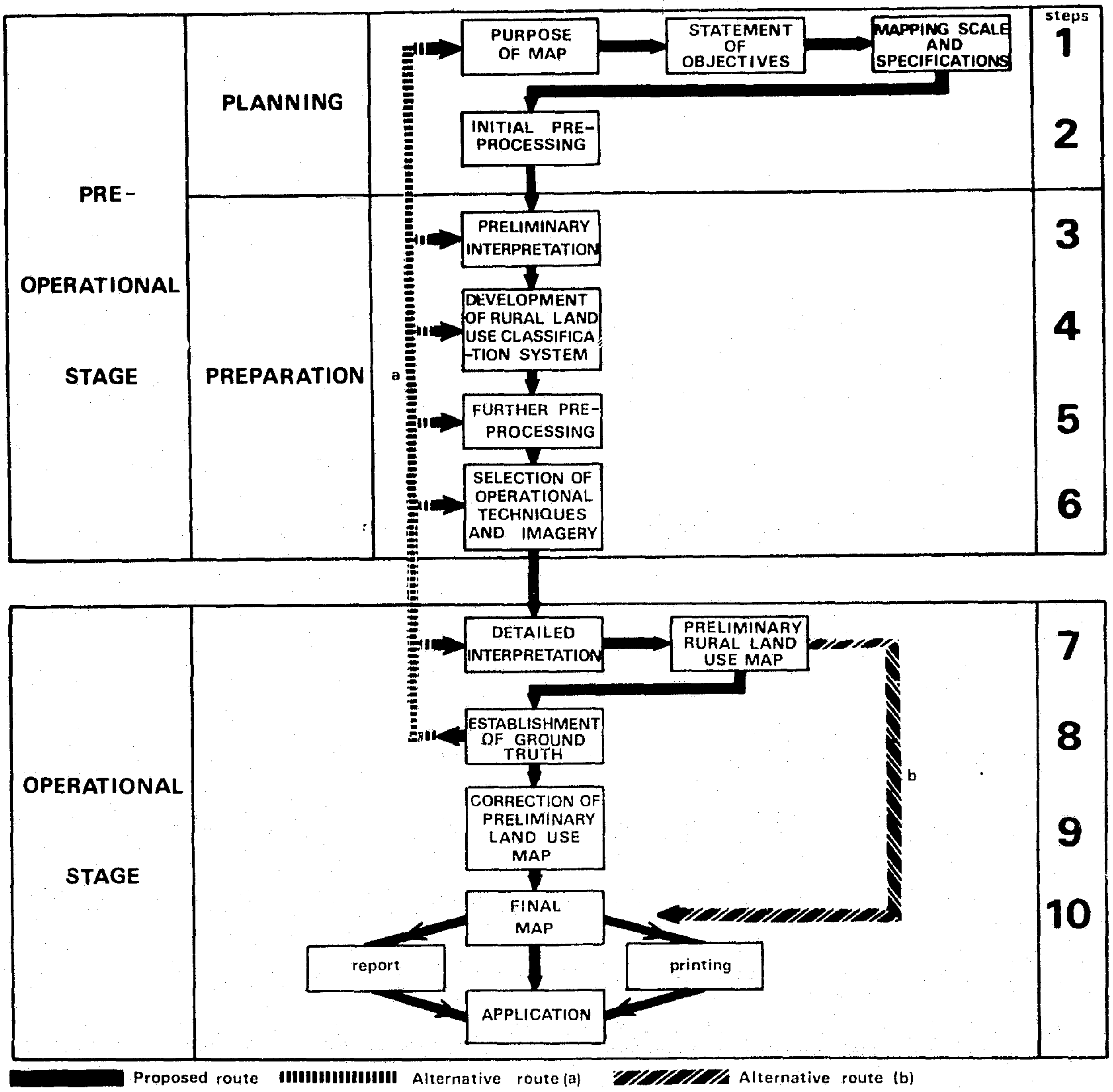



Fig 1 DIAGRAMMATIC REPRESENTATION OF A PROPOSED METHODOLOGY FOR THE PRODUCTION OF SMALL-SCALE RURAL LAND USE MAPS FROM LANDSAT MSS IMAGERY

N.B. THE METHOD ADOPTED IN THE PRODUCTION OF THE LAND USE MAP OF MURCIA PROVINCE WAS VERY SIMILAR TO THE PROPOSED ROUTE SHOWN IN THIS DIAGRAM

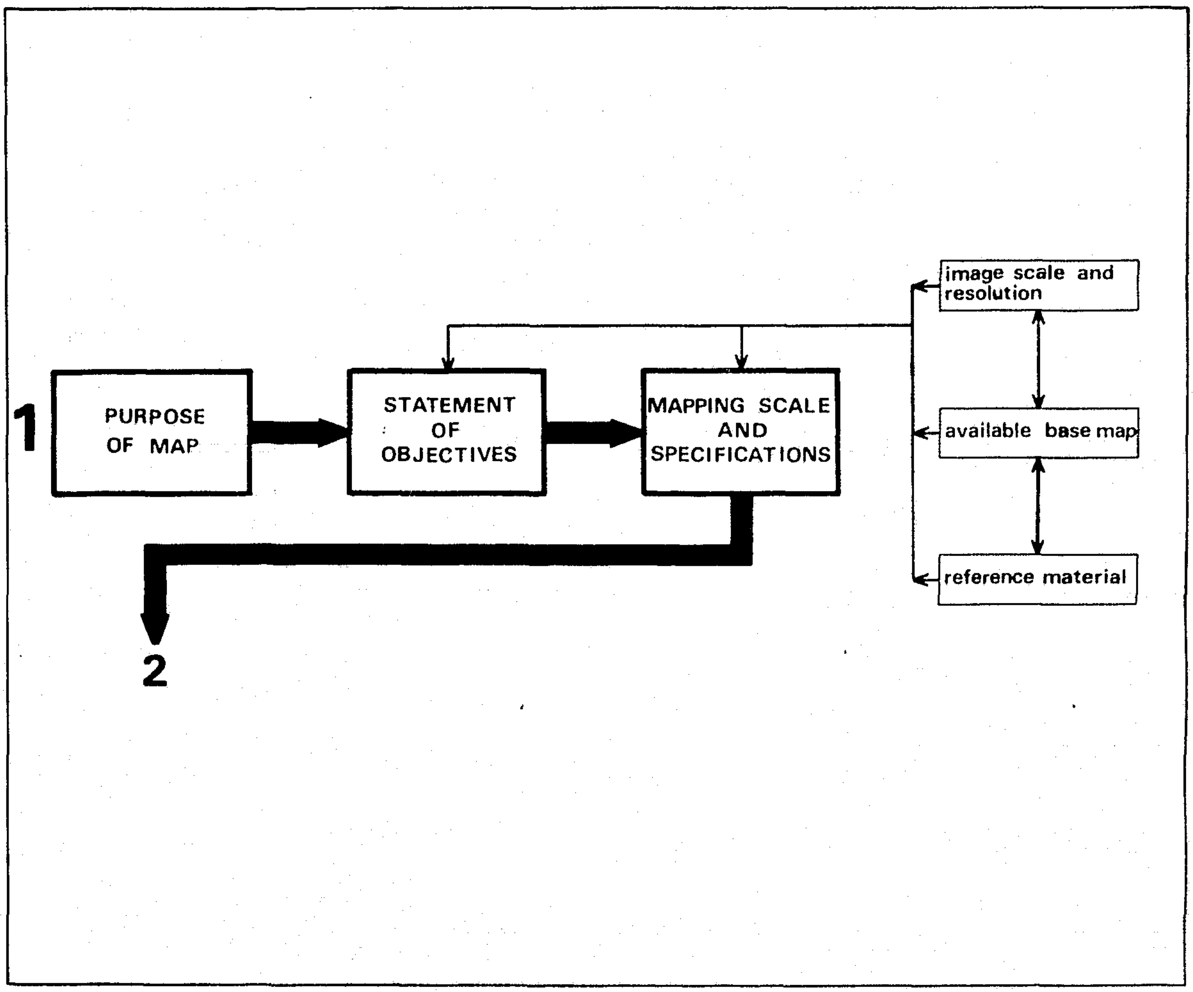
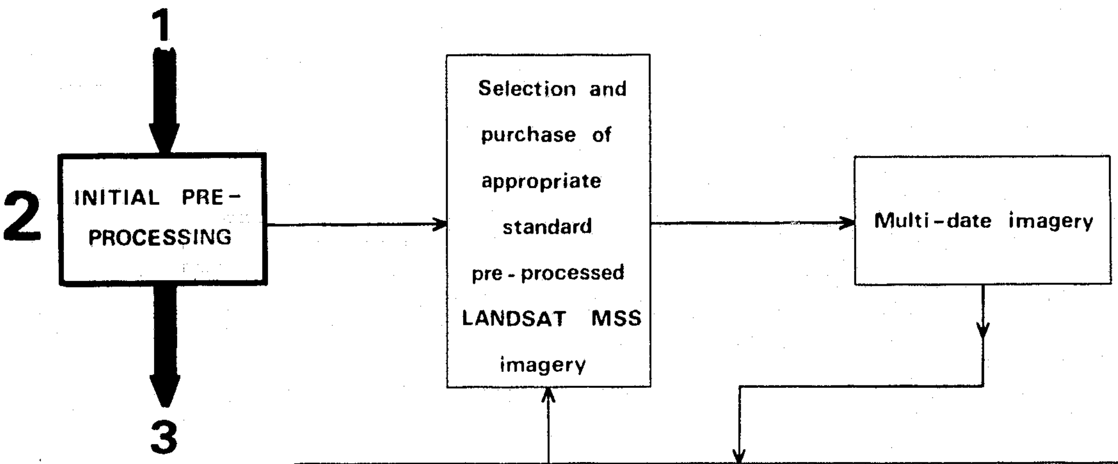



Fig 2 STEP 1 INITIAL PLANNING




| Image Size | Scale | Format | Black and White Unit Price US \$ | Colour Composite Unit Price US \$ |
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| 2·2 inch | 1:3,369,000 | Film positive | \$ 3 00 | \$ N A |
| 2·2 " | 1:3,369,000 | Film negative | 4.00 | N A |
| 7·3 " | 1:1,000,000 | Film positive | 5. 00 * | 12.00 |
| 7·3 " | 1:1,000,000 | Film negative | 6. 00 | N A |
| 7·3 " | 1:1,000,000 | Paper | 3. 00 | 7. 00 |
| 14·6 " | 1:500,000 | " " | 8. 00 | 20. 00 |
| 29·2 " | 1:250,000 | " " | 15. 00 | 40. 00 |

Information; USGS EROS Data Center, August 1975.

COLOUR COMPOSITE GENERATION( when not already available )

| Image Size | Scale | Format | Unit Price |
|---|---|---|---|
| 7·3inch | 1:1,000.000 | printing master * | \$ 50 US |

* COST OF PRODUCT FROM THIS COMPOSITE MUST BE ADDED TO TOTAL COST

Fig 3 STEP 2 INITIAL PRE-PROCESSING

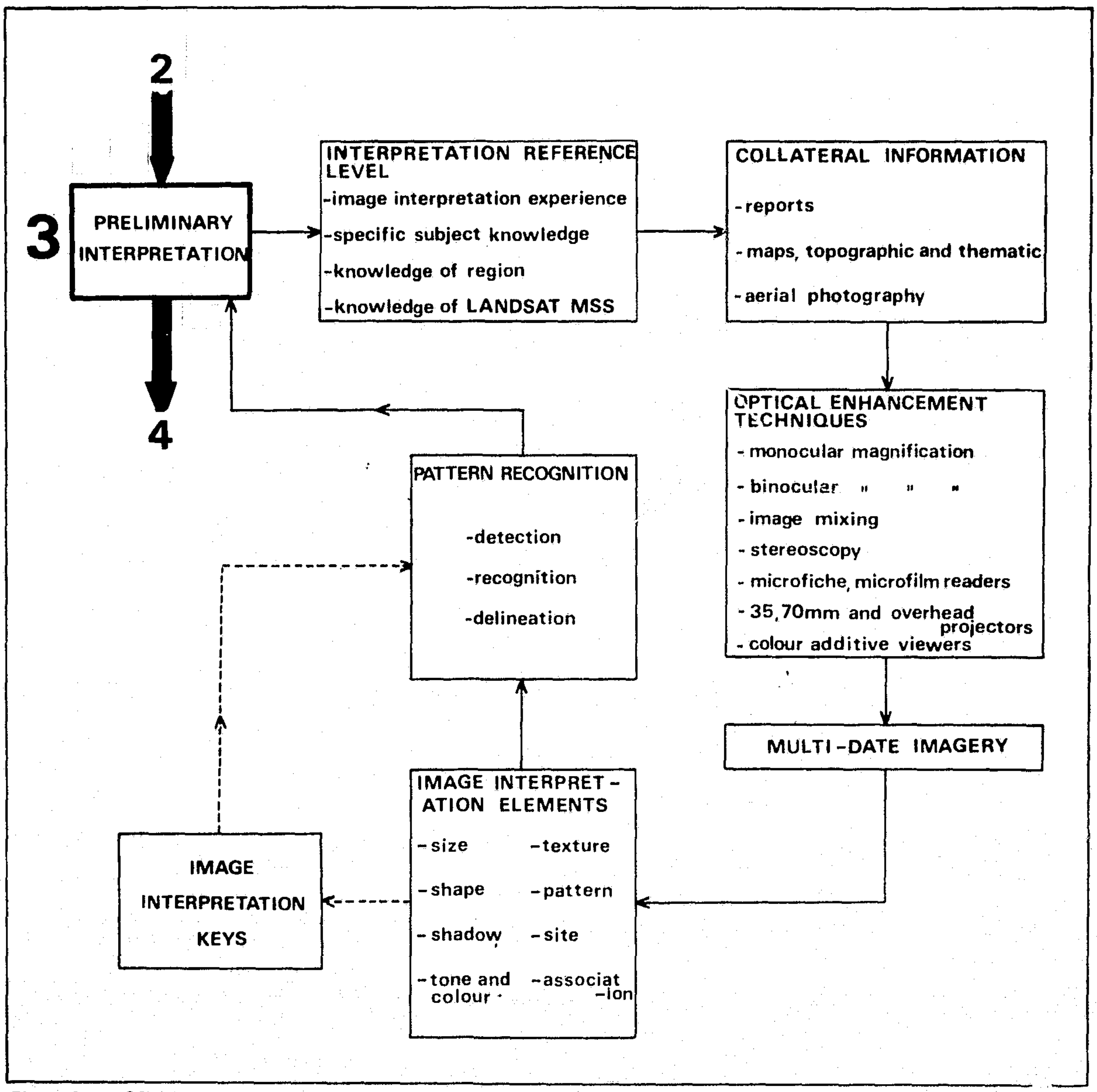


Fig 4 STEP 3 PRELIMINARY INTERPRETATION

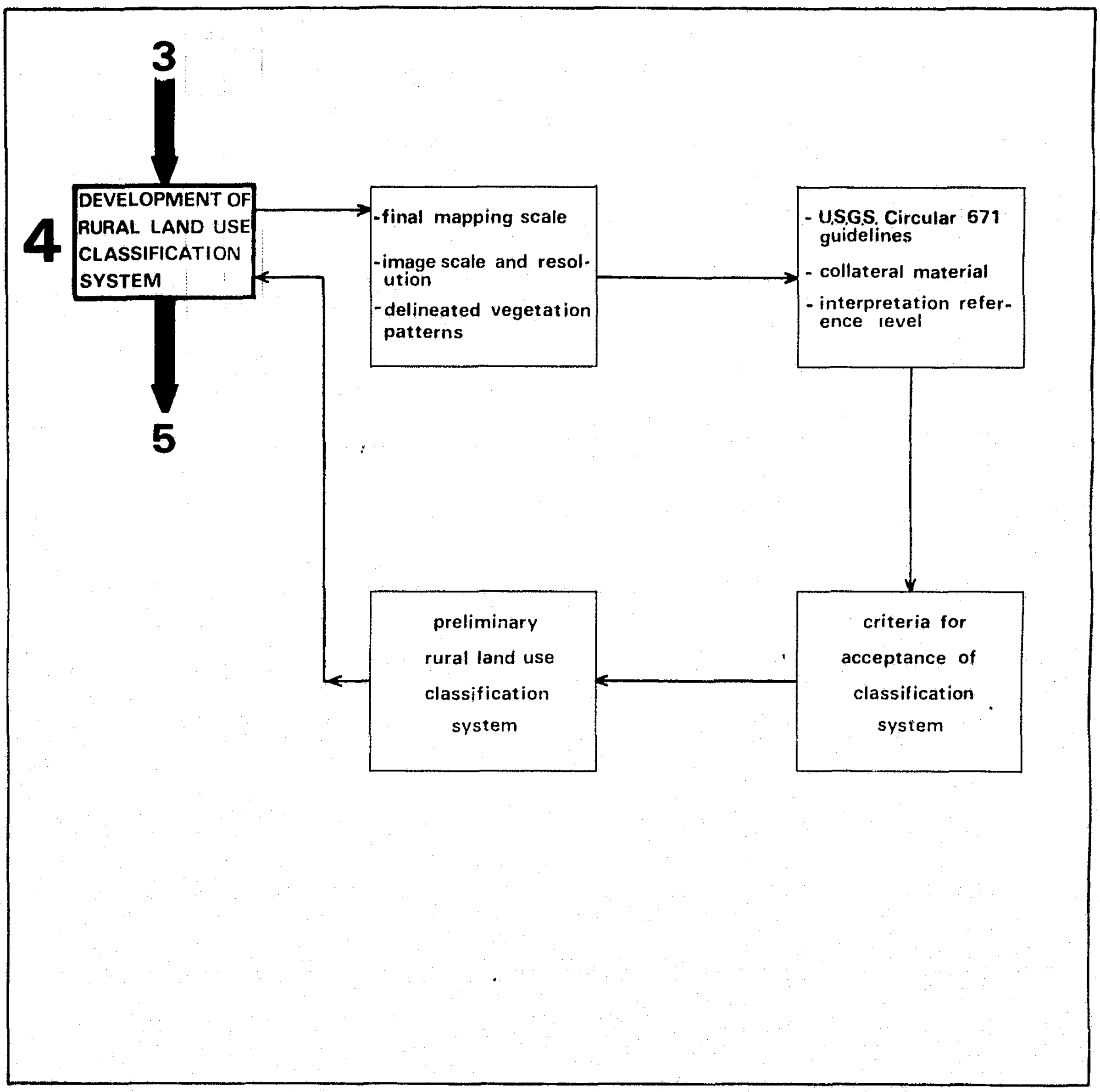


Fig 5 STEP 4 DEVELOPMENT OF RURAL LAND USE CLASSIFICATION SYSTEM

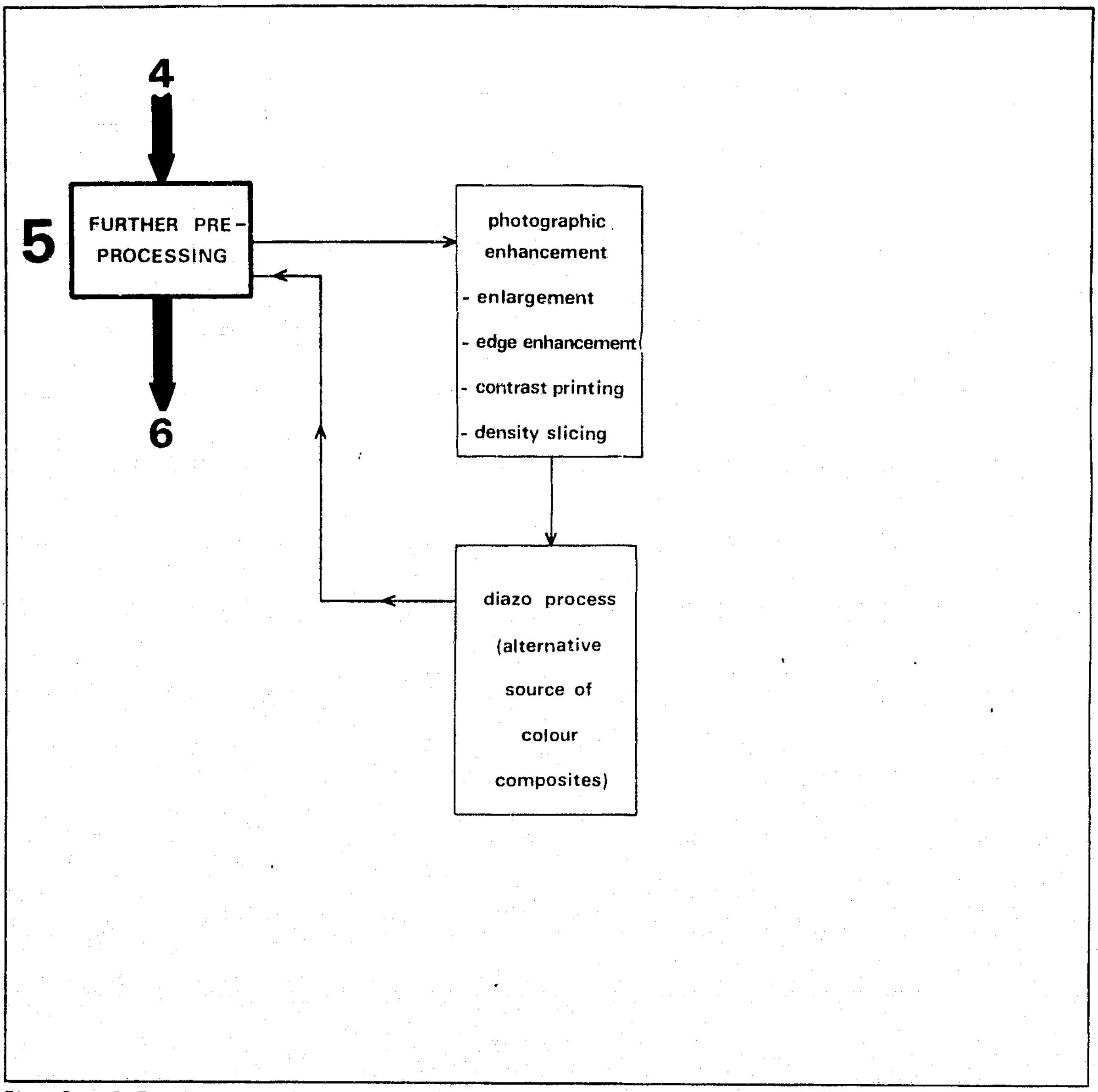


Fig 6 STEP 5; FURTHER PRE-PROCESSING

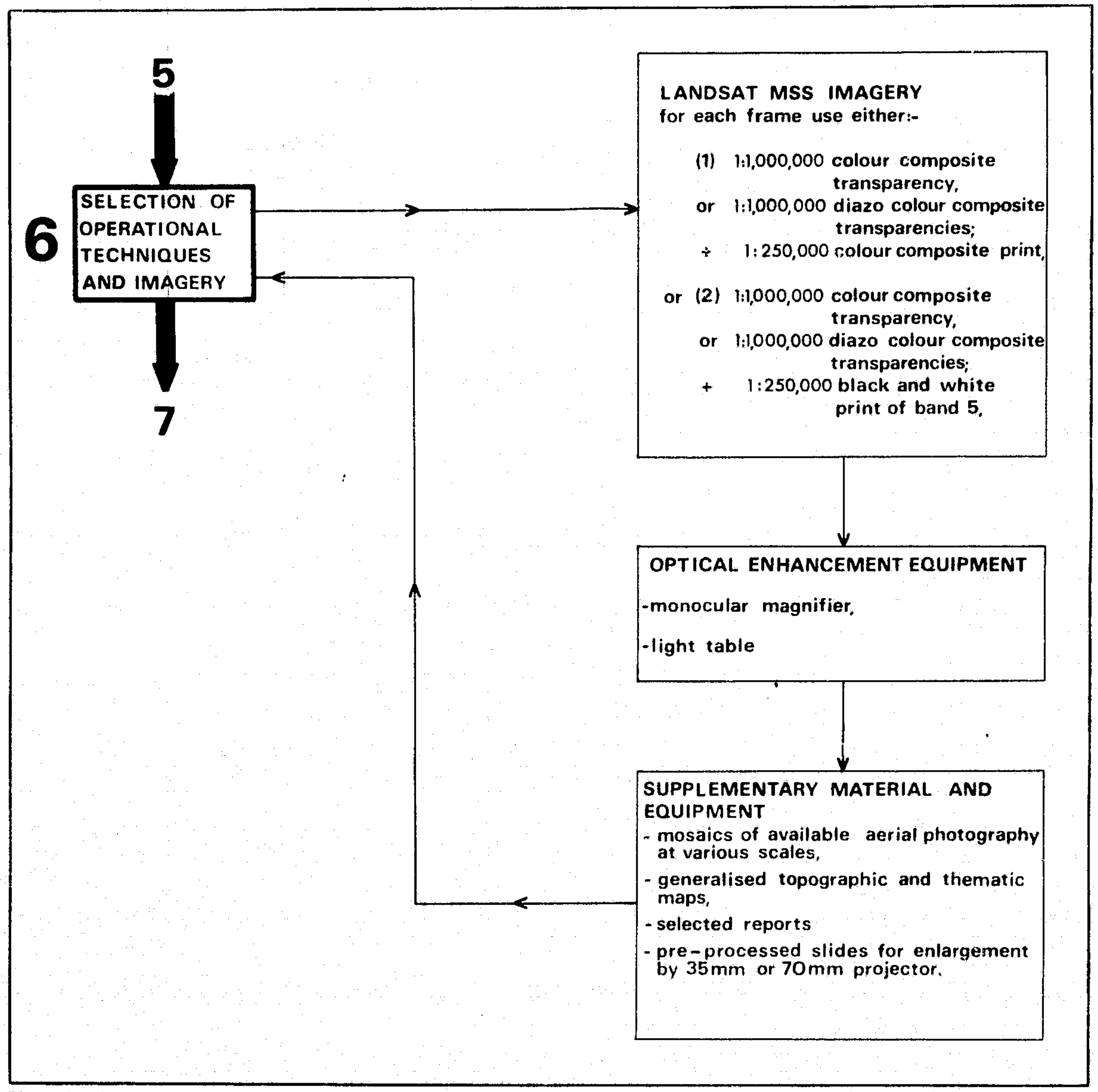


Fig 7 STEP 6 SELECTION OF OPERATIONAL TECHNIQUES AND IMAGERY

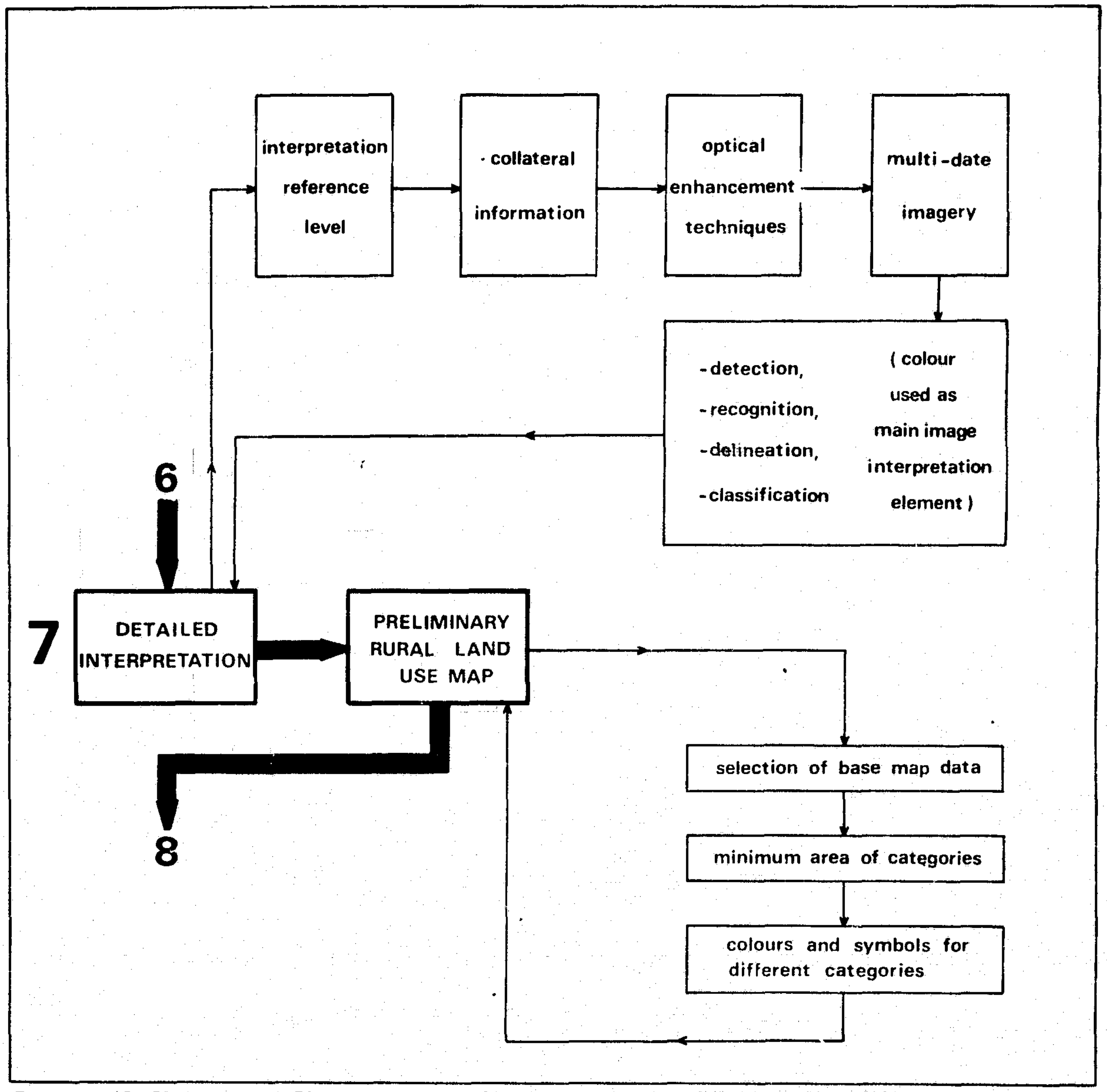


Fig 8 STEP 7 DETAILED INTERPRETATION AND PRODUCTION OF PRELIMINARY RURAL LAND USE MAP

ORIGINAL PAGE IS
OF POOR QUALITY

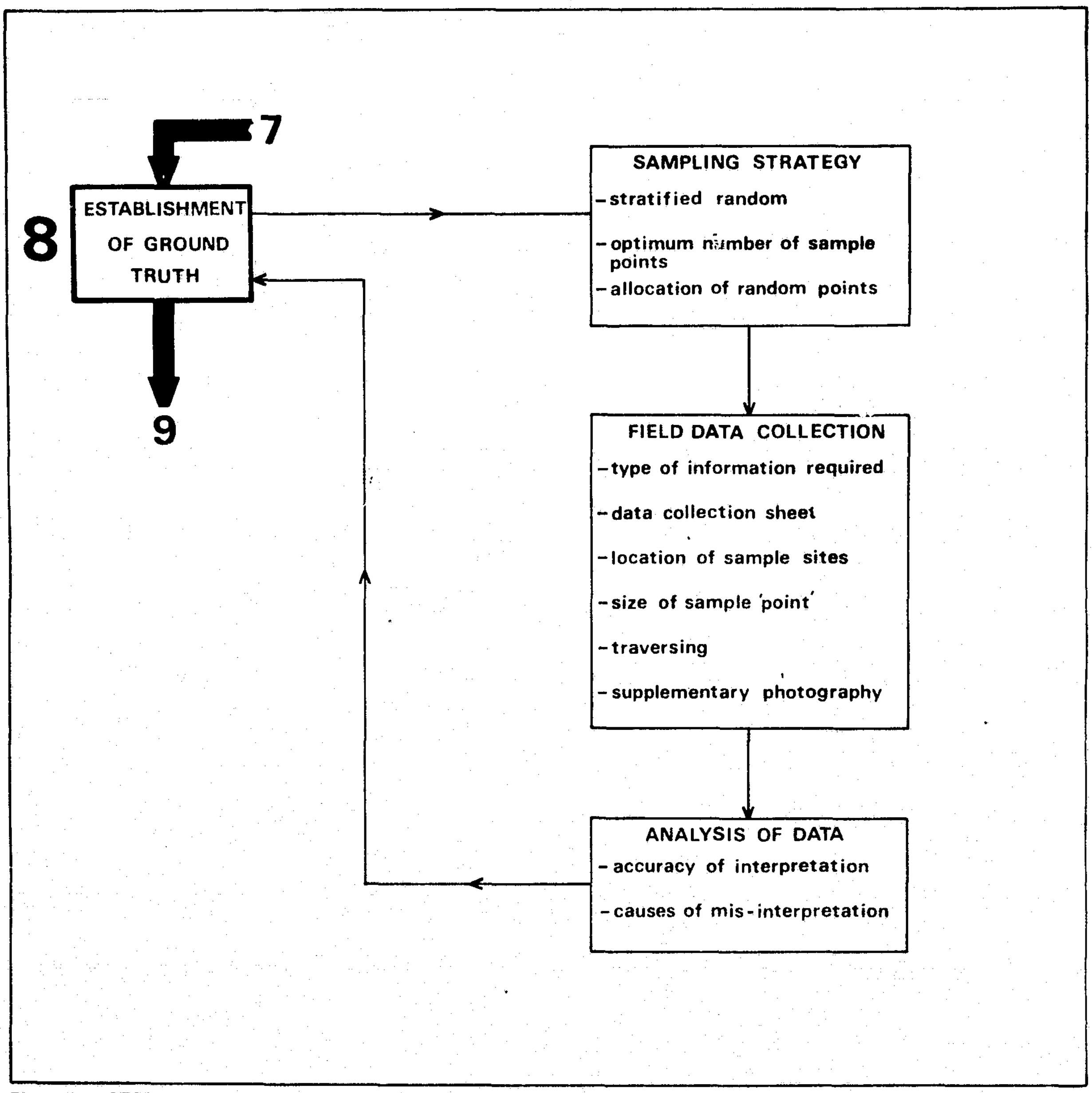


Fig 9 STEP 8 ESTABLISHMENT OF GROUND TRUTH

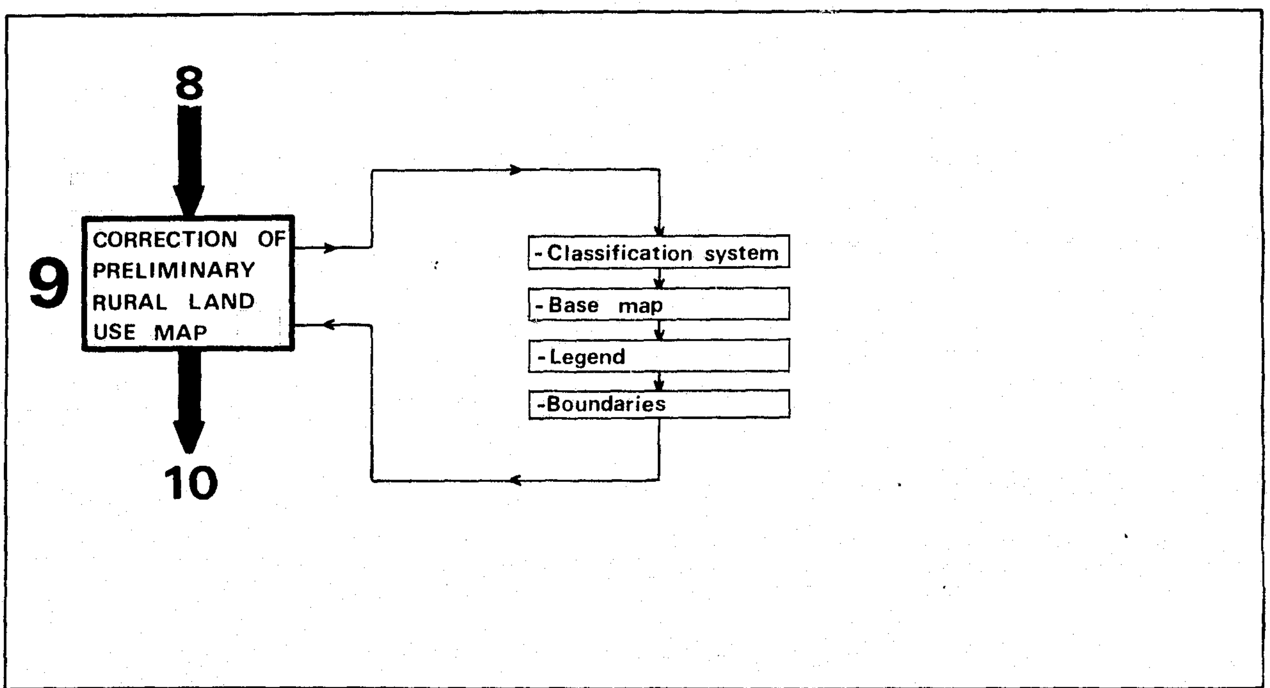


Fig 10 STEP 9; CORRECTION OF PRELIMINARY RURAL LAND USE MAP

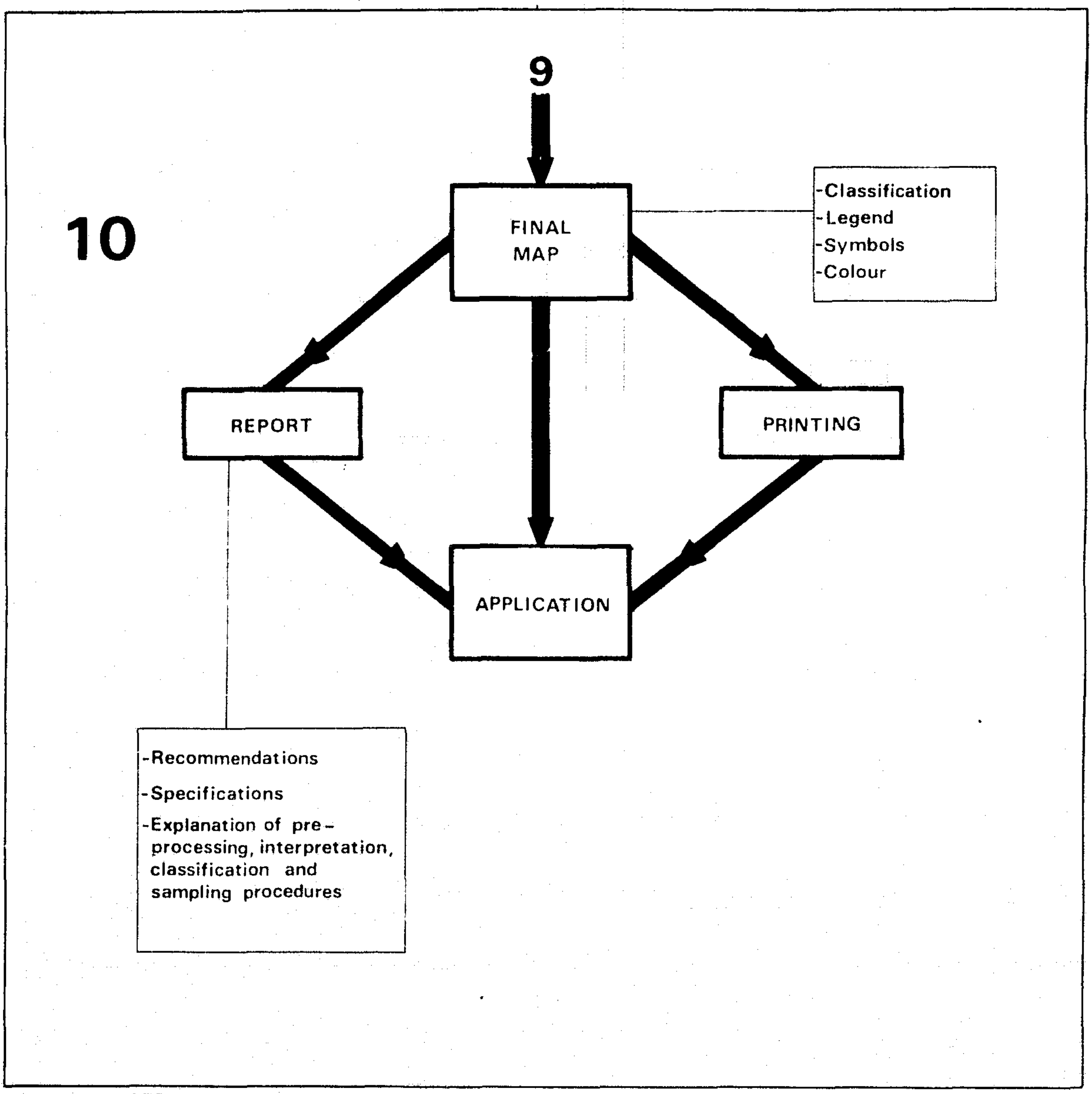


Fig 11 STEP 10, FINAL MAP