Chapter 2. DESCRIPTION OF THE LAND SYSTEMS MAP AND LANDSCAPE FACETS

Land systems were the smallest geographically defined units of this survey. An individual land system represents an area or group of areas throughout which there is a recurring pattern of climate, landscape and soils. It is a unit of land, identifiable both on the ground and from satellite imagery, within which the same type of farming is likely to succeed. Clearly, the delineation of these land units is fundamental to developing practical agricultural technologies. Further, such delineation provides a mechanism for computerizing and comparing land in a geographical context and a means of summarizing land information within a common base.

This chapter describes the steps taken to produce the Land Systems Map in Volume 2 and explains the codes used on it.

Satellite and Side-Looking Radar Imagery

Satellite and side-looking radar imagery at a scale of I to I million and, in some cases, larger scale aerial photography, were used to help define land-system boundaries.

Satellite imagery dates to the launching of the LANDSATI satellite in 1972 under the ERTS (Earth Resources Technology Survey) program of NASA (National Aeronautics and Space Administration), a civil entity of the United States Government (U.S. Geological Survey, 1977). This was succeeded by the launching of LANDSAT-2 in 1975; additional satellites with more sophisticated sensing equipment are now in orbit, and even more are planned. Each image covers 185 sq km of territory. The resolution is better than 100 M. Techniques for interpreting satellite imagery, and remotesensing techniques generally, are well documented (Draeger and McClelland, 1977; Lintz and Simonett, 1977), and advances in this field continue steadily (Barney et al., 1977; Johannsen, 1977).

With the exception of wetter areas, most of the delineation of land systems was carried out by satellite imagery using black and white photographic prints. Spectral band 5, the lower red frequency, was most commonly used; this gave a useful image of vegetation and topography. For some regions, spectral band 7, the near infrared end of the spectrum, was selected as it gave better haze penetration and land-water discrimination. Color-composite imagery, which is false color obtained by the integration of the four spectral bands, would have been preferred, but was ruled out because of cost. Figure 2-1 illustrates land-system mapping on a satellite image of the

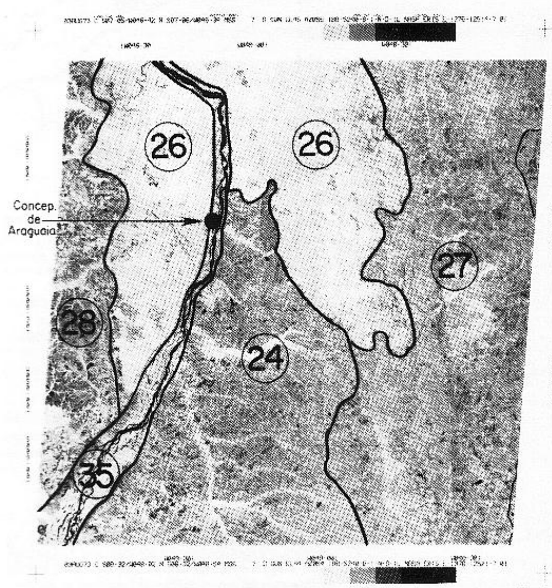

Fig. 2-1 Land-system mapping on a satellite image of the environs of Conceição do Araguaia, southeast boundary of Amazonia Central Brazil.

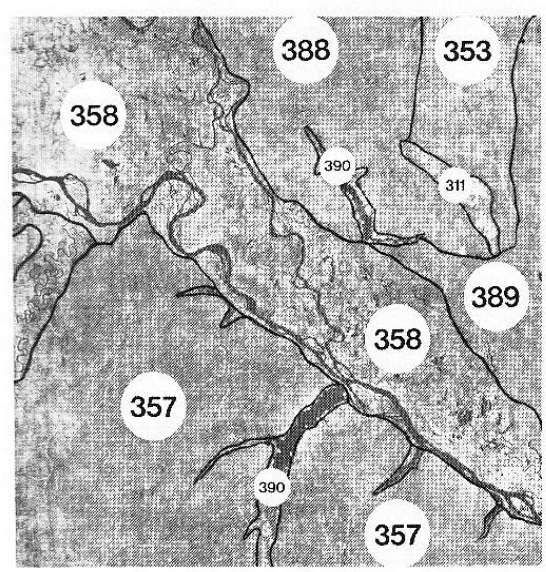

Fig. 2-2 Land-system mapping on radar imagery along the Amazon river about 350 km west of Manaus.

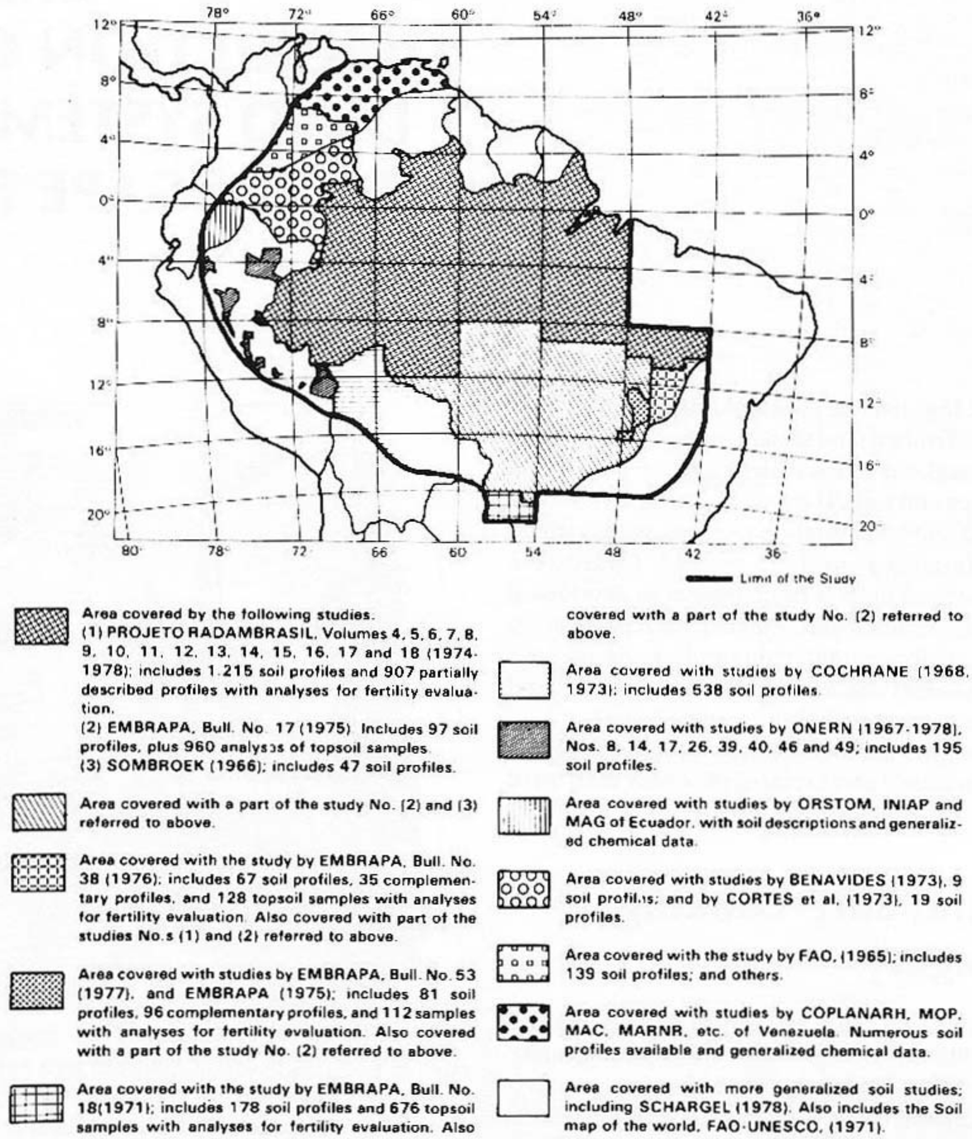

Fig. 2-3 Principal soil studies used as sources of information in the land-resource study.

environs of Conceição do Araguaia, on the southeastern fringe of Amazonia.

Satellite imagery has one major drawback. Due to the relatively short period of time the LANDSAT satellites had been transmitting when the study started, and because orbits were designed to pass over the same area at relatively infrequent intervals (originally 20 times a year, but now more frequently with LANDSAT-2 in operation), it was not surprising to find that, for the wetter areas, it was difficult to - get cloud-free imagery.

The largest area affected by the cloud problem was Amazonia. Fortunately, side-looking radar imagery, which is not affected by the presence of clouds, was available for most of Brazil's Amazonia (available from Projeto Radambrasil, Minist6rio das Minas e Energia), and this was used as a geographical base for the delineation of land systems throughout that region. Side-looking radar imagery produces an excellent topographical picture of the landscape, but it is not nearly as effective as satellite imagery in helping to identify vegetative cover and soil drainage characteristics. Figure 2-2 shows land system mapping on radar imagery along the Amazon River 350 km west of Manaus.

For some areas, including the wet eastern piedmont of Bolivia, aerial photography was used for interpreting the landscape picture.

Land-System Delineation

After climatic analyses and literature research were completed, land-system boundaries were drawn provisionally on the satellite and side-looking radar imagery. The principal soil survey references used are summarized in Figure 2-3. A guide to the reliability of the major soil-mapping coverage is given on the appended Land Systems Map.

Although the work was mainly an exercise in condensing existing information to a common identifiable base, wherever

Table 2-1. Nine physiographic regions delineated on the Land Systems Map.

Physiographic region code	Region	Physiographic region code	Region
A	Amazon Basin	M	Mojos Pampas
B	Brazilian Shield	O	Orinoco Basin
E	Elbow of the Andes	P	Pantanal
F	Andean Foothills	R	Parana Basin
G	Guayana Shield		

Table 2-2. Seven climatic subregions delineated on the Land Systems Map.

Climatic subregion code	Climate		
	WSPE[a] (mm)	Wet months[b] (no.)	WSMT[c] (°C)
a	>1300	>9	>23.5
b	1061-1300	8-9	>23.5
c	900-1060	6-8	>23.5
d	900-1060	6-8	<23.5
e	<900	<6	>23.5
f	Subtropical		
o	Others		

a. WSPE: total wet-season potential evapotranspiration, the sum of the potential evapotranspiration of the wet months.
b. Wet months are months with a moisture availability index (MAI) >0.33.
c. WSMT: wet-season mean monthly temperatures.

possible and when little or no information was available in the literature, a limited amount of field work was done to check the photo-interpretation and to standardize descriptive criteria. A small Piper PA-18, STOL (short-take-off-landing) airplane was flown by the first author to cover hinterland areas; every effort was made to examine the principal landscape facets within a given land system. During the course of the field work, land system boundaries were fixed.

Map Making

The land systems were compiled by drafting boundaries directly from the imagery. They were completed on a segment-by-segment basis, according to the index used by the 1: 1,000,000 International Chart of the World at the Millionth Scale (see Figure 1, after Kerstenetzky, 1972).

Computerization and Thematic Maps

The system originally adopted for the computer storage and reproduction of the maps was to subdivide the 1 to 1,000,000 maps into 4-minute longitude by 5-minute latitude segments (approximately 3300 ha at the equator), and then to assign a land-system code on the basis of that land system occupying the greatest proportionate area in any one segment. Once these codes were recorded, it was a straightforward exercise to reproduce maps at desired scales and projections and produce thematic or single-factor maps. Thematic maps were computer produced by assigning a rating of any of the coded and recorded land-system features to the land-system codes. In the case of land systems with more than one land facet, unless otherwise stated, this feature represents a characteristic of, the major land facet of the land system. The computerization of the land systems maps is discussed in greater detail in Chapter 3.

The Printed Land Systems Map

The printed Land Systems Map of the Central Lowlands of Tropical South America (Volume 2) is a composition based on, and reduced from, the original I to 1,000,000 sheets. It was produced to provide a geographical overview of the region, always within the precisional imitation of map reproduction at a scale of approximately 1:5,000,000. This map provides a guide to the location of individual land systems; it identifies the predominant land systems in any region of special interest; and it draws a picture of the major advantages and constraints for land use, particularly germplasm suitability or adaptability, for that region. The land systems have been -assigned numbers for ease of reference. Apart from depicting land systems, the printed map synthesizes information on climate, topography, vegetation, and soils.

Codes used on the map are described as follows.

Physiography. The capital-letter code preceding the land system number identifies the land system as belonging to one of nine, readily appreciated, broad physiographic regions

Table 2-3. Four topographical classes delineated on the Land Systems Map.

Topography classification	Description	Shading code
Flat, poorly drained	Flat, poorly drained or seasonally flooded	small dots
< 8%	Almost flat, mainly well-drained with slopes less than 8%	unshaded
8-30%	Undulating to rolling; slopes 8-30%	large dots
>30%	Hilly to steep; slopes greater than 30%	triangles

(Table 2-1). These regions are described in more detail in Chapter 4; they are only approximate separations to provide a very generalized picture of the ma or physiographic regions within the study area.

Climate. On the Land Systems Map, a small-letter code distinguishes climatic subregions (Table 2-2). The climatic subregions and the terminology used are defined in Chapter 3. The subdivision according to WSPE (wet-season potential evapotranspiration) provides a novel climatic separation; it is an approximate accounting of the amount of energy mature vegetation growing on well-drained soils can use annually, assuming that little or no growth takes place during the dry season. The number of wet months adds to the definition of the climatic subregions, and the temperature criterion separates lowland from higher land and/or higher latitude regions.

Topography. Four broad topographical classes identify the topography of the principal land facets of the land systems bv the use of shading codes (Table 2-3).

Vegetation. The natural physioenomiction classes occurring on the principal land systems "facets" are identified through color codes. These include the following classifications, which are defined in Chapter 4:

1. Well-drained, isohyperthermic savannas
2. Well-drained, isothermic savannas
3. Poorly drained savannas
4. Tropical rain forests
5. Tropical semi-evergreen seasonal forests
6. Tropical (semi-)deciduous seasonal forests
7. Caatinga
8. Gallery forests, associations with palms and other vegetation complexes of poorly drained lands
9. Submontane, subtropical forests.

Soils -the soil classification legend. *A Legend to the Land Systems Map,* for classifying the soils of the land facets of each land system, is also enclosed in Volume 2 of this book. The coding key used is illustrated in Figure 2-4. This is explained in more detail in Volume 2.

Soils were classified to the Great Group category of Soil Taxonomy (Soil Survey Staff. 1975) according to the FAO-UNESCO Soil M ap of the World Legend (1974), and by-their textures and fertility constraints as rated in the Fertility Capability Classification (FCC) system of Buol el al- (1975). Great Group soil classes, according to Soil Taxonomy (Soil Survey Staff, 1975) are identified by a series of five-letter codes for the principal land facets of the land systems. The

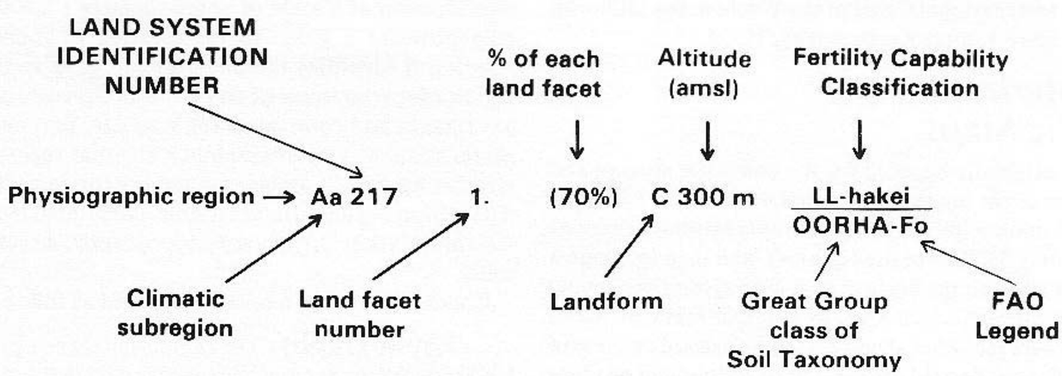

Fig. 2-4 Soil classification legend for the Land Systems Map, including descriptions of the land facets of the land systems.

Table 2-4. Coding used to identify soil Orders, Suborders, and Great Groups according to Soil Taxonomy (Soil Survey Staff, 1975), on the Land Systems Map.

Order		Suborder		Great Group	
Name	Code	Name	Code	Name	Code
Alfisols	A	Aqualfs	AQ	Natraqualfs	NA
				Tropaqualfs	TR
		Udalfs	UD	Hapludalfs	HA
				Rhodudalfs	RH
				Tropudalfs	TR
		Ustalfs	US	Paleustalfs	PA
				Haplustalfs	HA
				Natrustalfs	NA
				Rhodustalfs	RH
				Tropustalfs	TR
		Xeralfs	XE	Haploxeralfs	HA
Aridisols	D	Orthids	OR	Cambrothids	CM
Entisols	E	Aquents	AQ	Fluvaquents	FL
				Haplaquents	HA
				Hydraquents	HY
				Psammaquents	PS
				Tropaquents	TR
		Fluvents	FL	Tropofluvents	TR
				Ustifluvents	US
				Xerofluvents	XE
		Orthents	OR	Troporthents	TR
				Ustorthents	US
		Psamments	PS	Quartzipsamments	QU
				Tropopsamments	TR
				Ustipsamments	US
Inceptisols	I	Andepts	AN	Dystrandepts	DY
				Hydrandepts	HY
		Aquepts	AQ	Haplaquepts	HA
				Humaquepts	HU
				Plinthaquepts	PL
				Sulfaquepts	SU
				Tropaquepts	TR
		Tropepts	TR	Dystropepts	DY
				Eutropepts	EU
				Ustropepts	US
Mollisols	M	Aquolls	AQ	Haplaquolls	HA
		Udolls	UD	Argiudolls	AR
			US	Haplustolls	HA
Oxisols	O	Aquox	AQ	Plinthaquox	PL
		Orthox	OR	Acrorthox	AC
				Eutrorthox	EU
				Haplorthox	HA
				Umbriorthox	UM
		Ustox	US	Acrustox	AC
				Eutrustox	EU
				Haplustox	HA
Spodosols	S	Aquods	AQ	Tropaquods	TR
Ultisols	U	Aquults	AQ	Albaquults	AL
				Paleaquults	PA
				Plinthaquults	PL
				Tropaquults	TR
				Hapludults	HA
		Udults	UD	Paleudults	PA
				Plinthudults	PL
				Rhodudults	RH
				Tropudults	TR
		Ustults	US	Haplustults	HA
				Paleustults	PA
				Rhodustults	RH
Vertisols	V	Uderts	UD	Chromuderts	CH

Table 2-5. Coding used to identify soils according to the FAO-Unesco Soil Legend (1974) on the Land Systems Map.

Soil Legend name	Code	Soil Legend name	Code
Chromic Vertisols	Vc	Dystric Planosols	WD
Lithosols	I	Gleyic Solonetz	Sg
Thionic Fluvisols	Jt	Orthic Solonetz	So
Calcaric Fluvisols	Jc	Luvic Phaeozems	Hl
Dystric Fluvisols	Jd	Haplic Phaeozems	Hh
Eutric Fluvisols	Je	Luvic Xerosols	Xl
Gleyic Solonchaks	Zg	Haplic Yermosols	Yh
Plinthic Gleysols	Gp	Dystric Nitosols	Nd
Mollic Gleysols	Gm	Plinthic Acrisols	Ap
Humic Gleysols	Gh	Gleyic Acrisols	Ag
Dystric Gleysols	Gd	Orthic Acrisols	Ao
Eutric Gleysols	Ge	Ferric Acrisols	Af
Humic Andosols	Th	Gleyic Luvisols	Lg
Albic Arenosols	Qa	Ferric Luvisols	Lf
Ferralic Arenosols	Qf	Chromic Luvisols	Lc
Dystric Regosols	Rd	Orthic Luvisols	Lo
Eutric Regosols	Re	Calcic Cambisols	Bk
Gleyic Podzols	Pg	Ferralic Cambisols	Bf
Plinthic Ferralsols	Fp	Dystric Cambisols	Bd
Humic Ferralsols	Fh	Eutric Cambisols	Be
Acric Ferralsols	Fa		
Rhodic Ferralsols	Fr		
Xanthic Ferralsols	Fx		
Orthic Ferralsols	Fo		

Table 2-6. Summary of the Fertility Capability Classification (Buol et al., 1975) codes used on the Land Systems Map.

Soil texture[a]		Soil fertility constraints[b]	
Code	Description	Code	Description
S	sandy	g	gleyey
L	loamy	d	dry
C	clayey	e	low ECEC
O	organic	a	Al toxicity
R	rocky	h	acidity
		i	P fixation
		x	X-ray amorphous
		v	vertic, Vertisol
		k	K deficient
		b	basic reaction
		s	salinity
		n	natric
		c	cat clay

a. Classified by the first two capital letters, which refer to the topsoil and subsoil respectively.
b. Or "condition modifiers", given as small letters following the capital letters.

first letter of the code identifies the Order; adding the second two letters gives the Suborder; and adding the last two letters gives the Great Group. For example, OUSAC refers to the Order, Oxisol (OUSAC); the Suborder, Ustox (OUS AC); and finally the Great Group, Acrustox (OUSAC). Table 2-4 summarizes the coding used to identify the soil Orders, Suborders, and Great Groups found in the region.

The coding used to identify soils from the Soil Legend was the same as that used by FAO-Unesco. Table 2-5 lists the soils identified in the region and their codes.

Table 2-6 summarizes the codes used to identify soils according to the Fertility Capability Classification (FFC). Some of the definitions used in this work to define fertility constraints or, to use FCC terminology, "condition modifiers," differ from those used by Buol et al. (1975): These include the definitions of Al toxicity, acidity, and K deficiency; however, the variation in definitions is relatively minor. The FCC coding and definitions are detailed in Chapters 5 and 6.

Apart from land-resource information, the Land Systems Map contains geographical information to identify the approximate location of major rivers, cities, and towns.

Synthesis

The Land Systems Map was prepared to provide a geographic reference base of the land systems and a pictorial representation of their main features in terms of climate, landscape (including natural vegetation), and soils. It is hoped that the innate complexity of agricultural land resources is thus emphasized, because these factors do vary from area to area. Fortunately, in our technologically advancing age, the detailed description and comparison of the many properties of the land systems and their facets can be handled by coding and computerization. In this study, the printed map can best be read and appreciated in the light of the computerized data base, summarized in the form of computer printouts in Part I of Volume 3, *Computer Summary and Soil Profile Descriptions of the Land Systems,* the computerized land resource summaries of the land systems, and Part 2, a selection of the meteorological data sets, also in Volume 3.