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THE NEED FOR AN INTEGRATED APPROACH TO PRESENTING PHYSICAL LAND RESOURCES SURVEY DATA

TABLE OF CONTENTS

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FOREWORD

This paper is in response to the call for by the EU Environmental mission report, April 2005 (Warren Olding and Juan Ochanove) for the need to standardize, and simplify, planning procedures throughout The Philippines based on one set of maps, data and planning and monitoring guidelines.

3. Problems with current systems of land use planning

Regulating land use means separating incompatible uses from compatible ones. Sound land use planning must be based on physical data that is easily understood and reliable. Standard mapping procedures currently require geology maps, soil maps, slope maps, vegetation maps, land use maps etc. Even with geographical information systems (GIS) the overlaying of up seven or eight maps to extract data for a particular site of a few hundred hectares, from maps of scale 1:250,000, is mind-numbing and time-consuming.

After all this, the end user of the data often has no idea what the area of interest looks like. Without soil surveys or topographic maps (with five-metre contour intervals), ecologically unsound decisions on land use may be made. This can result in inappropriate land use causing land degradation, damage to water catchments, fatal landslips/landslides etc.

4. Presenting land resources data at the reconnaissance level

The natural features of a landscape of significance to land use are: *landform*, soils, vegetation, drainage and climate. Dividing a region into landforms (or terrain types), e.g. beaches, alluvial plains, meander belts, alluvial valleys, hills, mountains, etc., and sub-dividing the landforms into *land systems* is the most effective way to present land resources data and simplify the procedures for land use planning and conservation. It is based on the ecologically sound assumption that associations of rock types, hydro-climatology, land forms, soils and organisms are interdependent.

Each landform consists of groups of *land systems* each with different associations of geology (e.g. limestone, sandstone, igneous, ultrabasic etc), topography, soils and organisms. A *land system* is an area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation. Every land system consists of a recurring pattern of *land units* (also called *land facets*) each with its own distinctive combination of topography, soils and vegetation. For instance, l*and units* making up a mountainous *land system* include hill tops, ridges, side slopes, and minor valleys.

A land system is not unique to one locality. The same land system reappears whenever the same environmental properties occur together[1]. Because of this, the potential and constraints for development on such sites will also be similar. Land systems are therefore effective ways of combining the various mixes of geology, soils, topography, and climate at any given site[2].

3. Three-dimensional block diagrams

By illustrating each land system as a three-dimensional block diagram the presence of areas as small as a few hundred square metres are made known for planning purposes (see Fig. 1-4 at the end of this paper). A table accompanying each block diagram provides information such as the slope range, dissection, underlying geology, soil type and depth, vegetation

[1] A land system can be viewed as a *species* of landscape, with land units representing its recognizable features

[2] In undisturbed conditions, different land systems indicate the presence of different vegetation types.

cover and present land use for each land unit. These give the land system its distinctive appearance.

The land systems map, block diagrams and tabulated description are therefore useful tools that help planners rapidly target areas with the biophysical characteristics most suitable for a required purpose. Those with unsuitable slopes or soils can be discarded.

6. Advantages over standard mapping procedures

Because all the environmental factors are mapped simultaneously, the land systems approach is a systematic and accurate method of recording the data on soils and slopes needed for the micro-level planning of hill farms and other land use strategies. Some advantages of this approach over standard mapping procedures, include:

- The patterns of land systems are *easily picked out on satellite imagery and air photographs*, and their component land units consistently recognisable under the stereoscope. This ability to recognise and map land systems from satellite imagery and air photos makes the method very attractive as the land units can be used to collate a wide range of information on land resources and to subdivide the local landscape for detailed planning.

- The same set of boundaries is used for all features (slope, soils, land units, etc). This overcomes the problems of existing maps where, for example, soils cover slope ranges 8-15%, 15-30% etc, while slope classes range from 8-18%, 18-30% etc. making the estimation of areas difficult.

- *Speed and relative cheapness*. Depending on the area to be covered, analysis of satellite imagery and 1:20,000 air photos can take a few months. A combination of data on soils, slopes and land use from past projects and government surveys, and systematic sampling, enables a multi-discipline team to cover several square kilometres per working day. For example, all of Indonesia's 418 land systems, from Aceh Province to West Papua Province, were described and mapped in five years[3].

- *Rapid communication of results* is achieved through the clear style of presentation. There is only one map showing the distribution of the various land systems, instead of eight or more maps of individual factors such as soils, slopes, geology, vegetation, land use, etc. By showing the relationships between soils, slope, vegetation and other factors within each land system, the block diagrams effectively combine the various maps for each of these features. The end user can immediately envisage what the terrain for the proposed land use looks like.

- *A picture is worth a thousand words!* When I was reviewing a Danida-funded soil and water conservation project in Tanzania some years ago, one of the constraints was that the local farmers couldn't understand the maps. Fortunately I had a land systems paper from neighbouring Zambia and asked farmers if they recognized any of the landscapes illustrated in the block diagrams (given at the end of this report). Not only did they recognize the landscapes, but they could point out the location where their farms were sited on the block diagram.

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[3] *Report of the Regional Physical Planning Programme for Transmigration* (RePPProT 1988). This reconnaissance survey of the land resources of Sumatra was produced jointly by the Land Resources Department (ODNRI) of the British Government's Overseas Development Administration (ODA) (now the Department for International Development (DfID), in association with the Republic of Indonesia's Ministry of Transmigration, Directorate General of Settlement Preparation.

5. Practical uses of the land systems map and block diagrams

This simple classification, based on the morphology of the land surface, has many practical applications for land use, erosion hazard, water conservation, engineering developments, etc.

5.1 Land use

The land systems map helps provide answers to administrators, agriculturalists, foresters, and planners on questions relating to natural resources. Experience has shown that the land systems map on the wall is more than a decoration - it is consulted.

5.1.1 Minority land units important for sustainable upland farming

The block diagrams make the end user aware of the presence of minority land types (e.g. land units such as flat hill tops, gently sloping crests, minor valleys, etc), which are too small to be shown on 1:50,000 scale maps. Although covering only a few hundred square metres, these land units may be important in determining the way an extensive area of steeply sloping land can be used to support sustainable upland agriculture, as shown by the Upland Development Programme's STOP[4] land suitability classification.

5.1.2 Maps indicate the presence of remnant patches of forest

Using GIS can determine the distribution and uniqueness of vegetation types from satellite imagery. If a land system is poorly represented then any remaining patches of vegetation will need strict protection even if they have been modified by human activity as they may also be scarce regionally.

Similarly, the block diagrams can alert decision makers to the presence of small patches of natural forest in the uplands. These may sometimes be only a few hectares in area, but their conservation and biodiversity value at the regional, national and international level may be extremely high, particularly if they are the only forest remnants remaining on that particular land system. They could then be given priority for protection.

In the EC-funded Leuser Development Programme, in northern Sumatra, I made use of the land systems report to show that the protected area and buffer zones had 10 out of the 11 land forms recorded in Sumatra and 42 out of the island's 78 land systems. The land systems approach enabled estimates to be made of the percentages of areas of the region's land systems occurring in the protected area, and the number and distribution of the locations.

5.1.4 Forest management

Research plots set up for forest inventory purposes, or to estimate tree growth rates, could benefit from the land systems approach. In Kalimantan, Indonesia, foresters were faced with widely disparate results from research measurements on forest growth and regrowth, complicating analysis. Identifying which land systems that the research plots were sited on would have allowed stratification of results because the soil types under different land systems would also probably be different and the forest types would be different. Both factors could affect tree growth.

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[4] Slope Treatment-Oriented Practices

5.2 Information on hazard risk

The land systems approach can provide important information on the risks of hazards associated with a particular land system.

5.2.1 Land slips/ landslides

Land systems prone to landslips or landslides, infamous in the Philippines for the death and destruction they cause after heavy rain, can be identified during the reconnaissance surveys and air photos and from LGU reports. By referring to the land systems map, LGUs can take steps taken to discourage people from settling in vulnerable areas.

5.2.2 Flooding

Similarly, the frequency of flooding in certain areas can be obtained from local government records and used to identify those low-lying land systems liable to devastating floods. Town planning can aim to locate infrastructure such as hospitals, schools, or warehouses for storing rice and corn on higher ground.

5.3 Infrastructure

5.3.2 Road construction

When planning the route of new roads through mountainous areas, the land systems map can help in selecting a route with the least number of streams to cross, thereby reducing the number of bridges and culverts needed, and avoid going through areas where the risk of land slides is greatest. Where the route can not avoid such areas, the LGU has a basis for issuing ordinances to stop the cultivation of annual crops on landslide-prone slopes above the road, and require tree crops be planted to stabilise the land.

5.4 Extrapolation of results to other similar areas

Extrapolation of results is possible because the characteristics of a land system can be quickly understood by studying the block diagram, cross section and tabular description. This helps to make comparisons between one region and another. Travelling around a country people often remark how similar a new area is to another distant area. This is probably because the areas are the same land system. Strategies, shown to be successful in a land system, can be transferred confidently to other parts of the country where the same land system occurs, without having to undertake time-consuming and expensive soil surveys, topographic mapping, etc.

7. Estimation of areas of land available for a particular use simplified

During the reconnaissance survey stage, the approximate percentage area of each type of land unit in a land system is estimated from air photos. A table is produced showing the areas of each land unit and slope ranges in a particular land system. Using a GIS, the areas with a particular slope range can be estimated for any given location.

7. Framework forms a permanent basis for future planning

The description of each land system states only what the land is and how to recognise it. Evaluation of the land follows at a later stage when sufficient information has been collected. The classification therefore has a neutral legend in line with one of its aims of providing a framework for the systematic collection and presentation of information.

The framework resulting from the land systems survey forms a permanent basis for future planning. Additional surveys will add further detail to the land systems map and block diagrams rather than alter them. This is significantly different from a land use plan, which becomes obsolete as new demands are made of the land,

8. Establish a website to aid data collection and provide land use information

8.1 Data collection

The data base can be expanded quickly by setting up a website. Agriculturalists, foresters, soil scientists, environmentalists etc from LGUs, NGOs and donor-funded projects, can send in their field observations and measurements of soils, slopes, crop yields, observations on erosion and landslides, floods etc. by e-mail. This will contribute to improving the accuracy of the maps. This is increasingly important as land degradation in the uplands is significantly reducing soil depths. Information on which land systems can no longer support corn or coconuts, for example, under drought conditions need to be shared as widely as possible. Map references of the sample sites can be provided using global positioning systems.

8.2 Providing information on land use

End users could contact the website seeking particular maps or information. For example, the land systems map could effectively target where to allocate the scarce funds for conserving biodiversity. Remnant patches of natural forest in those land systems with a very limited occurrence could be given the highest priority for protection. Knowing that a particular patch of forest may be the sole surviving remnant of an otherwise extinct forest type could result in a decision to maintain the biological integrity of the remnant by reforesting the surrounding area using a mix of seeds and seedlings collected from the same forest patch.

Investors or bankers may want to know whether proposals for establishing irrigation schemes or plantations, such as rubber and oil palm, are sound propositions. By logging into the website and entering the coordinates of the schemes, they could see from the block diagrams whether land systems have the appropriate slope classes, soil types and depths for the scheme. By plotting the 300-metre contour line on the land systems map, the bankers etc could also see how much of the scheme is above this altitude, which is generally unsuitable for rubber and oil palm production, and so a bad loan risk.

9. Conclusion

The land systems approach is a short and snappy method of presenting land resource data at the reconnaissance level. It is a convenient, easily understood way to standardize and simplify planning procedures. The creation of a website will make the land systems map, accompanying 3-D block diagrams, and tabulated land use data readily accessible nation-wide, and help improve planning at all levels. It is recommended that funding be found to map the *land systems* of the Philippines and prepare the 3-D block diagrams.

Fig. 1-2 Examples of 3-dimensional block diagrams of land systems from the Luangwa Valley, Zambia (from Astle, Webster and Lawrence, 1971)

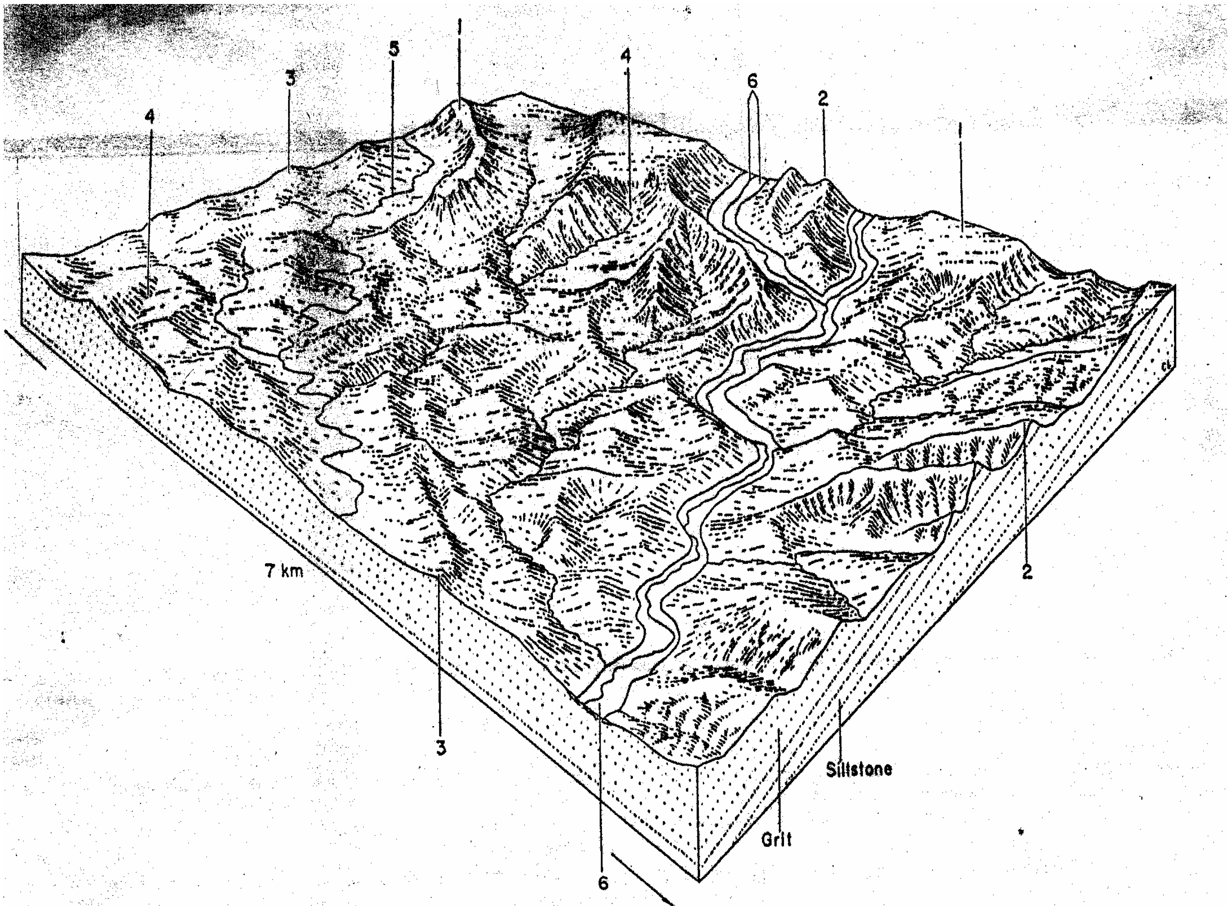


FIG. 4. Land system 4, dissected siltstone and grit.

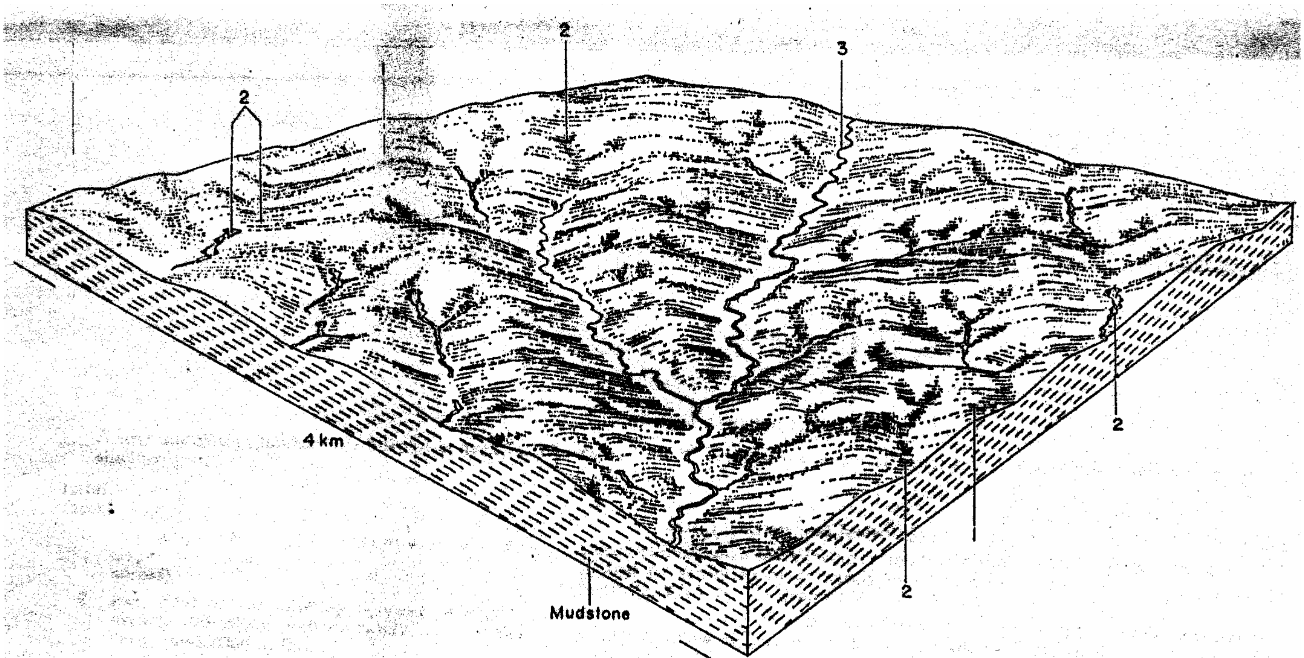


FIG. 6. Land system 6, the Chifungwe Plain on mudstone.

Fig. 3-4 Examples of 3-dimensional block diagrams of land systems from the Luangwa Valley, Zambia

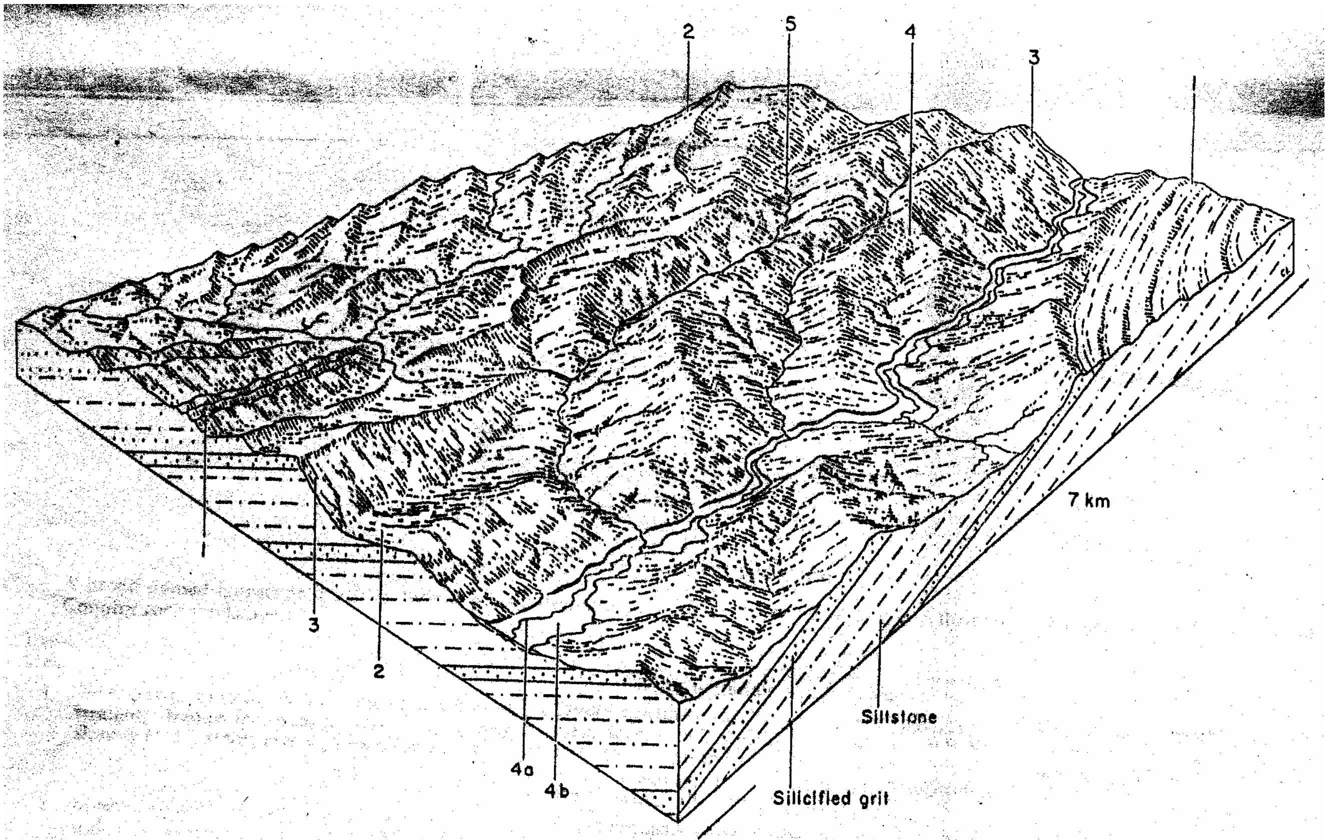
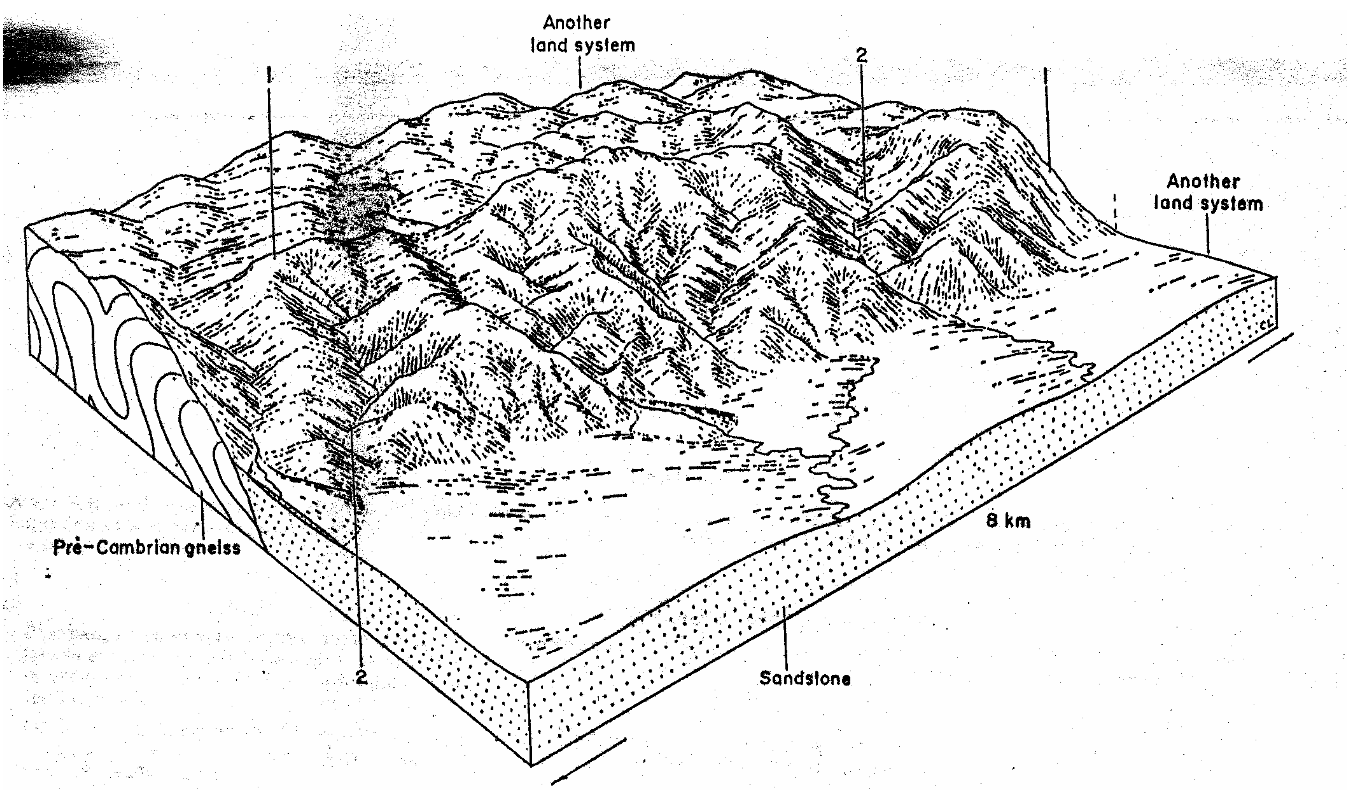


FIG. 5. Land system 5, lineated cuesta pattern of interbedded siltstones and grits.



APPENDIX 1

AN INTEGRATED APPROACH TO PRESENTING PHYSICAL LAND RESOURCES SURVEY DATA

A. Interests to be considered

Interests to be considered when planning the management of watersheds include:

- agriculture, both irrigated, lowland and upland;
- agroforestry;
- production forestry;
- protection forestry;
- collection of minor forest products;
- soil and water conservation;
- road location; and
- recreation.

The minimum area of interest for general planning and management is likely to be one to seven hectares (i.e. the average size of a smallholder's farm). The Upland Development Programme's STOP[5] land suitability classification has shown that minority land types (i.e. flat hill tops, gently sloping crests, or minor valleys), although covering only a few hundred square metres, are important in determining the way an extensive area of steeply sloping land can be used to support sustainable upland agriculture. Such reasonably uniform areas are too small to be shown on 1:50,000 scale maps.

B. Requirements for zonation and planning

To cater for this variety, a general purpose classification scheme is needed which:

- enables land resource data to be collected, stored and used in a cost-effective way;
- recognises and takes into account the presence of minority land types, without mapping them at the regional level;
- groups such individual occurrences into mappable units for planning purposes, while retaining their identity for storing relevant detailed information;
- can be carried out quickly using the available air photo and satellite imagery cover (which means the land classes to be mapped should be identifiable on the photographs).
- caters for areas with similar slope ranges but which may have different soils, elevation and drainage;
- enables a limited amount of data from a small area to be extrapolated, with reasonable reliability, to similar areas elsewhere.

This type of integrated survey, sometimes called the Land Systems approach, maps all factors of the environment simultaneously. It is a systematic and accurate method of recording the data on soils and slopes needed for the micro-level planning of hill farms and other land use strategies.

[5] Slope Treatment-Oriented Practices

1. THE LAND SYSTEMS APPROACH

1.1 Assessment of the physical environment

Sound land use planning must be based on physical data that is easily understood. The land system concept is a short and snappy way of presenting land resource data at the reconnaissance level. It is based on the ecologically sound assumption that associations of rock types, hydroclimatology, land forms, soils and organisms are interdependent. A land system is not unique to one locality because the same land system reappears whenever the same environmental properties occur together. Because of this, the potential and limitations for development on such sites will also be similar. Land systems are therefore an effective way of combining the various mixes of geology, soils, topography, and climate at any given site[6].

1.2 Definitions

1.2.1 Land system

A *land system* is an area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation. It consists of a recurring pattern of *land units* (also called *facets*) each with its own distinctive combination of topography, soils and vegetation (Christian & Stewart 1968).

1.2.2 Types of land system

Land systems may be classified into *simple*, *complex* or *compound* forms:

a) A *simple* land system consists of visibly recognisable units that recur in association and do not involve major vegetation or soil transitions due to the climatic factor. For example:

   – a flood plain subdivided into a number of smaller, less diverse land units with slight differences in altitude but important differences in depth of flooding and resulting differences in soils and agricultural potential.

   – an igneous intrusion such as a low foothill.

b) A *compound* land system is one in which two or more, simple, geomorphogenetically unrelated, simple land systems occur. For example:

   – where a number of small foothills, outliers of a more extensive hill land system, are isolated within a sedimentary area such as an alluvial flood plain.

c) A *complex land system* is a combination of two or more systems that are geomorphogenetically related. For example:

   – the Sierra Madre Mountains.

[6] In relatively natural conditions different land systems also indicate the presence of different vegetation types.

1.3 Block diagrams

As mentioned above, the minority of the land units in some land systems are often only a few hectares in size. For example, a minor valley of perhaps 20-30 metres across, or a gently sloping hill crest or ridge. These units or elements are too small to be mapped individually at the 1:50,000 scale but may be important if they enable an area to support even a few families in the long-term.

By illustrating each land system with a three-dimensional block diagram the presence of such small areas is made known for planning purposes (see Figures 1-4 for examples). A table accompanying each block diagram provides on formation such as the slope range, underlying geology, soil type (and depth), vegetation cover and present land use, *for each land unit*.

The land systems map, block diagrams and table are a useful tool to help planners rapidly target areas with the biophysical characteristics most suitable for a required purpose. Those with unsuitable slopes or soils can be discarded.

Figures 1-4. Examples of 3-dimensional block diagrams

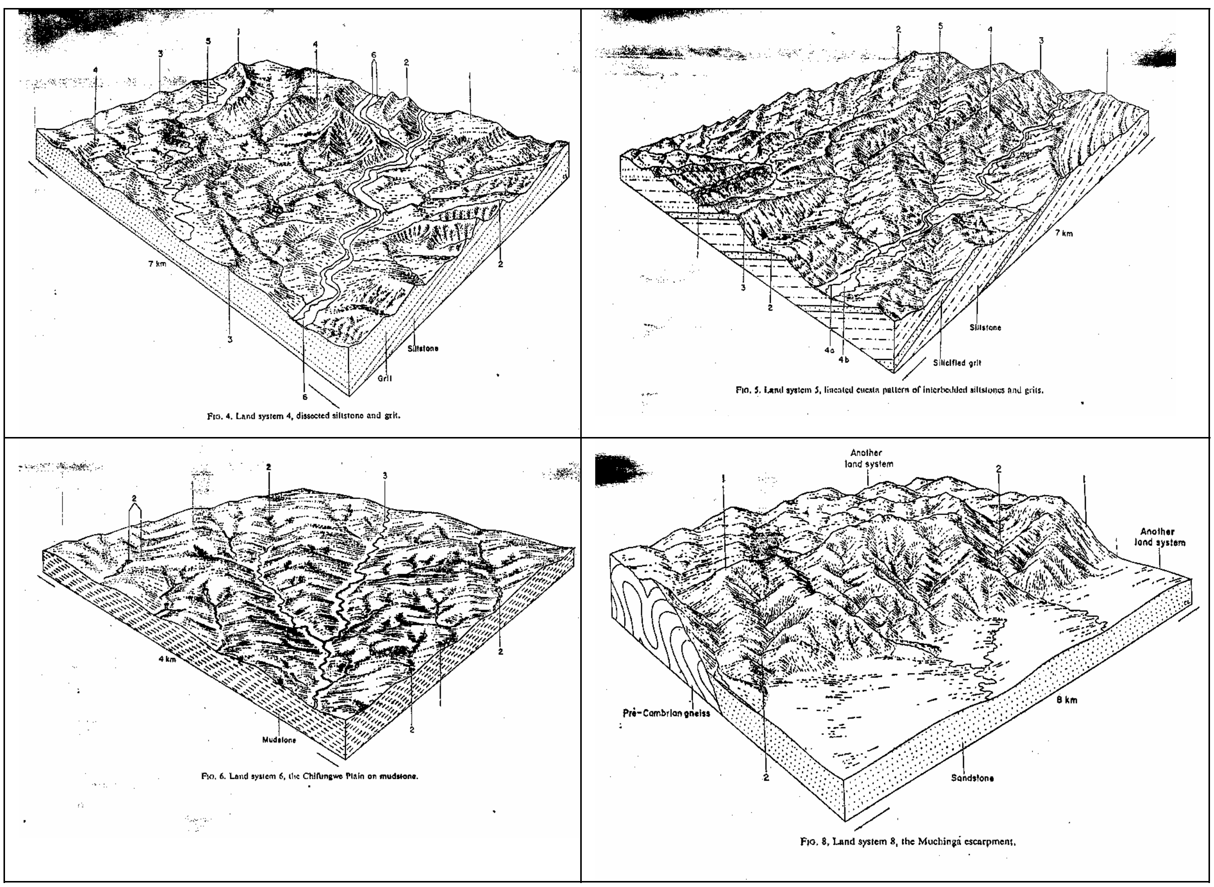


FIG. 4. Land system 4, dissected siltstone and grit.

FIG. 5. Land system 5, lineated cuesta pattern of interbedded siltstones and grits.

FIG. 6. Land system 6, the Chifungwe Plain on mudstone.

FIG. 8, Land system 8, the Muchinga escarpment.

1.4 Main advantages of the Land System Approach

a) Speed and relative cheapness

A multi-discipline team (geomorphologist, soil scientist, agriculturalist, ecologist, forester) can cover several square kilometres per working day making complete coverage of a region possible in a few years. (This can be reduced to a few months by systematic sampling and using satellite imagery and 1:20,000 air photos). Indonesia's 418 land systems were described and mapped in five years[7]. With the aid of global positioning systems, data from soil surveys and former donor-funded projects can be incorporated into the data base radily quickly.

b) Integrates different environmental factors

The same set of boundaries is used for all features (slope, soils, land management units, etc) overcoming the problems of the existing maps where slope classes differ. E.g. soils cover slope ranges 8-15%, 15-30% etc, while slope classes range from 8-18%, 18-30% etc, making estimation of areas difficult.

c) Clear communication of results

Rapid communication of results is achieved through the clear style of presentation. There is only one map (showing the distribution of the various land systems in the region covered) to comprehend instead of eight or more maps of factors. The block diagrams, by showing the relationships between soils, slope, vegetation and other factors within each land system, effectively combine the various maps for each of these features.

d) Permits extrapolation of results

Through studying the block diagram, cross section and tabular description the essentials of a land system can be rapidly comprehended. This aids comparison between one region and another. "This land system looks very similar to Area A where successful agroforestry projects have been established". It provides the means whereby successful strategies, tested and documented in the pilot watersheds, can be transferred safely and confidently to similar areas elsewhere in the Province.

Agriculturalists, foresters, planners and administrators find the land systems map helpful in providing answers to questions that arise on natural resources. As Dent and Young (1981) note: the land systems map on the wall is more than a decoration, it is consulted.

Differentiating the range of land systems in a region is the simplest basis for zoning a watershed using biophysical criteria. These geomorphic units are distinctively recognisable parts of the landscape. Their significance from the planning point of view is that they are blocks of land with similar physical characteristics and where environmental conditions tend to be uniform.

The problems or potential for agriculture, or other land uses, can therefore be expected to be the same. Land systems with little potential, or where problems have been found to be insurmountable elsewhere in the region, can be excluded from further consideration.

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[7] *Report of the Regional Physical Planning Programme for Transmigration* (RePPProT 1988). This reconnaissance survey of the land resources of Sumatra was produced jointly by the Land Resources Department (ODNRI) of the British Government's Overseas Development Administration (ODA) (now the Department for International Development (DfID), in association with the Republic of Indonesia's Ministry of Transmigration, Directorate General of Settlement Preparation.

ANNEX 1

PROCEDURE FOR LAND SYSTEMS MAPPING

1. Land systems mapping

1.1 Introduction

The patterns of land systems are easily distinguished on satellite imagery and air photographs, and their component parts consistently recognisable under the stereoscope.

This ability to recognise and map land systems from satellite imagery and air photos makes the method very attractive as the component parts of the land system can be used to collate a wide range of information on land resources and to subdivide the local landscape for detailed planning.

The inherent features of a landscape of consequence to land use are: landform, soils, vegetation, drainage and climate.

This simple classification, based on the morphology of the land surface, has many practical implications to land use, erosion hazard, water conservation, engineering developments and transport.

1.2 Procedure

The land systems approach has three phases:

- a) satellite image and photo-interpretation (30% of time);
- b) field survey (50% of time); and
- c) collation of results (20% of time).

1.3 Photo-interpretation

- Study the satellite image and classify the patterns that can be seen on them and delineate them on the photo mosaics (see Annex I for notes on Photogeo-morphology and Photogeology).

AT THIS STAGE NEITHER THE BOUNDARIES NOR THE LANDSCAPE CLASSES ENCLOSED BY THEM SHOULD BE REGARDED AS FINAL.

- Set up 1:12,50 - 1:20,000 scale air photos under the stereoscope.

- Delineate representative portions of the each area (i.e. those showing the full range of variation) on the air photos and study them in detail.

- Define the land units (or facets) and note their interrelationships by plotting the main drainage lines, crest lines and slope breaks;

1.4 Field survey

Field visits are made to samples of most of the provisional land systems identified in the photo-interpretation phase. Those land systems which are obviously of low agricultural potential, e.g. such as the steepest and highest mountains, will not usually be surveyed in detail.

A team including a geomorphologist, a soil surveyor, an ecologist, land use or farm systems experts, and maybe an hydrologist, traverse each land system.

The component units or facets are described by means of surveys based on caternary traverses. The following features are measured:

- relief amplitude (height variation within the system) see Table 1.1;
- slope gradient (both per cent and degree readings should be taken) see Table 1.2;
- slope form (convex, concave etc);
- slope length;
- width of crests, ridges, valleys and streams;
- absolute height above sea level;
- soil type and depth (including presence or absence of rocks) see Table 2.3;
- vegetation types.

Table 1.1 Definition of relief categories

Negligible	< 10 m
Very low	10-40 m
Low	41-75 m
Moderately high	76-150 m
High	151-300 m
Very high	> 300 m

Table 1.2 Categories of slope angles

Level	0-2°	0-4%
Gentle	3-5°	5-9%
Moderate	6-10°	10-18%

Steep	11-18°	19-33%
Very steep	19-45°	34-100%
Precipitous	> 45°	>100%

Table 1.3 Categories of soil depth used in the Philippines

Very shallow	< 25 cm
Shallow	25-50 cm
Moderately deep	50-90 cm
Deep	90-150 cm
Very deep	> 150 cm

1.5 Collation of results

The results are presented in the form of a land systems map and 3-dimensional block diagrams of each land system. It is important to ensure that as far as possible all the interrelationships are understood and the picture of the landscape is complete.

Check that the list of land units is comprehensive. i.e. that all types of land are accounted for.

- Define the land system in terms of the land units present and the pattern formed by their interrelations.
- Check that there is all land within the watershed belongs to one or other of the defined land systems.
- Having defined the land systems: confirm, modify or, if redundant, eliminate the original boundary lines.
- For each land system produce a general description of the landscape as a whole, and then descriptions of the land form (which includes slope range), soil, rock and vegetation of the individual land units.
- Illustrate each land system with a block diagram to show a typical pattern and the characteristic interrelations between the land units. Examples of a block diagram of a land system (from Swaziland) and the tabular description of its component units or facets are given in Figure 1.1 and Table 1.4 respectively.

2.6 Framework for an information system

The description of each land system states only what the land is and how to recognise it. Evaluation of the land follows at a later stage when sufficient information has been collected.

The classification therefore has a neutral legend consistent with one of its aims of providing a framework for the systematic collection and presentation of information.

The framework resulting from the land systems survey forms a permanent basis for future planning. Additional surveys will add further detail to the land systems map and block diagrams rather than alter them. Note that this is significantly different from a land use plan, which becomes obsolete as new demands are made of the land,

When further field studies are undertaken, the land unit from which samples are taken needs to be recorded and its position recorded using a GPS. The tabulation can then be expanded to include data on soil analyses, vegetation successions, etc.

The approximate percentage area of each type of facet in a land system can be estimated from air photos. As many samples as possible should be taken. Simple extrapolation gives the areas of each in the province.