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Pilot Analysis of Global Ecosystems (PAGE)

Agriculture Component

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Agroecosystem Assessment for Latin America: Agriculture Extent, Production Systems and Agrobiodiversity

by

Manuel Winograd and Andrew Farrow

with the participation of

Marta Aguilar, Luz Amira Clavijo, Daniel Debouck, Peter Jones, Glenn Hyman, German Lema, Andrew Nelson, Federico Holmann, Joe Tohme, Orlando Toro and Osvaldo Voysest.

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1. The Agroecosystems

Agroecosystems are unique ecosystems because their functions and dynamics relate directly to:

- human activities;
- reconversion of other types of ecosystems;
- maintenance of production capacities; and
- internal and external effects of agroecosystems.

In other words, agroecosystems explicitly include the human population as a fundamental component. This inclusion explains why the relationships of agroecosystems with the environment, in addition to being complex, and nonlinear, also depend on spatial and temporal dimensions. Likewise, the close connection with national, regional, and global policies and strategies (prices, economic opening, subsidies, etc.) directly affects agroecosystem dynamics, functioning, and sustainability. Thus, an integrated agroecosystems approach should be determined by the different types of agroecosystems and their biophysical attributes, as well as by the social, economic, production, and technological conditions prevailing at a given site at a given time.

1.1 Defining an Agroecosystem

To be consistent and congruent with the other components and studies of Pilot Analysis of Global Ecosystems (PAGE), the definition of "agroecosystems" adopted by this study is broad. An "agroecosystem" is an area where humans use physical and biological resources to produce food, feed, and fiber by growing crops, extracting products, and rearing animals. An agroecosystem is a dynamic entity whose long-term capacity to remain productive is largely determined by the interaction between its biophysical resources and the productive uses to which they are put (IFPRI,1998; Swift et al.,1996; Waltner-Toews,1994).

1 2 Importance of Agroecosystems in Latin America

Agroecosystems, in addition to producing goods and services, are important because of the beneficial or detrimental effects these and other ecosystems (forests, savannas, aquatic ecosystems, coastal areas) generate. Although activities carried out at the agroecosystem level may lead to the deterioration of soil and water resources and air quality or to the loss of habitats and biodiversity by reconverting natural ecosystems, they may also yield several environmental and socioeconomic benefits. In addition to producing food and raw materials for human use, agroecosystems could serve as sink/source of greenhouse gases; they also conserve and enrich biodiversity and landscapes, while preventing floods, landslides, and land erosion.

In 1996, agroecosystems covered 747 million hectares in Latin America (37% of total surface), of which 153 million hectares were planted to crops (8% of total surface) and 594 million hectares were in grasslands (29% of total surface) (WRI, 1998). From the socioeconomic viewpoint, agroecosystems in Latin America and the Caribbean, including agro-industries, generated 30% of the GDP, 27% of total exports, and 40% of employment in 1996 (World Bank, 1998). Many national economies in the region depend directly on agricultural activities, nevertheless the mismanagement and misuse of agroecosystems is at the heart of the problem of increased poverty, rural migration, and rapid degradation of the natural resource base.

1.3 Agroecosystem Trends in Latin America

Historically, two characteristics of agroecosystem management in Latin America have been extensive agricultural and livestock activities and an expansion of the agricultural frontier. However, as of the 1990s, agroecosystem use and management have tended more towards the modernization and intensification of agriculture. This is particularly valid for export products because a high percentage of agricultural production continues to consist of so-called "wage benefits" (Trigo, 1995; Rivas, 1998; Vera and Rivas, 1997). This is why subsistence agriculture in hillside areas of Latin America accounted for 30 percent of total agricultural production in 1980-1985, occupying nearly 40 percent of rural population, 17 percent of total surface, and 29 percent of total agricultural land (World Bank, 1990; IFAD, 1993).

The modernization and intensification of agriculture in Latin America have led to an increased use of inputs. This use, however, is still low if compared with that of other regions. In 1996, the region used, on average, 67 kg of fertilizers per cultivated hectare, while average use was 123 kg in developed countries, 114 kg in low-income countries, and 258 kg in average-income ones (World Bank, 1998). Crop yields are still below the world average. Average yields of cereal grains in Latin America in 1996 were 2.5 tons per hectare compared with the world average of 2.8 tons per hectare (WRI, 1998). Irrigated lands now represent more than 11% of total cultivated surface. In Mexico, Chile, and Peru, for example, more than half of the total value of agricultural production comes from irrigated areas. However, poor irrigation management has led to salinisation and desertification, and now 33% of irrigated land in the region is desertified (CEPAL, 1991).

Despite the expansion of improved grasses and the intensification of the livestock sector in recent years, the use of lands for livestock activities in Latin America has been characterized by low efficiency, small yields and low stocking rates (only 0.6 animals per hectare) (FAO,1999). The 1990s have been marked by the phenomenon of crops being planted in native savannas of the region (Pampas, Cerrados, Llanos) while cattle is being raised in traditionally agricultural areas (Andean hillsides and the lowlands of Mexico and Central America).

Concentration of land in a few hands continues to characterize the region's agroecosystem structure. Concentration indices have not only remained practically unchanged since 1950, but are also the highest worldwide (FAO, 1988).

The high diversity of ecosystems, species, and production systems is one of the main characteristics of Latin America agroecosystems but is seldom taken into account. Latin America generated 35% of the world's basic staples and industrial species (Kloppenburg and Kleinman, 1987). However nearly 90% of the region's agricultural production can be attributed to only 15 cultivated species, which usually result from fairly homogeneous genotypes bred for higher yields. The resulting genetic erosion has been accompanied by an abandonment of important crops and varieties, especially in hillside areas where subsistence agriculture prevails. In these areas, more than 200 potentially arable crop species (roots and tubers, grains, vegetables, and fruits) exist, but are at risk because of the homogenization in crops, land uses, and production systems (NRC, 1989).

Regarding the potential for agroecosystems, Latin America has 193 million hectares with agricultural potential that could be added to the 153 million hectares currently under agricultural production. If a low level of inputs is used, Latin America would need to cultivate 19% of its surface (100% of the land with agricultural potential) to feed its population by the year 2030. If an intermediate level of inputs were used, it would need to cultivate 7% of its surface (38% of the land with agricultural potential). If a high level of inputs were used, it would have to cultivate 4% of its surface (22% of the land with agricultural potential) (Gómez and Gallopín, 1995).

2. Methodology for Assessing Agroecosystems in Latin America

To perform an integrated ecosystem assessment, not only must the pressures and driving forces within and between ecosystems be known, but also the status and situation of ecosystems and natural resources, the impact/effects of human activities on ecosystems, and society's responses to improve or protect these ecosystems. Furthermore, the cause-effect relationship of development on ecosystems should be analyzed as well as the trade-offs between current and potential uses of ecosystems, goods and services within and between ecosystems, and on-site and off-site effects of the use and management of ecosystems and natural resources.

The first stage of PAGE basically aims to analyze the status of ecosystems, particularly their nature and importance. Within this limited framework and in the case of agroecosystem status, the first step is to define a methodological framework. This framework should help determine the extent and distribution of crops and grasslands, identify predominating production systems, define existing types of agroecosystems, group agroecosystems according to intensity of use and management, and analyze the use and location of each ecosystem's biodiversity (see Figure 1).

2.1 Defining Indicators

Given the special characteristics of agroecosystems, indicators must be defined in order to make visible signs/symptoms of:

- The pressures or driving forces of change exerted by human activities on agroecosystems, including development processes, planning activities, programs, strategies, and policies;
- The state of agroecosystems, including elements affecting agroecosystem condition and value, as well as the ability of the agroecosystem to continue providing goods and services;
- The impacts, both positive and negative, on the function, dynamics, and management of agroecosystems, including the capacity and limitations of each agroecosystem to absorb the effects of human activities;
- The responses, generated by society, including changes in policies, markets and consumption patterns, access to technologies and technology generation/adoption; and most importantly
- The cause-effect relationships within and between ecosystems, including relationships between the spatial and temporal dimensions, to determine where, when, and how pressures, changes, impacts, and responses can occur.

To satisfy these needs, different conceptual frameworks may be used to define and develop indicators (OECD, 1997; IFEN, 1998; FAO/UNDP/UNEP/World Bank, 1997; CIAT/World Bank/UNEP, 1998). However, given the scope and objectives of this first stage of PAGE, the definition of indicators aims to generate pointers on agroecosystem extent, structure, productivity, goods, and services and on existing methodologies and data for future use. Within this context, indicators refer more to status indicators within the Pressure-Status-Impact-Response framework. Indicators defined for this first prototype stage of PAGE are presented in Table 1.

Table 1. Indicators for the Agroecosystem Assessment in Latin America

State	**Condition**	**Extent:** Agriculture Extent
		Structure: Crop Density/Pasture Density
		Productivity: Production Systems
		Key Species: Original Crops Distribution
	Value	**Goods:** Agriculture Management/Intensification
		Services: Agrobiodiversity Hotspot Areas

However, given the importance of an integrated agroecosystem approach, Annex 1 lists examples of possible indicators in terms of the Pressure-State-Impact-Response framework.

2.2. Steps for Assessing Agroecosystems in Latin America

The first stage of the proposed study will attempt to define the extent and location of agroecosystems. To do so, spatial and tabulated information, such as regional and national maps of land use/cover, national and subnational agricultural and livestock statistics and accessibility, will be needed as inputs. The objective is to define an initial typology that determines and verifies the location and extent of areas under agricultural and/or livestock production. Two types of information can be obtained.

The first consists of an inventory of available data and an assessment and analysis of information quality and types. The second relates to maps on extent and location of agricultural and livestock activities and on density of crops and pastures (Figure 1).

The second stage seeks to define and locate existing, predominating production systems within the agroecosystems (Figure 1). To do so, a typology of production systems must be defined (Figure 2). Inputs used in this stage include those produced in the first stage, i.e. the agroecosystems extent map, as well as consultation with experts. The output will be a production system map according to 5 categories: annual crops, perennial/semiannual crops, mixed production systems, native pastures, and improved pastures.

The third stage will define the distribution and location of agroecosystems in relation to biophysical characteristics (Figure 1). It is not enough to know the location and extent of agroecosystems because the production of goods and services, agroecosystem management, intensification, uses, and positive or negative impacts are affected by the climate, relief, and soil quality. In addition to the information generated in the first two stages, inputs needed to produce an agroecosystem map in this stage include relief, soil, and climate maps as well as consultation with experts.

The fourth stage of the process aims to identify the level of prevailing management and intensification of the different production systems and assign them accordingly (Figure 1). Two levels–intensive and non-intensive–are defined and can be combined with each category of production systems (Figure 2). The information generated in previous stages will be used and consultations conducted with experts. The output will be a map on agroecosystem management/intensification.

Figure 1. Flow-steps for the Agroecosystem Assessment for Latin America

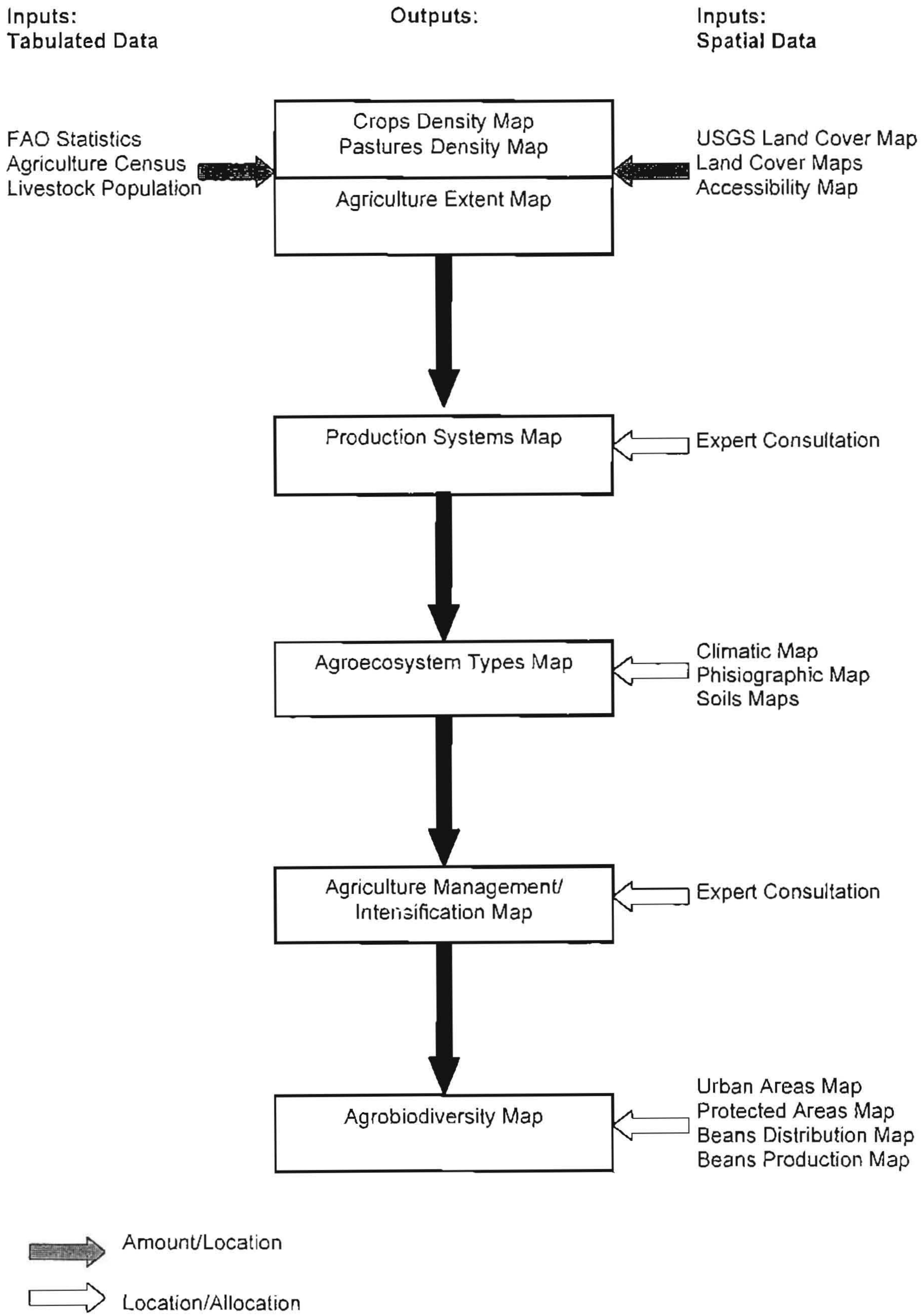

Figure 2. Typology for the Definition of Agriculture Extent, Production Systems and Levels of Management/Intensification.

Agriculture Extent:	*Production Systems:*	Level of Management/Intensification:
	Annual crops	intensive non intensive
Cropland	*Perennial/semi-annuals crops*	intensive non intensive
	Mixed systems	intensive non intensive
Pastures		
	Natural pastures	non intensive
	Improved pastures	intensive non intensive

The last stage analyzes the use and status of agrobiodiversity of an important and cultivated native species. The distribution of biodiversity will be shown in this case for beans (*Phaseolus* sp.), and production areas located (Figure 1). Inputs required for this stage are distribution maps of wild and cultivated bean varieties, a distribution map of bean production, and a map of protected and urban areas. The planned output is a map indicating the distribution of biodiversity for beans and its relationship to both protected and production areas.

3. Results

The outputs generated by this pilot PAGE study on Latin America agroecosystems go beyond the production of maps on the extent of agriculture, production systems, intensity of agroecosystem management, types of agroecosystems, and agrobiodiversity. In particular they suggest methodologies and methods for conducting integrated agroecosystem assessment, for analyzing and managing information (quality and type), and for defining and using indicators necessary for monitoring. Outputs will accordingly apply to Latin America and, in some cases, to a given subregion (Central America, Andean region) because the maps aim to illustrate the type of outputs and methodological analyses, as well as aspects related to availability, quality, and type of information.

3.1 Agriculture Extent Map

The first step of any evaluation consists in determining the extent and location of ecosystems, which is fundamental to correctly defining and locating areas belonging to a given ecosystem. Therefore, available information sources and types (both tabulated and spatial) should be identified, and data quality assessed. Given the information sources that are available, and to complement other PAGE components, the information contained in the USGS seasonal land cover map (USGS, 1995) was reviewed and assessed. This low-resolution satellite coverage has been used by different institutions to prepare maps of land use/cover, with different results (see Annex 3).

The results of location and extent of agroecosystems, derived from the USGS seasonal land cover map, are compared with several regional and national sources of information (Table 2). While inconsistencies are found in the *extent* of agroecosystems, the more significant issues are those related to the *location* of agroecosystems (Annex 3). The main areas where problems occur are in the tropical and subtropical areas, where mixed production systems, small plots, and/or type of crop could affect data interpretation. As a result of this evaluation, Figure 3 shows a map indicating the percentages of disparity between two basic sources of information (national agricultural censuses and the USGS seasonal land cover map using the IFPRI classification).

In order to produce an agriculture extent map, given the large discrepancies between sources of the extent and location of agroecosystems in LAC, it is

Table 2. Cropland and Agriculture Extent: Comparison between Different Sources

Country	FAO Cropland Area (km2) 1991-93 1	FAO Pasture Area (km2) 1991-93 2	FAO Agriculture Area (km2) 1991-93 3 = 1+2	USGS-IGBP Agriculture Area (km2) 1992-93 4	USGS-IFPRI Agriculture Area (km2) 1992-93 5	Census Cropland Area (km2) 1985-95 6	% FAO Cropland/ USGS-IFPRI Agriculture 7 = 1/5	% FAO Agriculture/ USGS-IFPRI Agriculture 8 = 3/5	% FAO Cropland/ Census Cropland 9 = 1/6
Argentina	272000	1420330	1692330	1123322	760415	129586	-280	45	366
Bolivia	23730	265170	288900	154533	157551	13769	-664	54	58
Brazil	505600	1857670	2363270	3595485	2386998	420343	-472	-101	83
Chile	42930	135830	178760	107655	96919	10259	-226	54	24
Colombia	54500	405670	460170	250468	242236	27301	-444	53	50
Ecuador	30120	20910	51030	83721	61637	26978	-205	-121	90
Fr. Guiana	0	0	0	4453	10328	187	n/a	n/a	n/a
Guyana	4960	12300	17260	30057	34086	695	-687	-197	14
Paraguay	22580	216000	238580	88621	72665	6306	-321	30	28
Peru	36300	271200	307500	138933	163331	31258	-445	53	86
Suriname	680	210	890	1226	19118	767	-2811	-2148	-113
Uruguay	13040	135200	148240	169327	86616	6641	-664	58	51
Venezuela	39120	177830	216950	229694	185701	16927	-475	86	43
South America	**1045560**	**4918320**	**5963880**	**5977495**	**4277601**	**691017**	**-409**	**72**	**66**
Panama	6580	14870	21450	28921	27414	n/a	-416	-128	n/a
Costa Rica	5300	23370	28670	1992	18584	n/a	-350	65	n/a
Nicaragua	12720	54830	67550	30765	33377	28696	-262	49	-226
Honduras	19040	15110	34150	3566	35868	4121	-188	-105	22
El Salvador	7300	6100	13400	7187	6952	4827	95	52	66
Guatemala	18170	25340	43510	3322	33938	4593	-187	78	25
Belice	570	480	1050	6628	5700	567	-1000	-543	99
Central America	**69680**	**140100**	**209780**	**82381**	**161833**	**42804**	**-232**	**77**	**61**
Cuba	33370	29700	63070	44742	33400	n/a	100	53	n/a
Dominican Rep.	14490	20	14510	11633	14500	n/a	100	100	n/a
Haiti	9080	4950	14030	10846	9100	n/a	100	65	n/a
Jamaica	2190	2570	4760	1967	2190	n/a	100	46	n/a
Caribbean	**59130**	**37240**	**96370**	**69188**	**59190**	**n/a**	**100**	**61**	**n/a**
Mexico	247270	744990	992260	324707	247300	213485	100	-25	86
Latin America	**1421640**	**5840650**	**7262290**	**6453771**	**4745924**	**947306**	**-334**	**65**	**67**

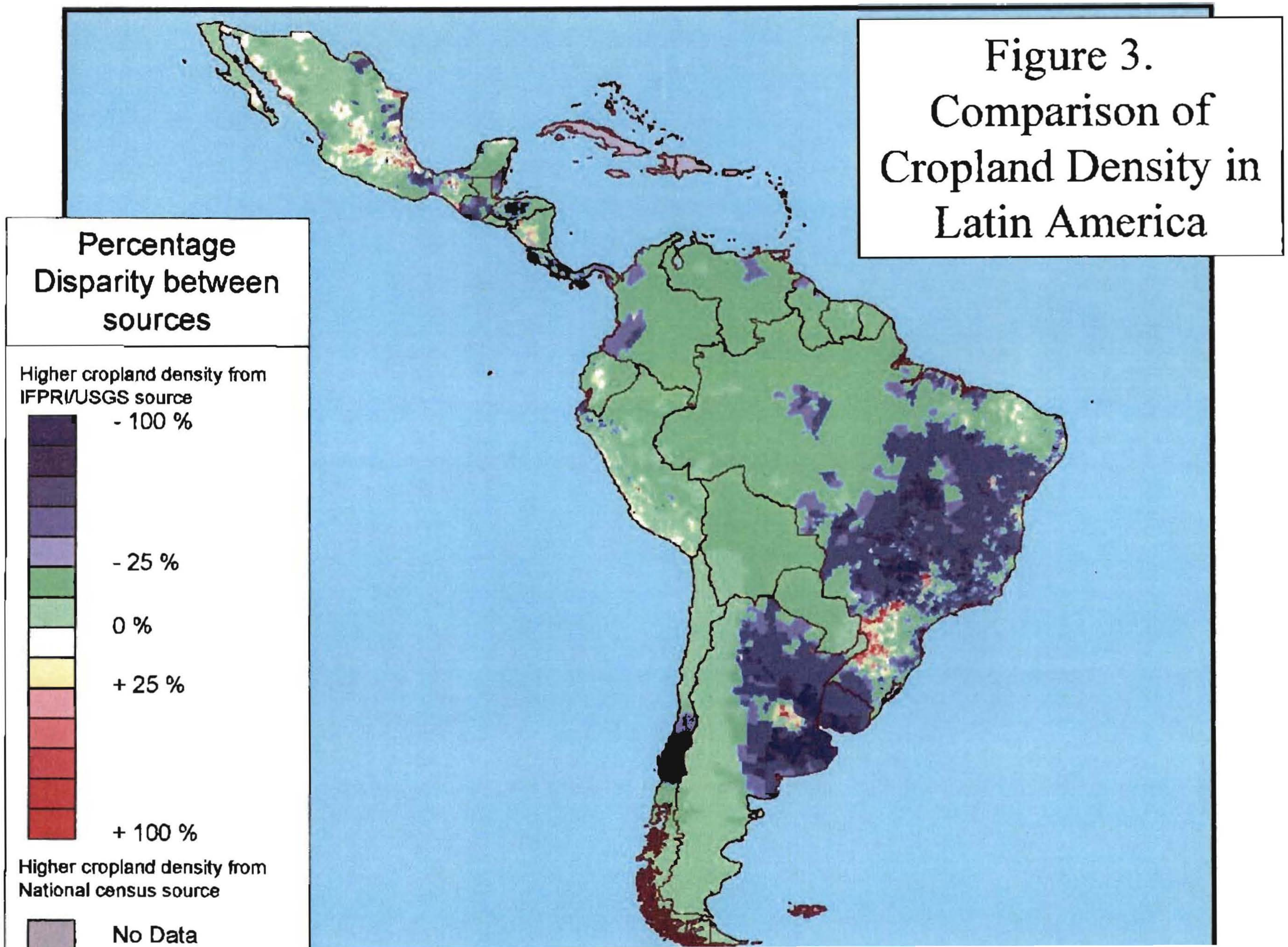
Figure 3.
Comparison of
Cropland Density in
Latin America
Percentage
Disparity between
sources
Higher cropland density from
IFPRI/USGS source
- 100 %
- 25 %
0 %
+ 25 %
+ 100 %
Higher cropland density from
National census source
No Data

necessary to use a number of different information sources. These are primarily the national agricultural and livestock censuses and national land use/cover maps (Figures 4 and 5). Annex 2 shows the information sources used to produce maps on crop and grassland densities for Latin America. Annexes 4 and 5 show the maps of crop and grassland densities used to produce the agriculture extent map for Central America (Figure 6). From this map the total area under agroecosystems in Central America (Figure 6) was 160,000 km^2 in 1990-1995. Of this total area, 28% is under crops and 72% under grasslands.

3.2 Agroecosystem Production Systems

To analyze the condition and importance of agroecosystems, in addition to information on their extent and location, production systems must be identified. The second stage attempts to classify agroecosystems in relation to major production systems, on the basis of a simple typology (see Figure 2). This classification offers several indications on structure and productivity, management, possible impact on the generation of goods and services, capacity to respond to change, and vulnerability. Categories have been defined as follows:

- Annual crops: areas with 60%-80% under cereal grains, legumes, oleaginous crops, roots and tubers.
- Permanent crops: areas with 40%-60% under permanent crops (coffee, banana, plantain, fruit trees, African palm) and semiannual crops (sugarcane).
- Mixed production systems: mosaic of areas with 40%-60% under grasslands, 40-60% under annual crops, and 0-20% under permanent crops, semiannual crops, and vegetables.
- Native pastures: areas with 60%-80% under native pastures.
- Improved pastures: areas with 40%-60% under improved pastures.

In general, regional production systems have undergone important changes in recent years regarding land use and tenure and have accordingly affected goods

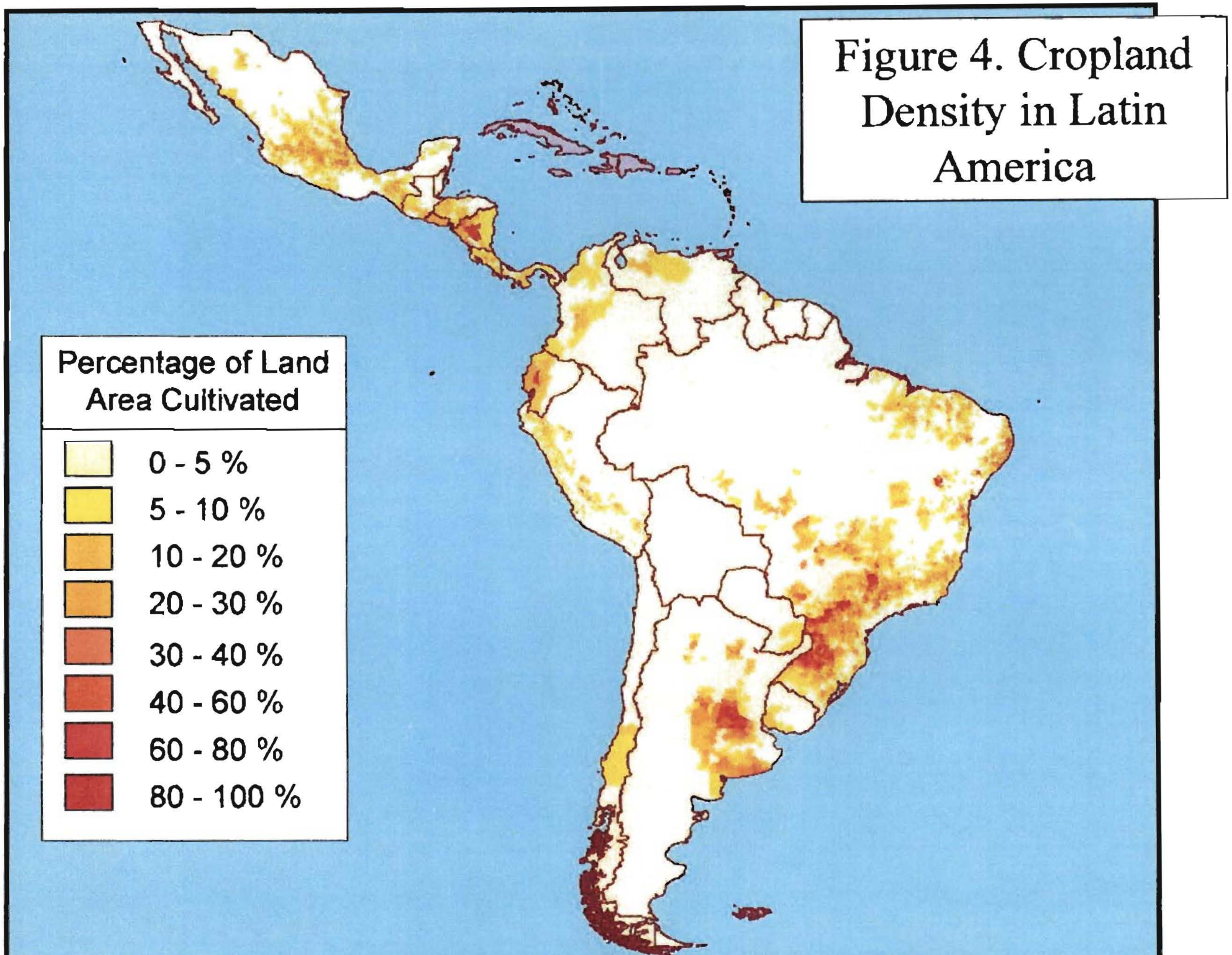
Figure 4. Cropland Density in Latin America
Percentage of Land Area Cultivated
0 - 5 %
5 - 10 %
10 - 20 %
20 - 30 %
30 - 40 %
40 - 60 %
60 - 80 %
80 - 100 %

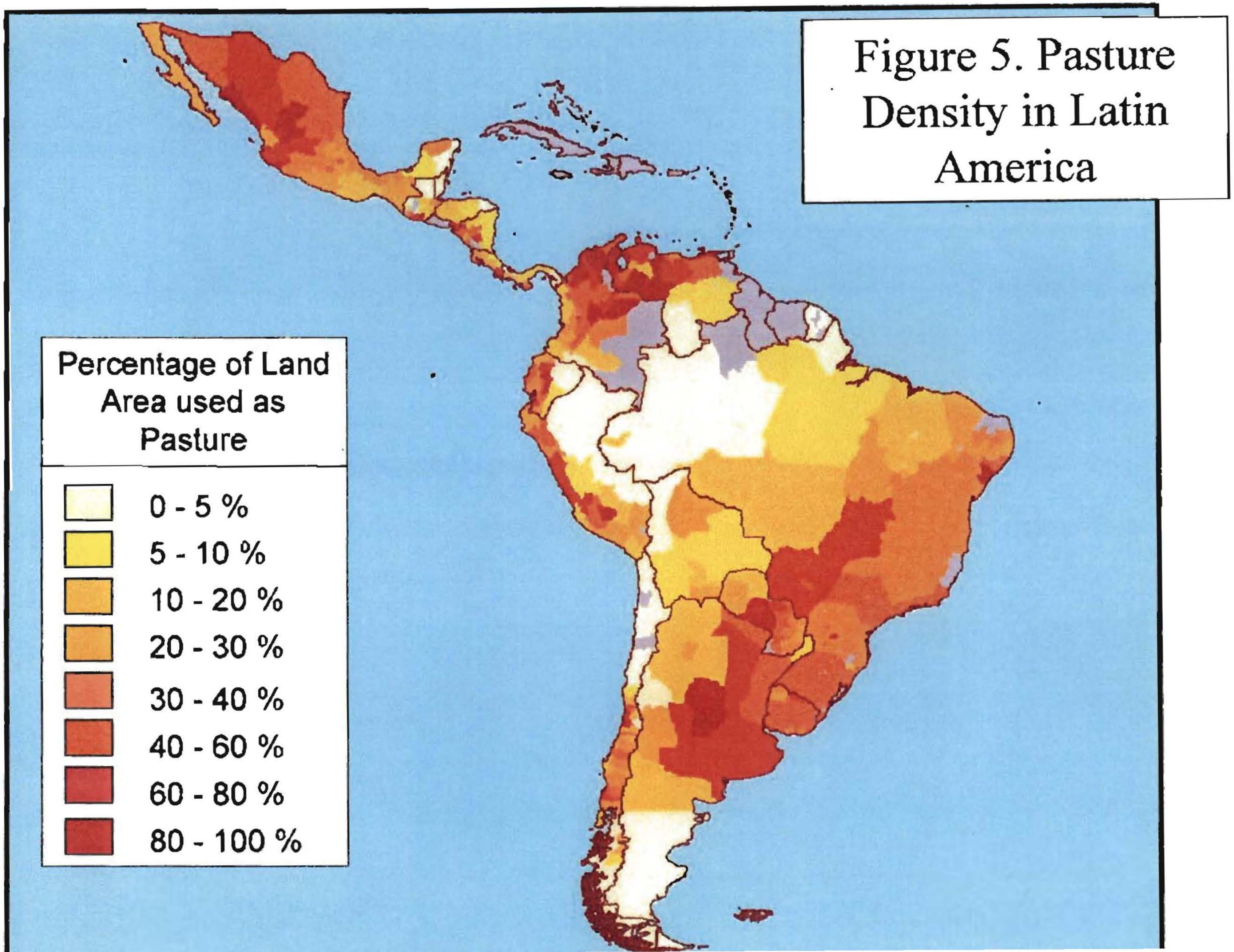
Figure 5. Pasture Density in Latin America
Percentage of Land Area used as Pasture
0 - 5 %
5 - 10 %
10 - 20 %
20 - 30 %
30 - 40 %
40 - 60 %
60 - 80 %
80 - 100 %

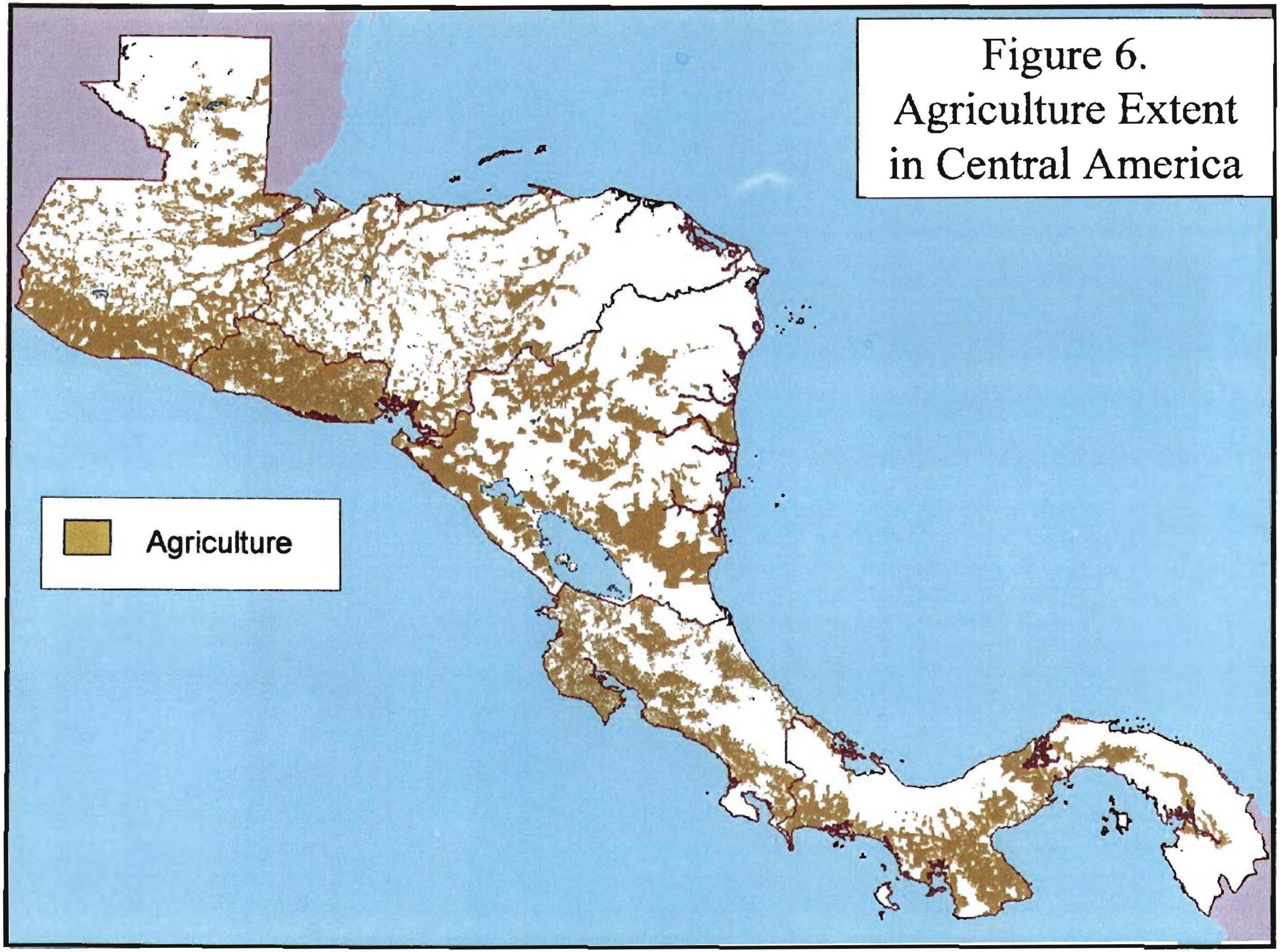

Figure 6.
Agriculture Extent
in Central America

and services. With the modernization and intensification of agriculture, the traditional predominance of mixed production systems and cultivation of annual crops for subsistence and the expansion of the agricultural frontier for pastures have been replaced by the intensive cultivation of annual and permanent crops for export and the sowing of improved pastures. These changes are mainly due to socioeconomic reasons, for example policies on economic opening, new markets, trade, product prices, transportation, changes in rural population, and poverty in rural areas.

Figure 7 shows the map of major production systems in agroecosystems of Central America. For 1990-1995, 62% of the total area of agroecosystems was under permanent pastures; 22%, mixed production systems; 10%, permanent crops; and 6%, annual crops. Figure 9 has been analyzed in relation to other information sources (CCAD,1998; FAO,1999; Leonard,1997; Utting,1991; Winograd et al., 1998) to observe trends in the extent of production systems in Central America. In 1980, permanent pastures accounted for 62%; annual crops 32%; and permanent crops 6%, compared with 72%, 14%, and 14%, respectively, for 1990-1995. In other words, with the modernization and intensification of agroecosystems, production systems have tended to homogenize with a predominance of permanent crops for export and permanent pastures, which are also located on the best soils and in the more accessible areas. These changes, however, are part of cycles of expansion-contraction, depending on medium- and long-term structural factors, for example agroecological potential, access to new lands, and land tenure. Short-term circumstantial factors are also important; these include changes in the market and in international and national prices, fiscal and agricultural policies, structural adjustments, and the opening of economies in the region. This explains why cotton-growing areas have almost disappeared, while not only the area planted to bananas but also the production figures have doubled in the last 15 years. Furthermore, not only have the areas planted to annual crops decreased, but their yields per hectare have remained stable. This is due to the lack of improved

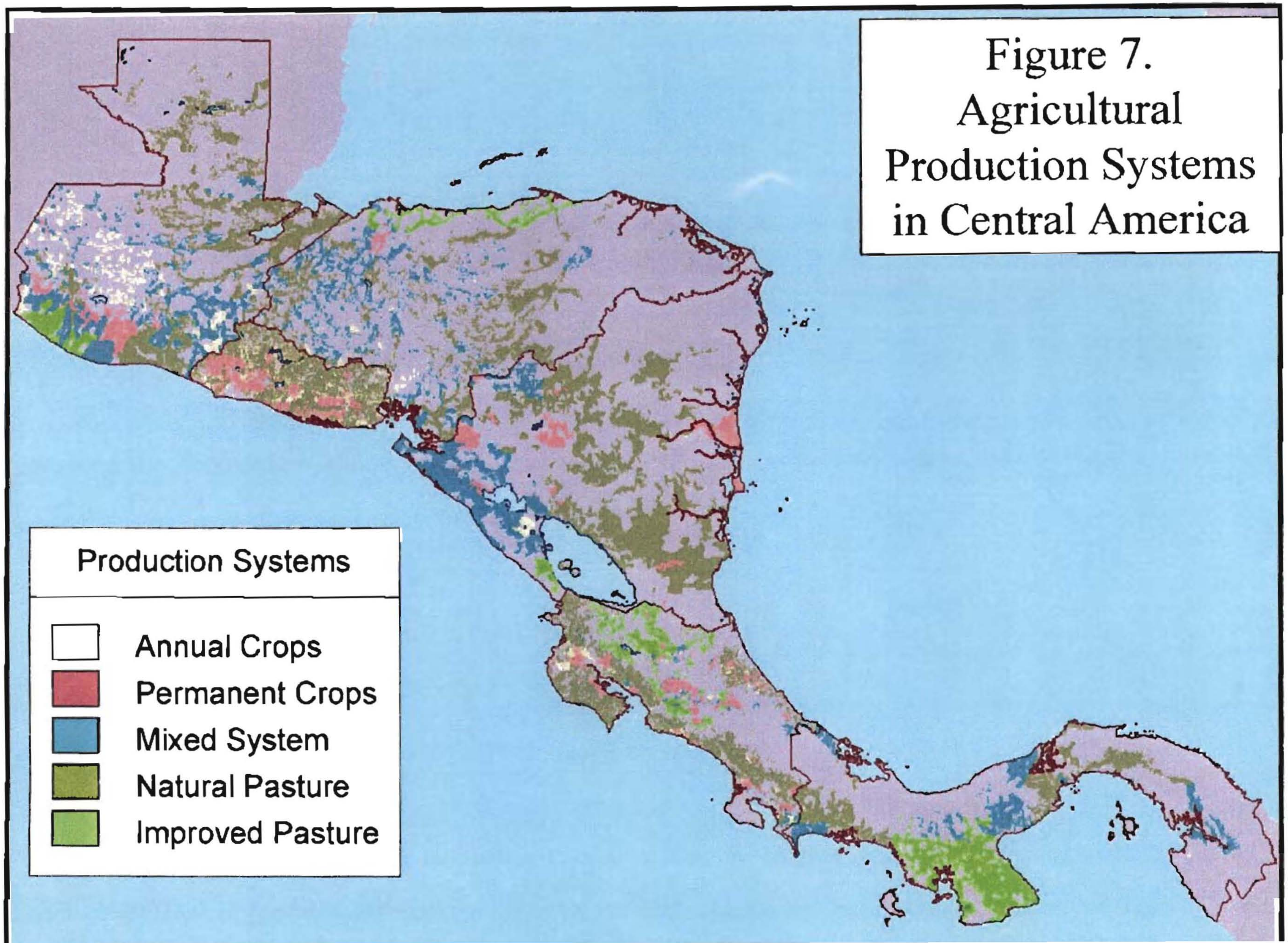
Figure 7.
Agricultural
Production Systems
in Central America
Production Systems
Annual Crops
Permanent Crops
Mixed System
Natural Pasture
Improved Pasture

technology or the difficult access to technology, and the continuous displacement of annual crops toward marginal areas, the only exception being rice. In addition to the loss of diversity of production systems, this situation has lead to reduced food security, increased rural poverty, and a marked dependency on the agroexport sector.

3.3 Types of Agroecosystems

Agroecosystem structure and productivity and the capacity to provide goods and services vary greatly from one area to another. Therefore it is important not only to know the extent and location of agricultural and livestock activities and major production systems, but also the types of agroecosystems in which productive activities are conducted. With this information one can analyze the potential that exists for using the land as well as giving an indication as to the effects/impacts these uses will have both in the agroecosystem itself and in other areas.

The most important characteristics of the region that should be taken into account regarding the type of agroecosystems include:

- Variability of temperature (warm and cool)
- Variability of rain and moisture (moist and dry)
- Soil quality and type (good and bad)
- Relief, slope, and drainage (slopes and flat)
- Major production systems (annual, permanent, pastures, mixed)

Based on these characteristics a map was produced showing the main types of agroecosystems in Central America. There is a great diversity of types of agroecosystems in the region (more than 60). However, 14 types cover 90% of the area (see Figure 8). Of these, 75% of the agroecosystems are located in moist areas with flat land and 25% in dry, hillside areas; also, 60% are located in good soils and 40% in bad soils. With respect to production systems, 35% of the pastures are located in good soils, while only 15% of the mixed production systems, 5% of the permanent crops, and 2% of the annual crops occupy these

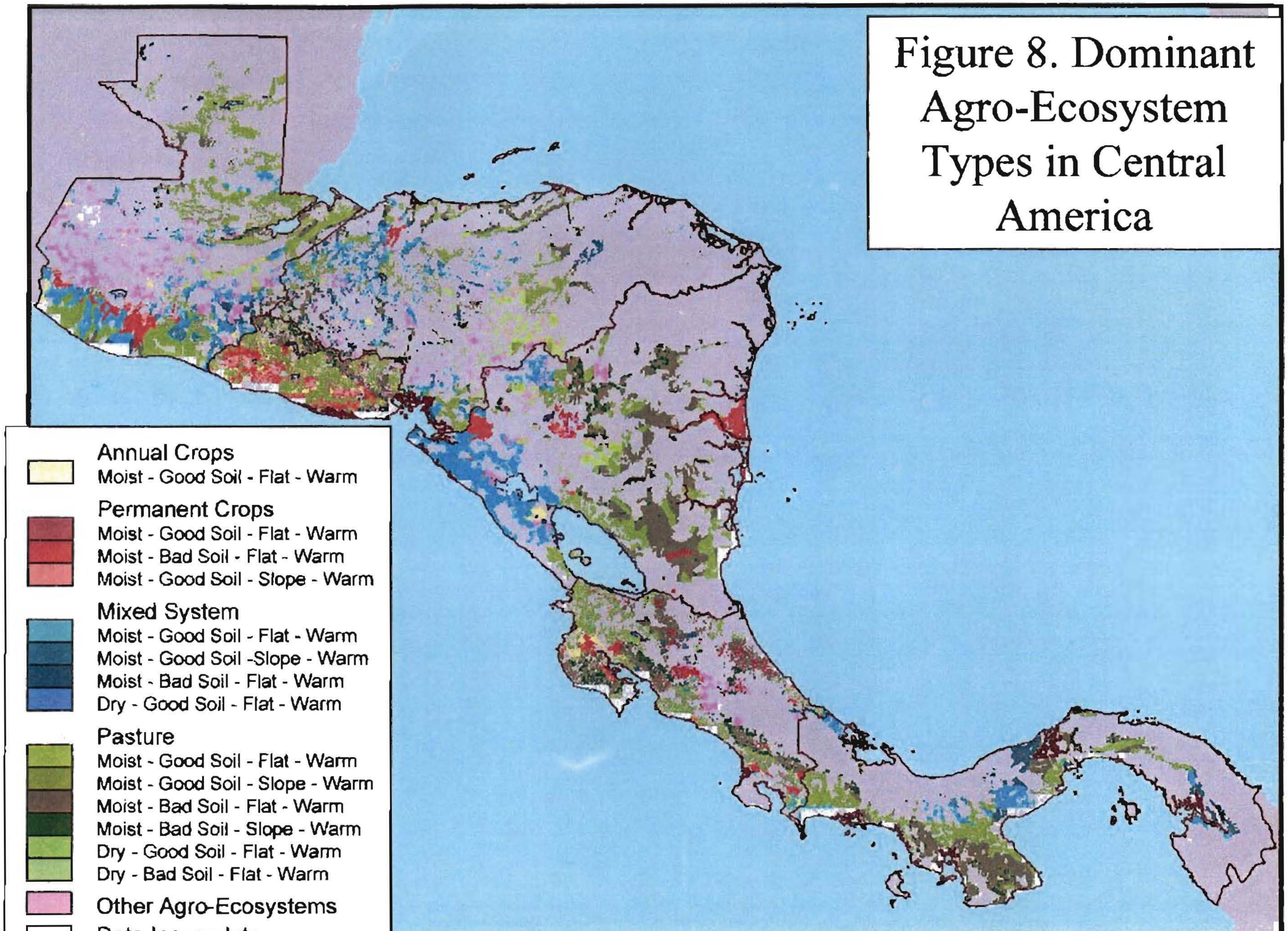

Figure 8. Dominant Agro-Ecosystem Types in Central America

soils (Figure 8). Although these biophysical factors play an important role in land use and production systems, socioeconomic factors continue to predominate in the region.

3.4 Levels of Agroecosystem Management/Intensification

The levels of agroecosystem management and intensification in the region have not only led to an increase in "homogenous" production systems, but have also had environmental effects different to those observed regarding the expansion of the agricultural frontier and the predominance of traditional production systems (annual crops, mixed systems, and pastures).

In traditional livestock areas (Pampas, Cerrados, and Llanos), the change of mixed production systems and livestock systems toward intensive, annual cropping systems is a predominant characteristic, mostly because of soybean and other grains (FAO,1999; Vera and Rivas,1997). Although this intensification may help restrain, to some extent, the expansion of the agricultural frontier in tropical rain forest areas, it has major effects on the environment because of the increased use of inputs and the absence of crop rotation. Furthermore, extensive raising of cattle has been displaced toward marginal areas, accounting for the apparently low livestock productivity in the region and making the problems of overgrazing and soil compaction even worse.

At the same time, stimulated by national policies and the prices of agricultural and livestock products, deforestation continues in tropical rain forest areas, especially to sow pastures and permanent crops. However, the expansion of the agricultural frontier is no longer an issue, except in some regions such as Brazil's northern Amazon region and some areas of Central America. This situation probably obeys a change in the expectation that land value will increase, which has become one of the greatest driving forces for change in land use instead of subsidies and speculation (CCAD,1998; Kaimowitz, 1996; Pasos et al.,1994; Rivas, 1998; Vera and Rivas,1997).

Likewise, it is now known that, in these tropical areas, the climax of succession for degraded pastures is secondary forest (Moran et al., 1994). More and more, an alternative to the continuous expansion of the agricultural frontier in the Amazon region, at least in the medium term, is believed to be the intensification of agriculture and livestock production in savanna and forest areas that have already been transformed (Rivas,1998; Vera and Rivas, 1997). However, while these processes are occurring in cattle raising and agricultural frontier areas, the inverse is occurring in traditionally agricultural areas. Between 1990 and 1995, major areas planted to permanent and annual crops–for example coffee and associated maize/beans in Andean hillside areas, cotton in tropical and sutropical lowlands, and maize in Mexico and Central America–have been replaced by pastures. This is mainly a result of low international prices and policies on economic opening that make it possible to import foodstuffs, for example beans, at lower prices (Rivas,1998; Vera and Rivas, 1997).

Figure 9 shows the level of agroecosystem management/intensification for Central America. Although deforestation has decreased in some areas, in others it has increased because of increased cultivation of permanent crops and livestock production. The intensification in areas under permanent crops (i.e., banana and sugarcane) has increased the use of inputs, thus contaminating waters and soils while also affecting human health (CCAD, 1998). Furthermore, these changes go beyond the simple conversion of forests and marginal lands, creating genuine poles of attraction and development. For example, in Costa Rica, the banana sector accounted for 13% of national agricultural employment, but covers less than 10% of total agricultural surface (CCAD,1998; FAO,1999). Plant health problems and changes in product prices can, however, turn these booms into a problem, making the agricultural and livestock sector more vulnerable to cyclic behavior and reducing food security.

In many areas, improved management and intensification has led to increased meat and milk production using less land thus curtailing the expansion of the

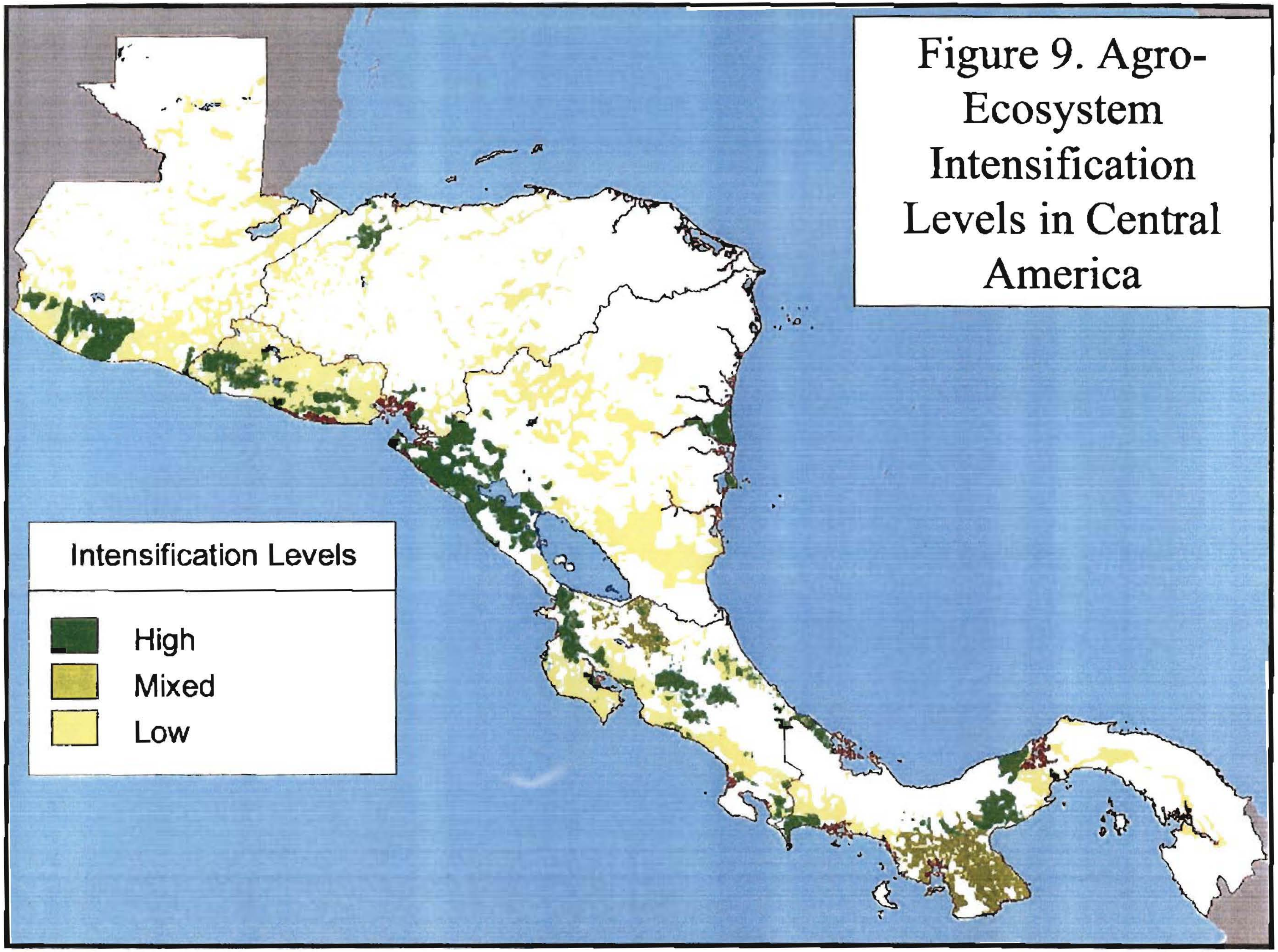
Figure 9. Agro-Ecosystem Intensification Levels in Central America
Intensification Levels
High
Mixed
Low

agricultural frontier. Another beneficial result is a decrease in soil degradation in these areas. To increase productivity, however, changes have been made that have displaced several traditional crops, such as shade-grown coffee, for systems that are more productive but have a greater impact on the environment, for example nonshaded coffee (Perfecto et al.,1996). Changes in production systems are also related to consumption pattern trends. In Central America, meat, milk, and chicken fed with imported grain show the most important increase in food consumption. Cattle raising continues to be the production system by which small and intermediate producers can save and accumulate capital. However, of the 12 million hectares under pastures, 4 million have been abandoned or left to fallow (CCAD,1998).

3.5 Agroecosystems and the Use of Agrobiodiversity

The biodiversity present in ecosystems and species allows them to adapt to new conditions, while generating a range of goods and services. Within agroecosystems, this component of biodiversity is referred to as agrobiodiversity. Agrobiodiversity helps ensure sustainability, stability, adaptability, and productivity in agroecosystems, regardless of the type or complexity of the ecosystem in which it occurs (Collins and Hawtin, 1998). Within cultivated species, agrobiodiversity is the genetic variability that allows them to adapt to new ecological and environmental conditions, by either natural or artificial selection, decreasing the risks of loss because of pests and diseases and increasing the capacities to exploit different environmental and productive characteristics (Collins and Qualset, 1998). Although modern agroecosystems generally depend on more uniform cultivated species, as compared with traditional and wild species, all agroecosystems depend on the conservation of agrobiodiversity to identify and use new genes to improve disease resistance, increase productivity, and diversify production options (Collins and Qualset, 1998; Swift et al., 1996). Traditionally grown species and varieties as well as wild species tend to be more heterogeneous genetically than modern varieties, and have proved to be excellent sources of genes for adaptation to new environments, cultivation conditions, and resistance to diseases and pests (Perfecto et al.,1996; Swift et al., 1996).

For example, in the case of beans, the most important grain legume for human nutrition, there are seven species (*Phaseolus vulgaris*, *P. lunatus*, *P. coccineus*, *P. polyanthus*, *P. purpuracens*, *P. glabella* and *P. acutifolius*), occupying 6% of the region's total agricultural area. Figure 10 indicates the distribution of diversity of wild bean species in the region, based on information on wild populations, climate, and elevation. The greatest diversity is found in the arid zones of Mexico and northern Argentina and the humid, hillside areas of Central America and the Andean region. Similarly, Figure 11 shows the distribution of diversity of wild populations of common bean (*Phaseolus vulgaris*), the most commonly used cultivated species, with the same potential regions for use of agrobiodiversity.

However, the diversity of cultivated species should also be analyzed at other levels, such as the heterogeneity of different bean market classes, the type of growth habits, and the diversity among cultivars within each production region (Voysest et al., 1994). Figure 12 shows the distribution of diversity of common bean (*Phaseolus vulgaris*) and its production areas. Genetic improvement of common bean in Latin America has been characterized by conservative breeding strategies designed to (1) adhere to consumer and market preferences for seed size, shape, and color; farmers' requirements for maturity; and growth habit types; and (2) overcome constraints, mainly diseases (Voysest et al., 1994). Excessive reliance by breeders on a few germplasm sources for disease resistance has reduced genetic diversity. Nevertheless, if we consider all the types and races of improved bean cultivars, traditional and wild varieties grown in these areas, the genetic diversity is higher than for most other crops (Voysest et al., 1994). Contrary to what happens in other regions with other crops, there has been no displacement of different varieties by improved common bean cultivars in Latin America. Therefore, the region has not lost biodiversity due to the intervention of new cultivars (Voysest et al., 1994). On the contrary, because the

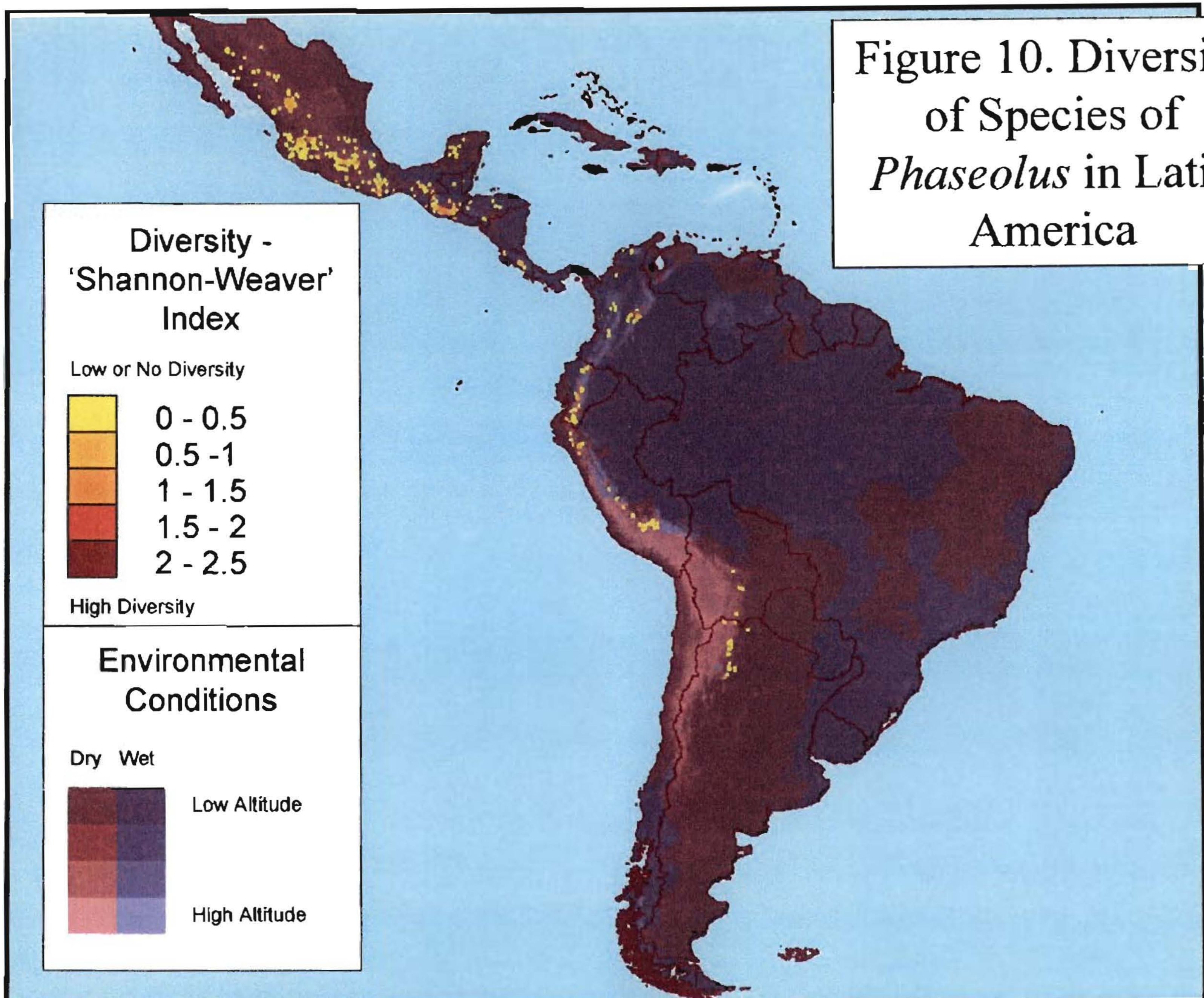

Figure 10. Diversity of Species of *Phaseolus* in Latin America

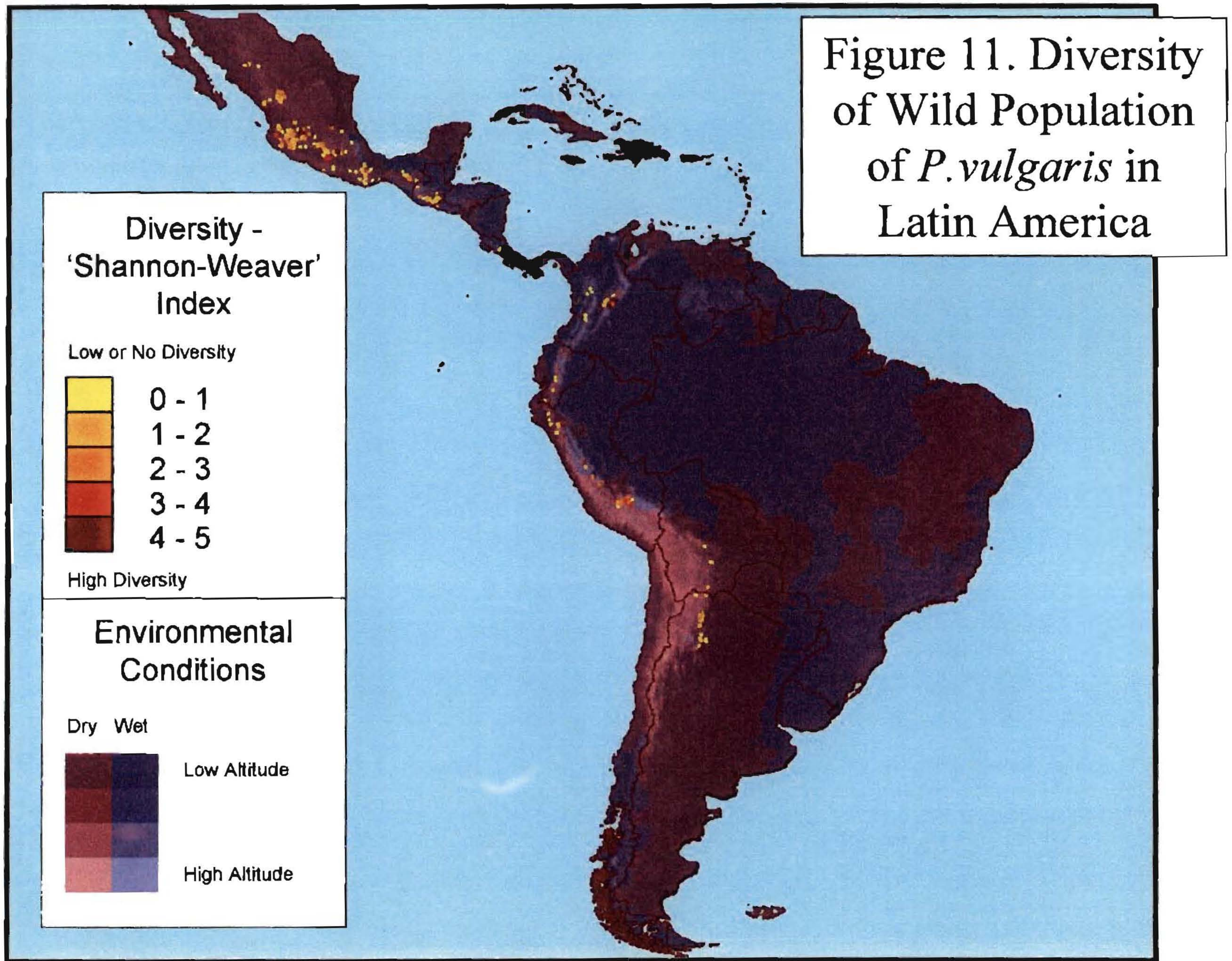
Figure 11. Diversity of Wild Population of *P.vulgaris* in Latin America
Diversity - 'Shannon-Weaver' Index
Low or No Diversity
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
High Diversity
Environmental Conditions
Dry
Wet
Low Altitude
High Altitude

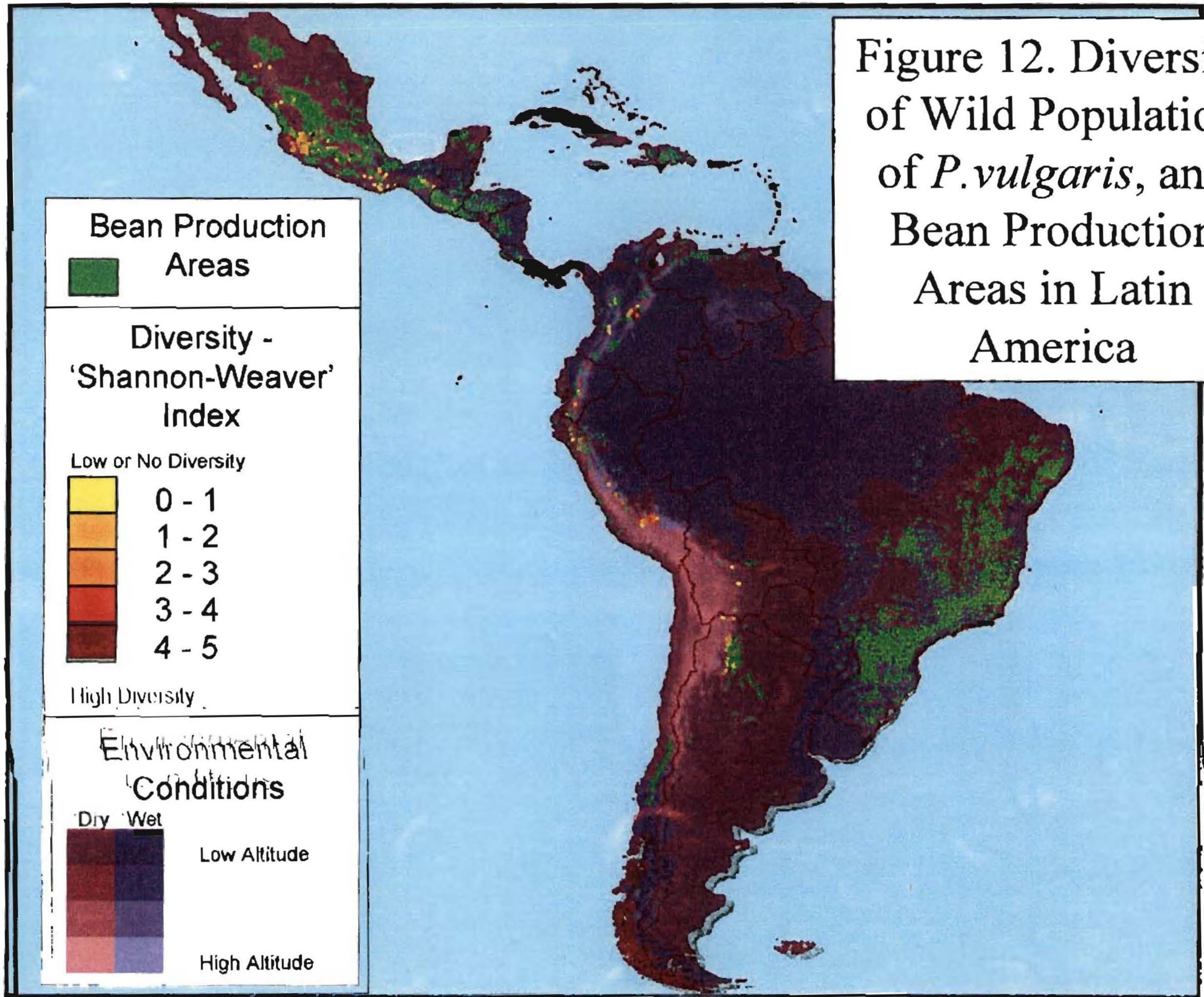

Figure 12. Diversity of Wild Population of *P.vulgaris*, and Bean Production Areas in Latin America

new materials released contain new genetic combinations, which were incorporated to overcome cultivar deficiencies, and although the genetic base for common bean cultivars is narrow at the intraracial level, genetic variability has been broadened and made more useful (Voysest et al., 1994).

But other aspects related to land use have important effects on agrobiodiversity, for example the creation of protected areas and urbanization. Figure 13 shows the distribution of diversity for different wild species of beans (*Phaseolus* sp.) in Meso-America and its relationship to both protected and urban areas. Figure 14 shows the distribution of diversity of wild populations of common bean (*Phaseolus vulgaris*) and its relationship to both protected and urban areas in countries of the Andean region. The first important aspect is that very few protected areas contain areas of bean biodiversity, which could reflect poor planning during the definition of protected areas by not considering agrobiodiversity as a priority criteria. Likewise, many areas harboring agrobiodiversity are currently located in urban areas or in areas of easy access, thus hindering the creation of parks and natural reserves in these areas. The dilemma between in-situ and ex-situ conservation should therefore be analyzed, taking into account these results. For example, in-situ conservation mechanisms are necessary in inaccessible areas with high agrobiodiversity, while ex-situ conservation mechanisms may be more suitable in areas where one finds high agrobiodiversity, high urbanization, and easy access.

4. Concluding Remarks

- Given the dynamics and functions of agroecosystems, and relationships between environment and development, all integrated ecosystem assessments should cover spatial (where), temporal (when), social (who), and economic (why) dimensions, as well as different levels of analysis (global, regional, national, local).

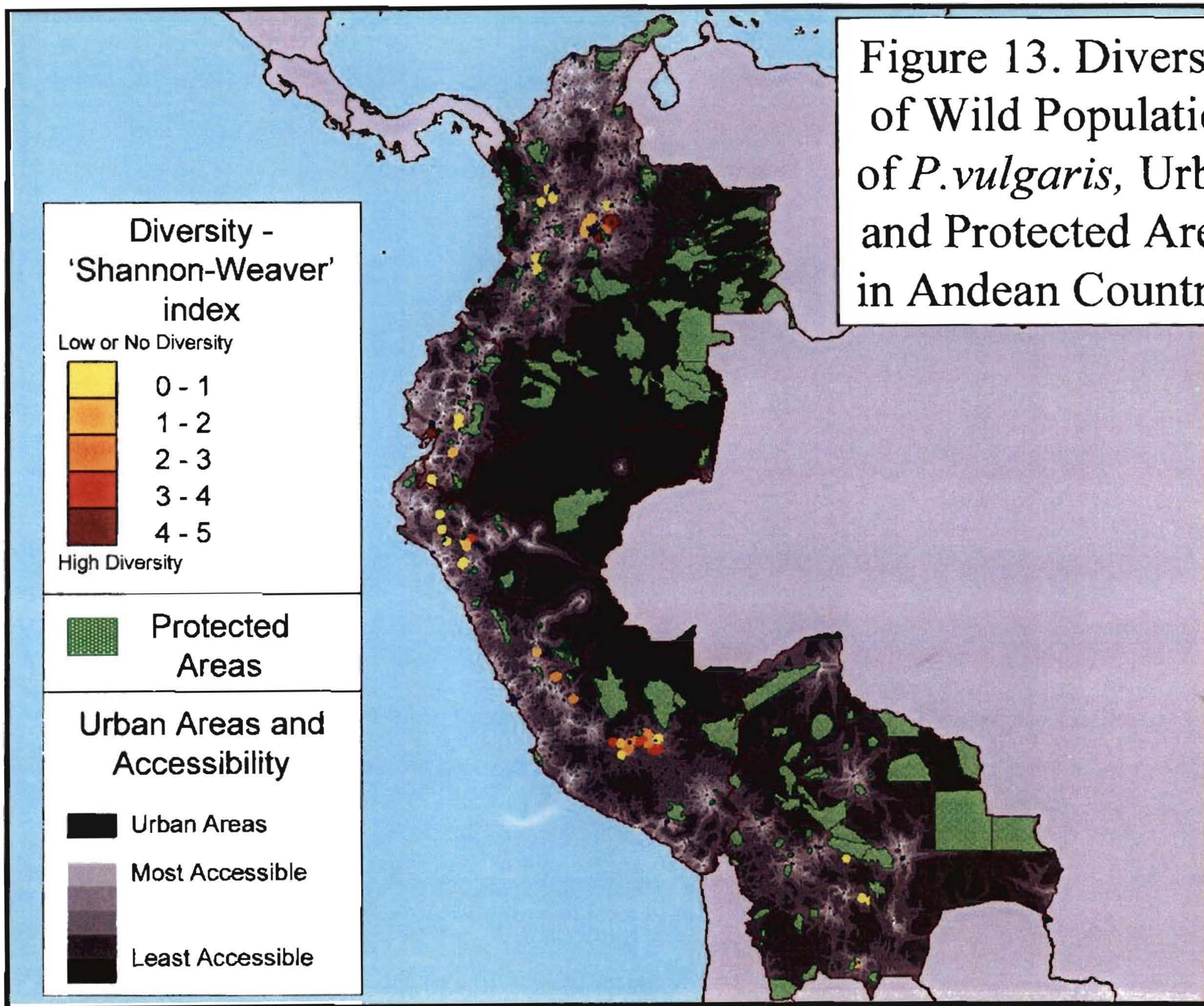

Figure 13. Diversity of Wild Population of *P.vulgaris,* Urban and Protected Areas in Andean Countries

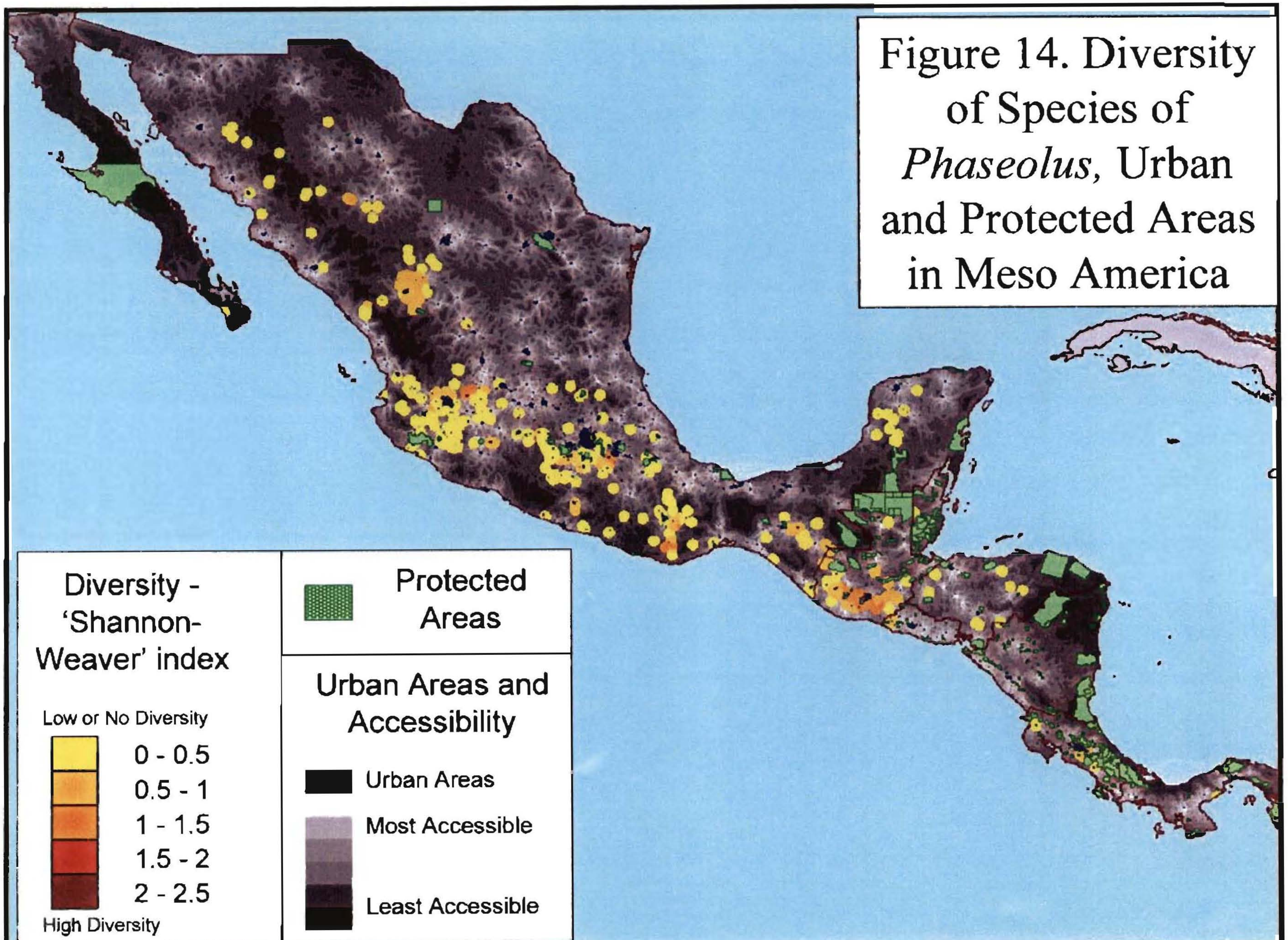

Figure 14. Diversity of Species of *Phaseolus*, Urban and Protected Areas in Meso America
Diversity - 'Shannon-Weaver' index
Low or No Diversity
0 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
High Diversity
Protected Areas
Urban Areas and Accessibility
Urban Areas
Most Accessible
Least Accessible

- An integrated ecosystems assessment not only requires that the status and importance of ecosystems be known, but also that pressures on natural resources, effects on ecosystems, and actions needed to maintain goods and services be identified. Indicators must be defined accordingly to measure and monitor the conditions and changes of the ecosystem and the trends in the use of natural resources.

- To prepare an integrated ecosystems assessment, a lot more than global data (i.e., low-resolution satellite images) are needed. Global and regional sources of information should be validated against national sources of information. The exchange, availability, and access to information will also need to be improved, resulting in a more appropriate use of information. The analysis of the costs, the effectiveness, and the usefulness of producing information would indicate how often this processing is needed.

- Although it is important to identify the constraints and potentialities of land use as well as the biophysical factors that play an important role in production systems, socioeconomic and political factors continue to be more important in Latin America. Thus, the modernization and intensification of production systems and the changes in land use are more directly related to price policies, subsidies and incentives, economic opening, land tenure, and rural population changes than to biophysical limitations such as soil quality, water availability, and risk of erosion.

- To truly assess the status and importance of agrobiodiversity, areas of biodiversity should be identified for other cultivated species that are native to the region, such as potato, maize, tomato, cassava, and sweet potato. That way the status and importance of agrobiodiversity at the regional level can be analyzed and priority criteria for protected areas defined. This variable should also be taken into account for in-situ and ex-situ conservation activities.

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6. Annexes

Annex 1. Examples of Agroecosystem Indicators for the P-S-I-R Framework

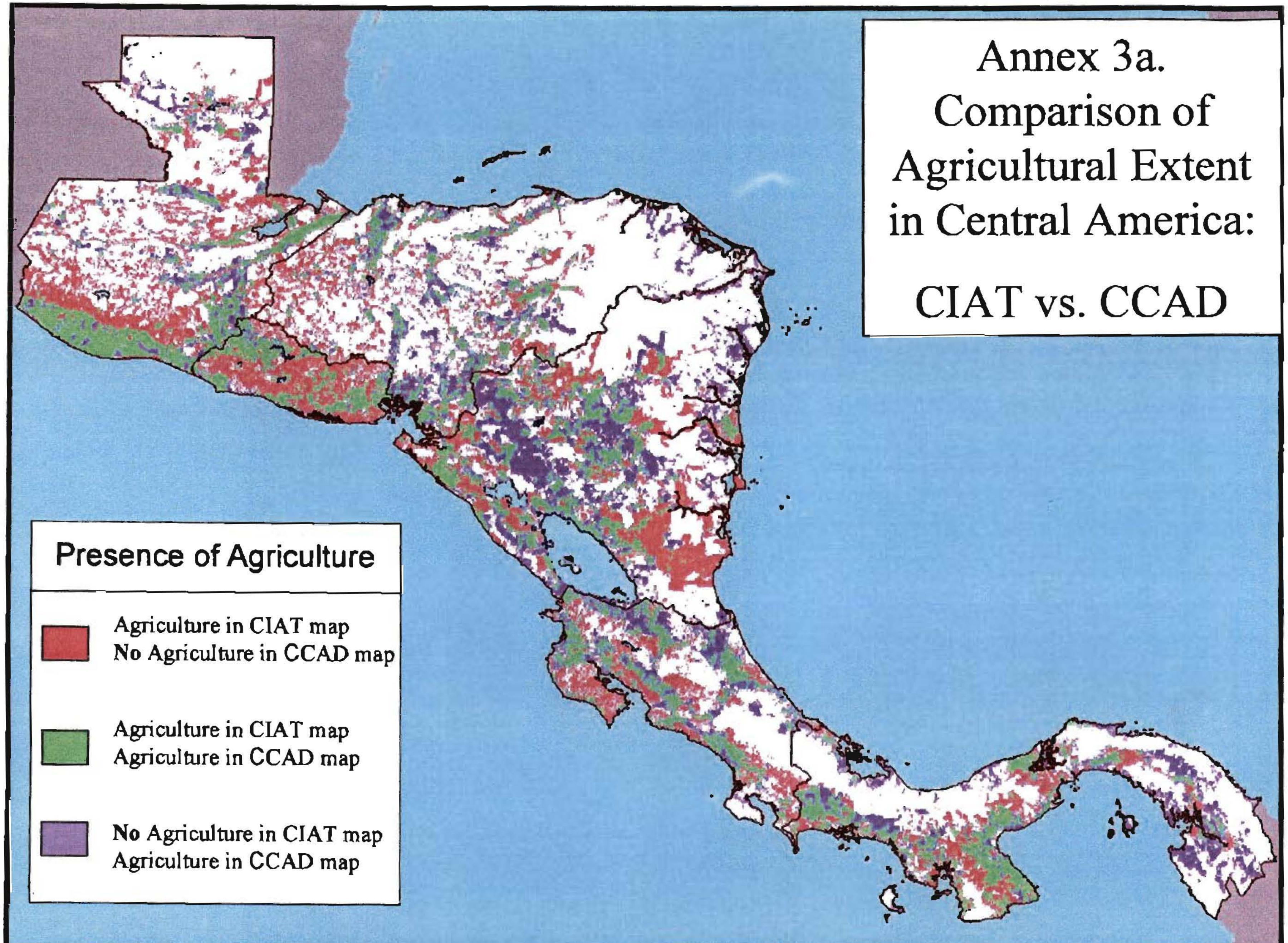
Category	Scale	Indicator
Pressure	Global to National	Agriculture as a % of GDP Accessibility Index Land Use Changes Irrigated Land Livestock Carrying Capacity Sectoral Water Annual Extraction
	National to Local	Pesticides and Fertilizer Use Land Use Greenhouse Emissions/Fires Location Number of Crops Varieties Used in Agriculture Crops Production Crops Prices Inputs Prices
State	Global to National	Agriculture Extent Crop/Pasture Density Agrobiodiversity Index Climatic Risk Index/Annual Rainfall Index Agrobiodiversity Hotspot Areas
	National to Local	Agriculture Land per capita Production Systems Agriculture Yields Agriculture Management/Intensification Net Balance of Greenhouse Emissions
Impact	Global to National	Agroecosystem Fragmentation Soil Degradation Index Crops Agrobiodiversity Factor (CAF) Import/Export of Foods Production/Supply of Foods
	National to Local	Change in Food Consumption People Poisoning by Agrochemicals Pest/Diseases Incidence Nutrient Balance in Soils Organic Material in Soils Erosion Rates Agriculture Productivity Emissions on Water
Response	Global to National	Land Use Index Agriculture Policies Potential Agriculture Yields
	National to Local	Yield Gaps Restored/Rehabilitated Land Diversification of Production Systems/Enterprises Investment in R/D

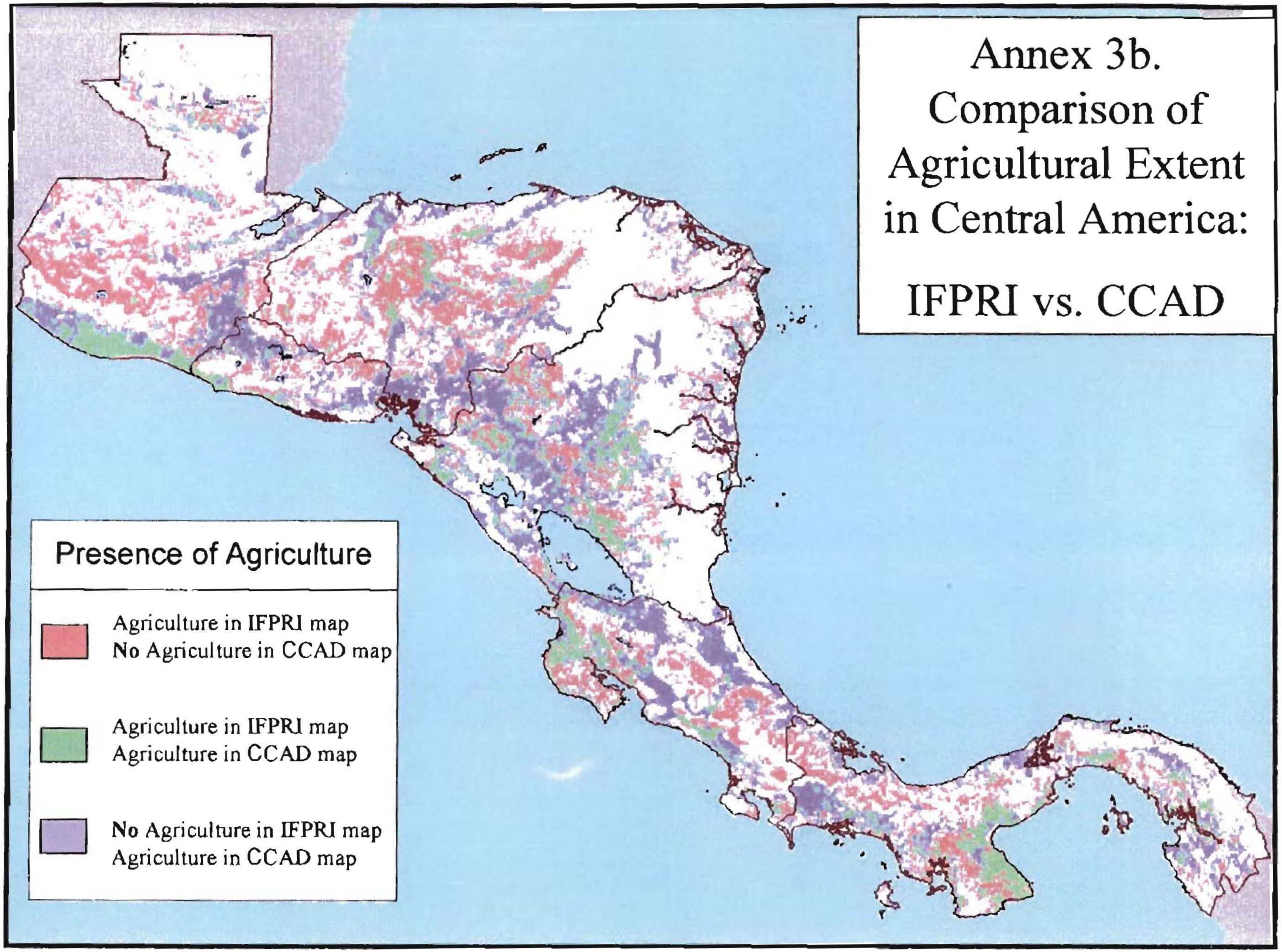
Sources: CIAT-World Bank-UNEP, 1998; FAO-UNDP-UNEP-World Bank, 1997; IFEN,1998; OECD, 1997; RIVM, 1997; Winograd et al.,1998

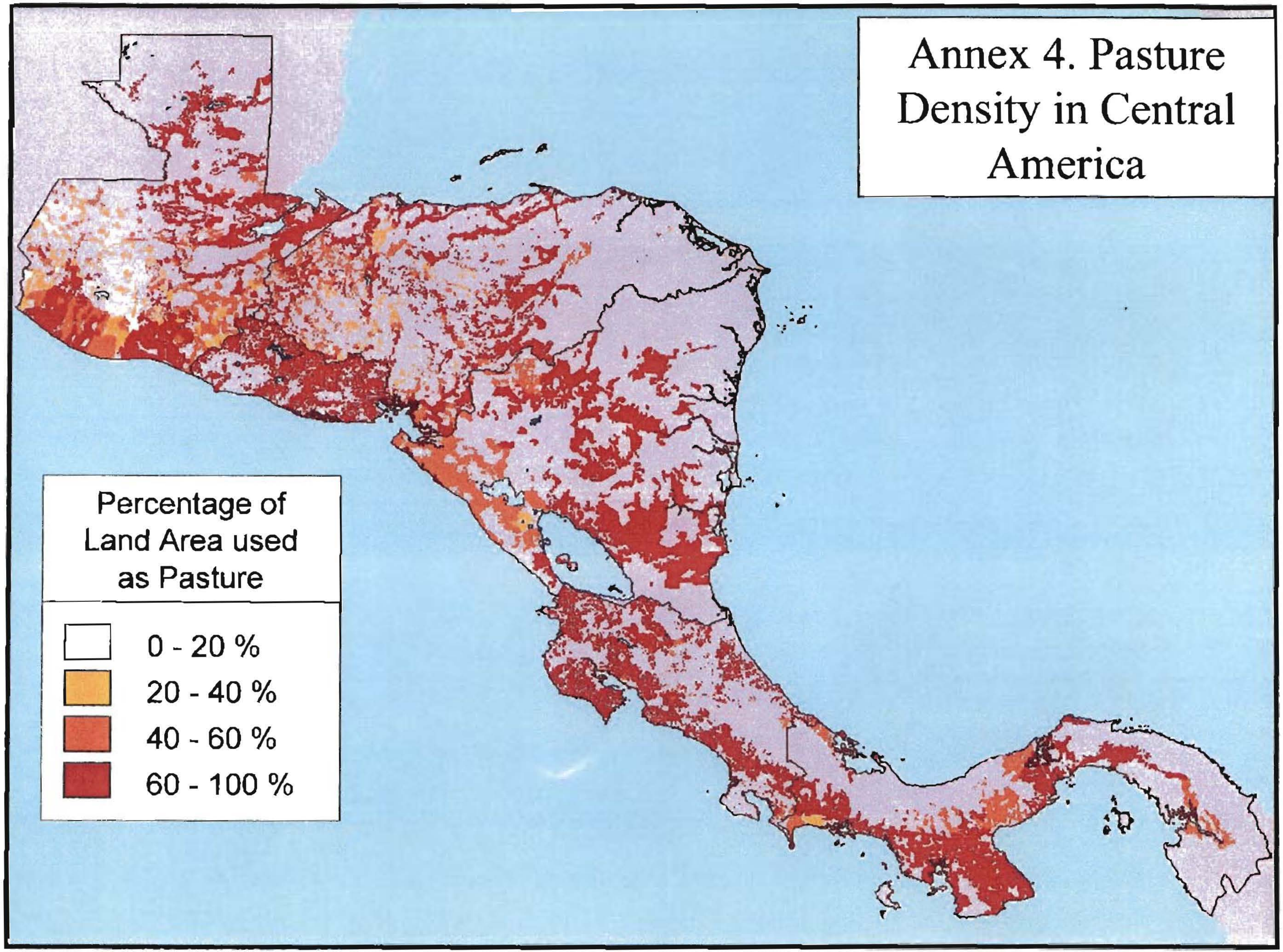
Annex 2. Data Source for the Cropland/Pastures Density and Agriculture Extent Maps for Latin America

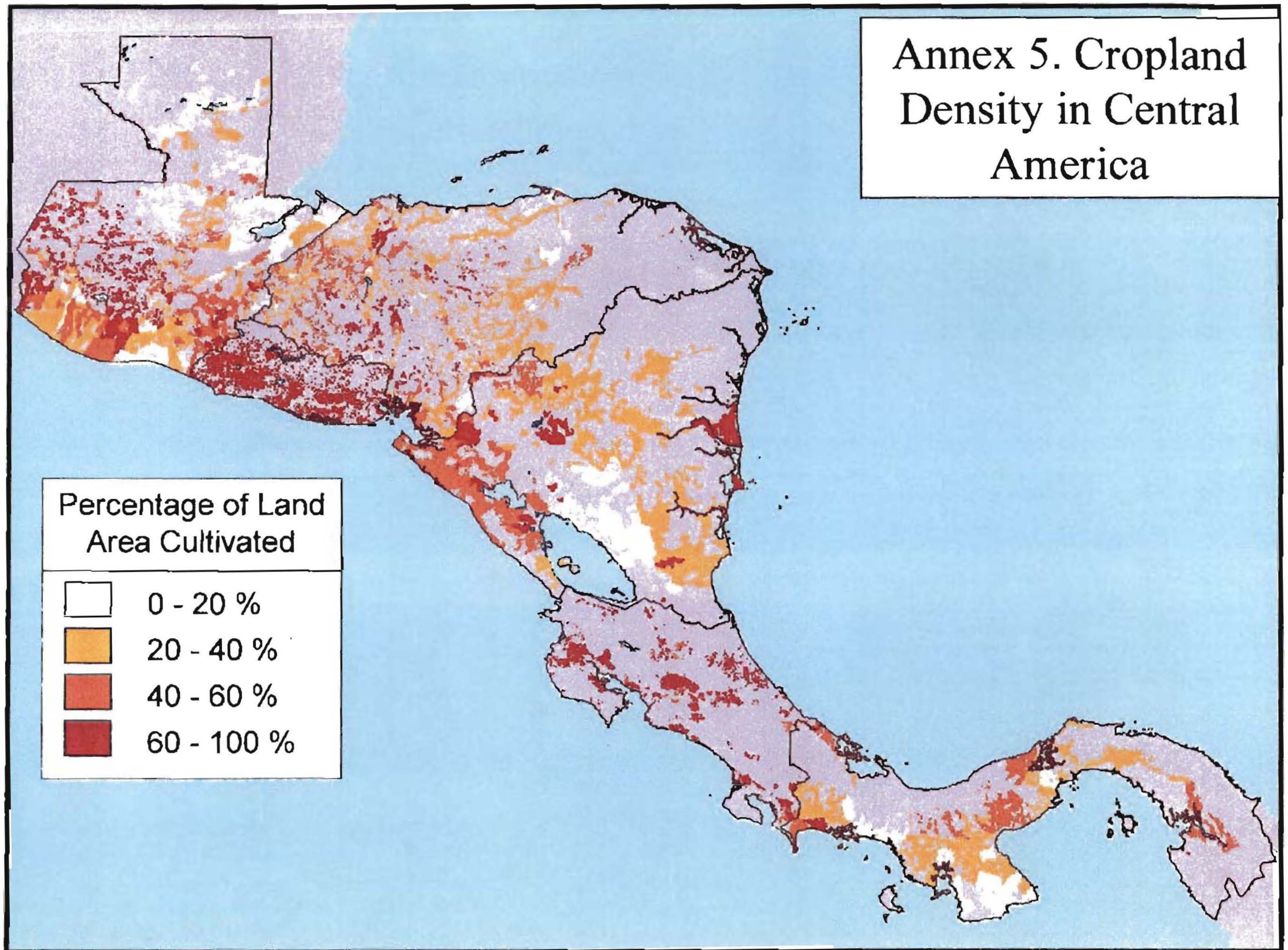
Country	Agriculture Census		Livestock Population		Land Use/Cover Map	
	Level	Year	Level	Year	Scale	Year
Belice	State	1994	n/a	n/a	n/a	n/a
Costa Rica	County*	1984*	State	1993	1:250.000	1992
El Salvador	State**	1994**	n/a	n/a	1:500.000	1993-94
Guatemala	County***	1979***	State	1996	1:500.000#	1992
Honduras	County	1993	State	1993	1:500.000#	1995
Nicaragua	County	1995	State	1995	1:500.000	1992
Panama	County	1991	State	1991	1:1.500.000#	1992
Mexico	County	1991	State	1991	n/a	n/a
Argentina	County	1991	State	1996	n/a	n/a
Bolivia	State	1995	State	1994	n/a	n/a
Brazil	County	1993	State	1993	n/a	n/a
Colombia	State	1993	State	1995	1:5.000.000	1987
Chile	State	1997	State	1997	n/a	n/a
Ecuador	State	1995	State	1995	1:500.000	1994
Guyana	State	1994	n/a	n/a	n/a	n/a
Paraguay	State	1995	State	1997	n/a	n/a
Peru	County	1993	State	1993	n/a	n/a
Surinam	State	1991	n/a	n/a	n/a	n/a
Uruguay	State	1993	State	1990	n/a	n/a
Venezuela	State	1995	State	1979	n/a	n/a

* also survey for 1995 at county level
** survey
*** also survey at state level for 1995
\# only forest and non forest classes


Annex 3a.
Comparison of
Agricultural Extent
in Central America:
CIAT vs. CCAD
Presence of Agriculture
Agriculture in CIAT map
No Agriculture in CCAD map
Agriculture in CIAT map
Agriculture in CCAD map
No Agriculture in CIAT map
Agriculture in CCAD map


Annex 3b.
Comparison of
Agricultural Extent
in Central America:
IFPRI vs. CCAD
Presence of Agriculture
Agriculture in IFPRI map
No Agriculture in CCAD map
Agriculture in IFPRI map
Agriculture in CCAD map
No Agriculture in IFPRI map
Agriculture in CCAD map


Annex 4. Pasture Density in Central America
Percentage of Land Area used as Pasture
0 - 20 %
20 - 40 %
40 - 60 %
60 - 100 %


Annex 5. Cropland Density in Central America
Percentage of Land Area Cultivated
0 - 20 %
20 - 40 %
40 - 60 %
60 - 100 %