LAND USE CLASSIFICATION IN BOLIVIA

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ABSTRACT

The Bolivian LANDSAT Program is an integrated, multidisciplinary project designed to provide thematic analysis of LANDSAT, SKYLAB, and other remotely sensed data for natural resource management and development in Bolivia. Among the first requirements in the program has been the development of a Legend, and appropriate methodologies, for the analysis and classification of present Land Use based on landscape cover.

The Land Use Legend for Bolivia consists of approximately 80 categories in a hierarchical organization which may be collapsed for generalization, or expanded for greater detail. The categories, and their definitions, provide for both a graphic and textual description of the complex and diverse landscapes found in Bolivia, and are designed for analysis from LANDSAT and other remotely sensed data at scales of 1:1,000,000 and 1:250,000.

The Land Use Legend and map products are designed to meet the data needs and requirements of multiple user groups in Bolivia, including the Ministry of Agriculture, Military Geographical Institute, Corporacion Minera de Bolivia, Yacimientos Petroliferos Fiscales Bolivianos, National Statistics Institute, Bolivian Geological Survey, regional planning agencies, etc., each of which have participated in the Legend and procedures development.

Procedures and example products have been developed, as described and illustrated, for the systematic analysis and mapping of present Land Use for all of Bolivia. This project, the first of its kind in Bolivia, is presently underway for areas of image availability.

The program is designed to provide detailed 1:250,000 Land Use Maps for the Country of Bolivia within the next year. This schedule, however, is presently hampered by the lack of sufficient cloud free and multi-date LANDSAT imagery for extensive areas in Bolivia. The current effort is based on the anticipation that LANDSAT-2 will provide the needed image requirements for this program so that effective resource management and development applications may proceed from the various user groups.

INTRODUCTION

The Bolivian Government, keenly interested in obtaining basic and necessary information about its natural resources, is actively using satellite remotely sensed data. To provide a sound focus and coordination of technical leadership and management to this effort, the Bolivian LANDSAT Program was created within the Bolivian Geological Survey (GEOBOL). Also participating in the Program, in a vigorous and active work program, are investigators and scientists from: other offices within the Geological Survey; the Bolivian Petroleum Company (YPFB); the Mineral Corporation of Bolivia; the National Statistic Institute (INE), Census Office; the Military Geographic Institute (IGM), the Ministry of Agriculture & Rural Affairs, and the various regional planning agencies. The present work program includes investigations in regional geology, petroleum geology, mineral geology, existing land use, cartography, soils, and forestry.

At the present time, Bolivia has conventional aerial photographic coverage, acquired over an extensive time period, for only approximately sixty (60) percent of the country. This has inhibited the preparation of various thematic maps necessary to carry out a program of comprehensive, definitive national planning and development at the regional and subregional scales. For this reason, images from LANDSAT and SKYLAB are of great value and are being intensively analyzed for multi-disciplinary objectives. With these satellite image data, the various Bolivian investigators are able to prepare the thematic maps and analyses necessary to carry forward national resource planning and development programs in a relatively short time frame. Consider, for example, the following: (a) various geological analyses may be, and are being, updated and revised, and used in the selection of new areas for mineral and petroleum exploration; (b) agriculturalists are obtaining basic information not only on the distribution of agricultural activities and forest types, but also on the characteristics and limitations of soils and land capability for agricultural expansion and colonization development, and forest inventory data basic to that resource's exploitation and development planning; (c) in 1973 the Bolivian Military Geographic Institute published a nationwide topographic map at 1:1,000,000 scale, using LANDSAT images; and (d) completion of the present effort to prepare a general hydrographic map and analysis will permit Bolivian investigators to determine the extent and influence of the large hydrologic basins and the quantification of the sub-basins and watersheds. This information, when combined with other data in adequate forms, will permit the selection of the most appropriate areas for utilizing water resources for hydroelectric power and irrigation development. Further, the above application examples have not taken into consideration the inventory preparation and application of existing land use data which is the purpose of the present report.

Considering its basic and fundamental importance to a variety of integrated applications and analyses, the Bolivian LANDSAT Program has proceeded with the preparation of the first national legend, and inventory, of existing land use based on land cover and landscape analysis. Attributes for all of the natural and cultural landscapes presently existing throughout the country are being studied at a regional and sub-regional scale. The Land Use Legend contains approximately eighty (80) categories for application at various scales. Preliminary tests, analyses, and legend revisions have demonstrated that the legend categories can be used in the analyses of LANDSAT and SKYLAB multitemporal images, along with available supplementary information which can be used for the Land Use Inventory in Bolivia.

The Land Use Inventory of Bolivia is being compiled at two scales, 1:1,000,000 and 1:250,000, each with appropriate levels of classification detail. The Legend, its development and its characteristics, are discussed in the next section of this report. This is followed by a brief synthesis of the techniques used for the present land use analysis and a description of the cartographic products being prepared.

The land use maps permit the location and spatial distribution, quantification, and analysis, at a sub-category level of detail, of areas that have rangeland, forest, cultivation, wetlands, water, barren, permanent snow and ice, and tundra cover, as well as areas of urban places and settlements. In addition, the land use maps can, and will, be applied in many ways and by numerous agencies and other user organizations, providing basic information for the planning and development of the country. Some of these potential applications are described in the final section of this report, as prepared by cognizant participants from the respective agencies to the Bolivian LANDSAT Program.

In summary, the Land Use Legend presented in this report represents a classification of Bolivian landscapes which meets the needs of various users for natural resource information and provides information which can be accurately obtained using proven satellite image analysis techniques and procedures. The Legend is capable of further refinement on the basis of additional data, and is capable of varied use and application. It is believed that this Legend, subject to modification and revision, provides the basis for standardized regional and national analysis and mapping of actual land use in Bolivia.

THE BOLIVIAN LAND USE LEGEND

The present use of land, or its present cover - whether a natural landscape or one modified by man's activities on the land - is a significant characteristic for resource planning, management, and development. The term "land use", however, is a difficult concept because there are different perspectives in the classification process as well as considerable diversity of opinion about what constitutes "land use". It is important to distinguish, for example, between potential land use and actual land use. The former requires a complex analysis of many physical characteristics of the land, including slope, soils, vegetation, etc., to determine the land's suitability for specific activities, i.e., crop cultivation. Actual land use, however, refers to the present use of the land, to a description of the present landscape characteristics without regard to its potential or future uses. The Land Use Legend described in this report refers to the latter, actual land use, and is one of the multiple inputs in the potential land use analysis process.

Anderson (1971)* discusses some of the conceptual issues important in developing a land use classification legend. "One concept that has much merit is that land use refers to 'man's activities on land which are directly related to the land (Clawson and Stewart, 1965)'. Land cover, on the other hand, would describe 'the vegetational and artificial constructions covering the land surface' (Burley 1961)". Thus the distinction between economic activity on the land, and the land cover, is drawn in describing land use, even though some economic activities of man are directly related to the land cover, such as agricultural activities and the resulting landscape patterns. In the Bolivian land use legend, land cover is the primary basis of classification and subsequent description and analysis.

Bolivia is a country of complex and diverse landscapes, from mountain tundra and glaciers to tropical rainforests and savannas. A land use classification legend must not only be specific and complete over the entire range of existing landscapes, but must also serve the needs and applications of multiple and diverse users in Bolivia. Although definitions have been developed, as presented in Appendix A, it is recognized that in almost any classification system it is often difficult to find clearly, unambiguously defined classes. Actual land use is no exception and most difficult problems can be encountered, particularly in areas of landscape or land cover transition.

For example, it may seem simple to draw a line on a map separating land and water, until we consider the presence of marshes with various kinds of plant cover. Further, some areas may appear to qualify for more than one category, or the category may change on a seasonal basis, such as seasonally wet areas. The definitions which are provided with each category in the land use legend are designed to provide guidelines to the land use analyst in establishing boundary and classification decisions. They also provide the land use data user with a better means of interpreting and using the land use data. Decisions that may seem at times arbitrary must be made; however, it is desired that if the categories are briefly explained, the land use analysis, inventory, and mapping process can be repeated in a systematic manner.

The Land Use Legend has been designed for the categorization of all parts of Bolivia, and the definitions are specific to the Bolivian landscape and the development of regional and national coverage maps at 1:250,000 and 1:1,000,000 scales. By relying principally on information derived from LANDSAT and SKYLAB images, with supplemental use of existing maps, aerial photography, and other data, the resulting maps will show actual land use information that is uniform in date, scale, and categorization.

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* See Anderson, J.R. (1971), Land Use Classification Scheme for Use With Remote Sensor Data, U.S. Geological Survey, Circular 671, Washington, D.C.

The Land Use Legend is hierarchical in design, as shown on Table 1. It may be expanded to include more detailed categorization at larger scales, and at the same time remain compatible with more generalized maps. (It is noted that the design of the Land Use Legend for Bolivia has many similarities to the classification system proposed for the United States of America, by Anderson et. al., 1971. Although Anderson's work certainly guided its structure, the contents of the Bolivian Legend are specific to the Bolivian environment and the resource inventory needs of the various users in Bolivia).

The Land Use Legend is multi-disciplinary in both its information content and its application. Similarly, the legend is the product of a multi-disciplinary team which, combined, included expertise in: the geography of Bolivia, its natural and cultural environments and landscapes; the development and application of land use data for resource management and development; the capabilities of LANDSAT, SKYLAB, and other remote sensing systems as sources of land use and natural resource information; and specialists in various resource related disciplines, including geology, agriculture, forestry, soils, regional planning, and cartography, etc. Using a multi-disciplinary, team approach, the group applied several criteria in designing the Land Use Legend, as follows:

1. The classification legend of actual land use must be specific to all types of landscapes and environments of Bolivia.

2. The map and other data products for actual land use must provide information which, when combined with other resource information, will directly meet information needs and requirements of multiple users in Bolivia.

3. Classification of various legend categories should permit vegetation and other types of land cover to be used as surrogates for the categories of actual land use.

4. The Legend should be designed for primary use of satellite imagery interpretation, including both LANDSAT and SKYLAB images as available, acquired at different times during the year.

5. In the hierarchical organization of categories, Level I categories should be interpretable and mappable at an image and map scale of 1:1,000,000; Level II and III categories should be interpretable and mappable at an image and map scale of 1:250,000.

6. The categories must be collapsible for map generalization.

7. Sub-categories, such as some Level III as well as additional future sub-categories, should be determinable through the effective use of aerial and ground reconnaissance surveys, aerial photographs, and other supplemental information.

8. The Legend and analysis procedures must be designed to enable repeatable results from one image interpreter to another, and from one time period to another.

9. The quality (accuracy) of the land use information interpreted from the satellite images, with supplemented data, must be comparable or superior to that obtained by other methods.

10. Mimimum map units, at 1:250,000 scale, should generally be 150 hectares for area features, and 125 meter widths for linear features; however, features smaller than these minimum units may be shown on the Land Use Maps, particularly when based on supplemental information.

It is noted that not all categories in the Land Use Legend may be interpreted from satellite imagery with equal reliability. In many cases, particularly for some Level II and Level III categories, supplemental data will be required and should be used effectively. Supplemental data, in this instance, includes aerial photographs, aerial and ground reconnaissance surveys, existing maps, and other data and records. Image analysis should also include multi-date imagery, particularly where seasonal or other temporal changes may assist in correct category identification.

LAND USE MAPPING PROCEDURES

The purpose of this section is to provide a brief summary of the procedures and techniques used in the preparation of the Bolivian land use maps. This discussion is not a procedures guideline, but rather a synthesis intended to provide readers and map users with a succinct background of factors which influence the map's characteristics and applications. The procedures have been standardized wherever possible in order to attain a consistent and accurate land use map series; it is recognized, however, that image interpretation often requires subjective and judgmental decisions by interpreters of varying background, experience, and skill.

It is planned that the Bolivian land use map series will be published at two scales, 1:1,000,000 and 1:250,000. These scales correspond to topographic and other thematic maps prepared for Bolivia. The map preparation can be described by the following scenario:

1. A preliminary interpretation is made on 1:1,0000,000 LANDSAT images at Level I detail of the Land Use Legend. The purpose of this exercise is to familiarize image interpreters with the region under study; identify areas of particular complexity or concern for which supplemental data will be required, and to identify and acquire available imagery, maps, and other supplemental information of the study area.

2. A detailed interpretation is made using 1:250,000 scale LANDSAT and/or SKYLAB imagery using all appropriate categories (Level III) of the Land Use Legend. During this analysis, all available multi-temporal imagery and supplemental information, including existing maps and aerial photographs, are utilized as appropriate to ensure accuracy and completion of the map detail. Field surveys are conducted to identify ambiguous areas and verify interpretations. The final, edited land use map, at 1:250,000 scale, constitutes a final product of the project.

3. Following completion of the 1:250,000 land use map, a revised 1:1,000,000 map is compiled, at Level II detail of the Land Use Legend, through the process of category aggregation of the larger scale data. This revised land use map also becomes a final product of the project.

The 1:1,000,000 scale Land Use Map series permits delineation of major landscape features and patterns, and provides a graphic analysis of the location and spatial relationships of landscape elements at a regional level. Bolivia is a country of complex and contrasting landscapes and environments; the differentiation of these landscapes at 1:1,000,000 scale is considered very important and useful for both analytical and display applications.

The 1:250,000 scale Land Use Map series permits additional delineation and classification of landscape features and patterns described in the legend. The cartographic products graphically portray location and spatial distributions at a sub-regional level. This product will be the scale of principal application and will also enable the accurate selection of areas requiring further analysis and/or greater detail to meet the information requirements of a specific application.

Interpretation Techniques

The interpretation techniques employed in this project are similar to those of conventional photo-interpretation and appropriate modifications for satellite image analysis. To date, most analyses have been based on multiband black and white print products, supplemented with (a) color composite transparencies at 1:1,000,000 scale using Diazo processing, and (b) color composites produced by an I^2S Addcol Viewer (Additive Color Projection Viewer). Both multi-spectral and multi-temporal combinations are used extensively, particularly for the discrimination and analysis of vegetative color patterns and seasonal and/or temporal landscape conditions. A Zoom-Transfer Scope is also available and used, particularly in the transfer of detailed multi-temporal and vegetative color interpretations from the 1:1,000,000 scale color composites to the 1:250,000 scale base map prints. At the present time, the more intensive use of large scale color composite and color enhanced image prints is being analyzed with ten (10) LANDSAT and two (2) SKYLAB scenes, and a color photographic processing facility is under construction.

Supplemental Data

A variety of supplemental information are used in the detailed analysis of the satellite images. This data includes existing aerial photography, maps, and textual and statistical information.

Aerial photography is presently available and current for approximately sixty (60) percent of the country, most commonly at approximately 1:40,000 scale on black and white film. In addition, the Bolivian LANDSAT Program has acquired an I^2S multi-spectral camera, mounted in a Cessna 402 aircraft. This system is used principally for large and medium scale aerial photographic acquisition and to date has been flown in the altiplano and Santa Cruz regions. And finally, an effort is underway to acquire and catalogue small format (35 mm) color oblique aerial photographs obtained at medium and high altitudes. When indexed, these photographs will provide a valuable source of supplemental information as has already been demonstrated in several regions.

A variety of thematic maps, at varying scales, are available for various regions of Bolivia and contain useful supplemental information. The map types include topographic maps at 1:50,000, 1:250,000, and 1:1,000,000 scales, hydrological, geological, and geomorphological maps compiled by satellite interpretation as well as conventional means and vegetation, soils, and ecological maps. The principal sources of these data are the Ministry of Agriculture, the Military Geographical Institute, the Bolivian Geological Service, the National Meteorological and Hydrological Service, the Bolivian LANDSAT Program, and the University of Major de San Andres.

Field Surveys

Field surveys are conducted both during the detailed 1:250,000 scale analyses, as necessary, and upon completion of the interpretation effort. The presently recommended procedure for the field surveys involves the use of low and medium altitude aircraft observations, particularly in the extensive regions of limited ground accessibility.

The objectives of the aerial field surveys is (a) to enable the image interpreters to acquire a greater knowledge of the study region that will be beneficial to multiple analyses and evaluations of the natural resources; and (b) to compare, confirm, and correct delineations and interpretations of the LANDSAT images. In addition, oblique aerial photographs are acquired of significant features in the study area.

During the flight planning for the field surveys, transectoral flight lines are drawn to cover a representative range of mapped land use units, areas of particular

significance, and areas of question or ambiguity. The flight lines, with distance and cardinal heading, on 1:1,000,000 scale LANDSAT prints which are then used as a pilotage navigation aid. This technique has been tested and demonstrated to be particularly effective in regions lacking accurate charts and facilities for aircraft navigation.

Classification Scheme Expansion for Special Analyses: An Urban Example

An important characteristic of the Land Use Legend is the ability to expand the hierarchical classification scheme to Level IV or greater detail to meet particular analysis applications or information needs. An example is in the urban categories of the Legend and the information needs of urban planners, the Census Office, and others who find a Level III detail at 1:250,000 scale inadequate. Level IV information relies almost exclusively on supplemental data, such as aerial photography, and field surveys.

Upon reviewing the Land Use Legend at Level III in the urban categories, Bolivian urban planning and Census Office investigators preliminarily identified the Level IV categories of interest, shown on Table 2. Existing black and white aerial photographs of the City of La Paz were available at scales of 1:40,000, 1:25,000, and 1:8,000. Land Use maps, at Level IV detail were prepared at each scale using conventional photo-interpretation techniques and procedures, and the results were compared and evaluated in terms of suitability of the Legend and scales. It was determined that the most optimal scale for the Level IV Legend and diverse user needs was approximately 1:25,000.

APPLICATIONS

The Land Use Legend and methodologies were developed by a multidisciplinary team of Bolivian investigators representing a variety of user agencies. Each agency has unique programs and responsibilities which place varying requirements on information need and its content. Of considerable importance is the effort to develop basic information which has broad application and is responsive to the varied users requirements. Such an objective can only be satisfied through time and experience, and with an adaptation to new forms of data derived from developing technologies.

Following the development of preliminary products using the Land Use Legend and methodologies described in previous sections, each "user group" was asked to briefly consider the merits of the Legend and map products in terms of their own programs and information requirements. While each had unique applications, many were very similar, reflecting a universal lacking of consistent natural resource and landscape information throughout the country. To this, the systematic analysis of LANDSAT and SKYLAB imagery has provided immeasurable benefits.

The following discussion briefly summarizes the applications of the land use products preliminarily identified by "users" representing the Ministry of Agriculture, the Census Office of the National Statistics Institute, the Geological Survey, the Military Geographic Institute, and the Ministry of Planification and Coordination.

Ministry of Agriculture

Land use maps at a scale of 1:1,000,000 were evaluated and determined to be of significant information value in several disciplinary areas: (a) the analysis of existing land use, particularly when combined with other resource data, can be effectively used to better identify areas of potential colonization and development based on land capability; (b) the extent and type of forest resources, previously poorly documented, are well delineated and provide basic data for analyses of wildlife habitats and commercial forest product exploitation; (c) areas of extensive erosion surfaces are identified, providing basic planning information for regional soil conservation programs;

(d) areas of natural pastures are identified and may be analyzed to determine better allocation of rangelands for livestock use; (e) the accurate determination of river and lake locations is of value to fisheries analysis and their exploitation, and (f) areas of saline soils and salt flats may be broadly defined and analyzed as appropriate to the planning and allocation of agricultural programs where these landscape conditions pose limitations to their use.

Census Office, National Statistics Institute

The Census Office maintains a locality of registry and mapping system for population characteristics throughout the country. A national census will be conducted next year and will acquire data on the social, economic, and geographic composition of the population. The regional land use maps, even at a very general level of detail, provide several important applications, particularly in the census planning phases. These range from the delineation of areal collection units, regional accessibility and communication based not only on road network but river courses as well, and the regional analysis of landscape features indicating the presence of humans. The use of supplemental information can accurately verify the locations of human settlement and the delineation of urban areas and the urban fringes as areas in transition. In addition, the Land Use maps provide a basis for the planning of an agricultural census in Bolivia.

Geological Survey

The Land Use maps provide a useful complementary data source to geological, and particularly geomorphological, analyses of LANDSAT and SKYLAB images. For example, landscapes characterized by exposed rock outcrops, sand dunes, and saline zones are important units for geological analysis. Vegetation, either natural or artificial (such as agricultural cultivation) can be an important surrogate of surficial materials and characteristics. The analysis of drainage networks also provide inferences of surface material, geological structure, and land forms.

Military Geographical Institute

The Military Geographical Institute (IGM) is the official cartographic entity in Bolivia. It has already demonstrated the use of LANDSAT imagery in the compilation of a 1:1,000,000 topographic map series in 1973. The Land Use maps are of IGM use in the delineation of urban, rural, and uninhabited areas, in the comparison of changes in river courses and the shape and size of lakes and lagoons, and in the determination of seasonally and permanently flood areas. In addition, the maps provide a basic resource for planning field work in conjunction to both topographic mapping programs as well as special purpose projects where a knowledge of general terrain characteristics and cover is beneficial.

Ministry of Planification and Coordination

The Ministry of Planification and Coordination is responsible for regional planning programs in Bolivia. The Land Use maps enable descriptions and analyses of physical, economic, and social characteristics in the plan development process as well as a diagnosis of probable future changes and developments. Additional studies can provide an evaluation of fiscal and technical resources available in both public and private sectors.

CONCLUSIONS

The previous discussion has presented a relatively recent application development for LANDSAT and SKYLAB imagery in Bolivia -- the development of a national Land Use Legend and methodologies for the preparation of cartographic products. Several points have been made, summarized as follows:

(1) LANDSAT and SKYLAB images can be used in the preparation of Actual Land Use maps in different scales to meet both national and regional objectives;

(2) It is necessary to use multi-temporal images in order to obtain the desired results;

(3) It has been concluded that the most optimal map and image scales for the Land Use analyses are 1:1,000,000 and 1:250,000;

(4) The general organization of the Land Use Legend was strongly guided by the previous work of James R. Anderson of the U.S. Geological Survey, and has broad applicability to diverse regions of the world at its more generalized levels. The detailed categories, however, at Levels III and IV are specific to the Bolivian environment;

(5) At the present time, the Land Use Legend must be considered preliminary; revisions will occur as the result of further experience in the LANDSAT and SKYLAB investigations as well as the applications of the participating "user" agencies. The present form of the Legend, however, provides a structure for a comprehensive and nationwide land use analysis for the first time in Bolivia.

TABLE 1

BOLIVIAN LAND USE LEGEND

LEVEL I	LEVEL II	LEVEL III
1 RANGELANDS Tierras con Pastizales	11 High Rangelands Pastizales de Altura	111 Wet high rangelands Pastizales de alturas húmedos 112 Temporally wet high rangelands Pastizales de altura temporalmente húmedos 113 Dry high rangelands Pastizales de altura secos 114 Dry high rangelands affected by salinity Pastizales de altura secos afectados por salinidad
	12 Intermediate Altitude Rangelands Pastizales de Altura intermedia	121 Wet intermediate altitude rangelands Pastizales de alturas intermedias húmedos 122 Temporally wet intermediate altitude rangelands Pastizales de alturas intermedias húmedos temporalmente 123 Dry intermediate altitude rangelands Pastizales de alturas intermedias secos
	13 Lowland Rangelands Pastizales de Tierras Bajas	131 Wet savannas Sabanas húmedas 132 Mesophytic savannas Sabanas mesofíticas 133 Xerophytic savannas Sabanas xerofíticas 134 Prairie lands Praderas
2 FOREST LANDS Tierras con Bosques	21 Deciduous Forests Bosque Deciduo	211 Dune deciduous forests Bosque deciduo de dunas 212 Lowland deciduous forests Bosque deciduo de tierras bajas 213 Galleria deciduous forests Bosque deciduo de galería 214 Piedmont deciduous forests Bosque deciduo de pie de monte 215 High hills deciduous forests Bosque deciduo de colinas altas 216 Montane deciduous forests Bosque deciduo de montañas

		217 Valley deciduous forests Bosque deciduo de valles
	22 Evergreen Forests Bosque Siempreverde	221 Dune evergreen forests Bosque siempreverde de vegas 222 Lowland evergreen forests, not flooded Bosque siempreverde de tierras bajas no inundables 223 Galleria evergreen forests Bosque siempreverde de galería 224 Piedmont evergreen forests Bosque siempreverde de pie de monte 225 High hills evergreen forests Bosque siempreverde de colinas altas 226 Montane evergreen forests Bosque siempreverde de montañas 227 High mountain evergreen forests Bosque siempreverde de alta montaña
	23 Transition Forests Bosque de transicion	231 Dune transition forests Bosque de transición de vegas 232 Lowland transition forests, not flooded Bosque de transición de tierras bajas no inundables 233 Galleria transition forests Bosque de transición de galería 234 Piedmont transition forests Bosque de transición de pie de monte 235 High hills transition forests Bosque de transición de colinas altas
3 CULTIVATED LANDS **Tierras Cultivados**	31 Cultivation in High Altitudes and the Altiplano Cultivos en Altura y Altiplano	311 Intensive cultivation Cultivos intensivos 312 Extensive cultivation Cultivos extensivos 313 Undifferentiated cultivation and pastures Cultivos y pastizales indiferenciados
	32 Cultivation in Intermediate Altitudes Cultivos en Alturas intermedias	321 Intensive cultivation Cultivos intensivos 322 Extensive cultivation Cultivos extensivos 323 Undifferentiated cultivation and pastures Cultivos y pastizales indiferenciados

	33 Lowland Cultivation Cultivos de alturas bajas	331 Intensive cultivation Cultivos intensivos 332 Extensive cultivation Cultivos extensivos 333 Undifferentiated cultivation and pastures Cultivos y pastizales indiferenciados
4 WETLANDS Tierras Húmedas	41 High Altitude Vegetated Wetlands Tierras Húmedas de Zonas Atlas con Vegetación	411 Permanent wetlands Tierras húmedas permanentes 412 Temporary wetlands Tierras húmedas temporales
	42 Lowland Vegetated Wetlands Tierras Húmedas de Zonas Bajas con Vegetación	421 Permanent wetlands Tierras húmedas permanentes 422 Temporary wetlands Tierras húmedas temporales
	43 Non-Vegetated Wetlands Tierras Húmedas sin Vegetación	
5 WATER Agua	51 Lakes Lagos	
	52 Small Lakes (including ponds) Lagunas	521 Permanent lakes Lagunas permanentes 522 Temporary lakes Lagunas temporales
	53 Rivers Ríos	531 Permanent rivers Ríos permanentes 532 Temporary rivers Ríos temporales
	54 Reservoirs Reservorios	
6 BARREN LANDS Tierras Eriales	61 Salt Flats Salar 62 Playas and Dunes Playas y Dunas 63 Exposed Rock Zonas Rocosas 64 Surface mines and quarries Desmontes mineros y canteras 65 Saline Lands Tierras Salinas	

	66 Badlands Mal País (Badlands) 67 Other Otras	
7 Permanent Snow and Ice Nieve y Hielo Permanente	71 Fields with Permanent Snow Campos con Nieve Permanente 72 Glaciers Glaciares	
8 Tundra Tundra	81 Wet tundra Tundra Húmeda 82 Dry Tundra Tundra Seca	
9 Urban Areas Areas Urbanas	91 Cities Cindades 92 Towns and Villages Pueblos	
	93 Transportation and Communication Facilities Transportes y Communicaciones	931 Airports and landing fields Campos de aterrizaje 932 Railroads and roads Carreteras y caminos 933 Others (pipelines, powerlines, etc.) Otros (oleductos, líneas de energia electrica, etc.)

TABLE II

EXPANDED LEGEND EXAMPLE FOR CITIES

91 Cities
Ciudades

- 911 Residential Areas
  Areas residenciales
  - 9111 Single Unit residential
    Unidad simple separada
  - 9112 Multi-unit residential
    Unidad múltiple conjunto
- 912 Commercial Areas
  Areas comerciales
- 913 Industrial Areas
  Areas Industriales
- 914 Urban Transportation
  Transportes Urbanas
  - 9141 Roads and Streets
    Caminos y avenidas
  - 9142 Railroads
    Ferrocarriles
  - 9143 Airports
    Aeropuertes
  - 9144 Canals & Pipelines
    Agua Canalizada y Oleoductas
- 915 Institutional
  Institucionales
  - 9151 Schools
    Escuelas
  - 9152 Churches
    Iglesias
  - 9153 Public Buildings
    Edificios públicos
  - 9154 Military
    Militares
  - 9155 Hospitals and clinics
    Hospitales y clínicas
- 916 Mixed
  Areas mixtas indiferenciadas
- 917 Open Spaces
  Espacios Abiertos
  - 9171 Parks
    Pargues
  - 9172 Recreational areas
    Areas de recreación
  - 9173 Other open spaces
    Otros espacios abiertos

APPENDIX A

LAND USE LEGEND DEFINITIONS

Bolivian LANDSAT Program
Servicio Geologico de Bolivia
La Paz, Bolivia

LAND USE LEGEND DEFINITIONS

1 RANGELANDS

Areas, either natural or influenced by man, where grassy or other herbaceous forage species predominate; included are the high rangelands (altiplano), intermediate altitude rangeland zones, and lowland areas (savannas and prairies).

11 High Rangelands

Areas of natural pasture/range cover, located above 3,500 meters altititude MSL.

111 Wet high rangelands
Areas of natural pasture/range cover with soils that remain wet the major part of the year.

112 Temporally wet high rangelands
Areas of natural pasture/range cover with temporary (seasonal) flooding.

113 Dry high rangelands
Areas of natural pasture/range cover developed in dry environmental conditions, characterized by shrubby vegetation.

114 Dry high rangelands affected by salinity
Areas of natural pasture/range cover, generally of limited vegetation growth due to salinity.

12 Intermediate Altitude Rangelands

Areas of natural pasture/range cover, located between 1,500 and 3,500 meters MSL.

121 Wet Intermediate Altitude Rangelands
Areas of natural pasture/range cover with soils that remain wet the major part of the year.

122 Temporally wet intermediate altitude rangelands
Areas of natural pasture/range cover with temporary (seasonal) flooding.

123 Dry Intermediate Altitude Rangelands
Areas of natural pasture/range cover developed in dry environmental conditions, characterized by shrubby vegetation.

13 Lowland Rangelands

Areas of natural pasture/range cover, located below 1,500 meters MSL.

131 Wet Savannas
Areas with a combination of woody species (generally scattered trees) and predominantly grasses, with soils that remain wet the major part of the year.

132 Mesophytic Savannas
Areas with rangeland and trees that grow in regions of intermediate humidity.

133 Xerophytic Savannas
Areas of rangeland cover and/or a combination of lowland woody species, growing in dry environmental conditions and arid climates.

134 Prairie Lands (Praderas)
Areas of herbaceous vegetation lacking woody species as a result of dry environmental conditions and/or an arid climate.

2 FOREST LANDS

Lands predominantly covered by forest vegetation associations, capable of producing lumber and other forest products, with water resources and supporting wildlife.

21 Deciduous Forests
Forested areas in which all or most species types lose their leaves in the most prominent dry season or in the winter.

The subcategories of Deciduous Forests are based principally on physiographic regions, each one of which has its own characteristics.

211 Dune deciduous forests
212 Lowland deciduous forests
213 Galleria deciduous forests
214 Piedmont deciduous forests
215 High hills deciduous forests
216 Montane deciduous forests (on high mountain slopes)
217 Valley deciduous forests (in montane regions)

22 Evergreen Forests
Areas with a dense community of trees and shrubs, commonly in layers or stratums with abundant epiphytics. The tree-tops form a continuous cover in their different layers, the branches are generally established high and little branching out. The dominant trees do not lose their leaves at any time of the year, except at fruit bearing in the period of flowering. The subcategories of Evergreen Forests are based on physiographic regions where each one has its own characteristics.

221 Dune evergreen forests
222 Lowland evergreen forests which are not flooded
223 Galleria evergreen forests
224 Piedmont evergreen forests
225 High hills forests
226 Mountain evergreen forests
227 High mountain evergreen forests

23 Transition Forests
Forests where the dominant trees (25-50%) lose their leaves at one time of the year (deciduous).

The subcategories of Transition Forests are based on physiographic regions where each one has its own characteristics.

231 Dune transition forest
232 Lowland transition forests which are not flooded
233 Galleria transition forests
234 Piedmont transition forests
235 High hills transition forests

3 CULTIVATED LANDS

Areas commonly employed in agriculture, including cultivated land, rotated pastures, lands in fallow and temporarily idle; these lands are further described as areas with intensive cultivation*, areas with extensive cultivation**, and areas of mixed or undifferentiated cultivation and pastures***.

31 Cultivation in high altitudes and the altiplano
Areas with appropriate cultivation of high altitude zones, located above 3,500 meters MSL.

311 Intensive cultivation*
312 Extensive cultivation**
313 Undifferentiated cultivation and pastures***

32 Cultivation in intermediate altitudes
Areas of cultivation located between 1,500-3,500 meters MSL.

321 Intensive cultivation*
322 Extensive cultivation**
323 Undifferentiated cultivation and pastures***

33 Lowland cultivation
Cultivated areas located below 1,500 meters MSL.

331 Intensive cultivation*
332 Extensive cultivation**
333 Undifferentiated cultivation and pastures***

* Intensive cultivation - Areas subjected to cultivation with adequate technical application and frequent human labor-intensive activities; these areas produce at least one harvest per year, the ecological conditions determining the production.

** Extensive cultivation - Areas subjected to cultivation with medium to low technical application, of which human labor-intensive activities are limited; the soil may be left in fallow for one or more years, and for the most part the harvests are of low production.

*** Undifferentiated cultivation and pastures - Mixed agricultural areas, within which both cultivation and pastures are found in varying proportions.

4 WETLANDS

Areas of temporary or permanent water cover, with hydrophytic vegetation and sometimes characterized by deficient drainage (curiches and banados).

41 High altitude vegetated wetlands
Depressions subjected to different periods of flooding, resulting in the development of aquatic vegetation; these areas are located in the mountain regions of the country above 1,500 meters MSL.

411 Permanent wetlands
Areas deprived of trees where a natural hydrophytic vegetation grows.

412 Temporary wetlands
Areas temporarily flooded with appropriate vegetation.

42 Lowland vegetated wetlands
Areas of water caused by flooding in hydrologic systems; sites of changing water levels due to the rivers' hydrologic regimes; these areas are located in the eastern plains of the country and are characterized by dense communities of hydrophytic vegetation species.

421 Permanent wetlands
Areas, with or without scanty trees and permanently flooded where floating herbaceous vegetation (curiche) develops.

422 Temporary wetlands
Areas temporarily flooded that may or may not have woody vegetation (banados).

43 Non-Vegetated Wetlands
Comprising areas of temporary flooding without vegetation, located in the mountains and lowland zones.

5 WATER

Natural or artificial bodies of water with irregular forms; in this category are included large lakes, small lakes and ponds, rivers, and reservoirs.

Water areas with vegetation are included under the wetlands category.

51 Lakes
Natural volumes of permanent water, with large dimensions, that receive water from affluent drainage systems, including Lakes Titicaca, Uru Uru, and Poope.

52 Small lakes (including ponds)
Natural deposits of water without any affluent and with smaller dimensions than a lake.

521 Permanent lakes
522 Temporary lakes

53 Rivers
Water courses that may be continuous or intermitent.

531 Permanent rivers
532 Temporary rivers

54 Reservoirs
Artificial water empoundments of planned and defined dimensions and capacities.

6 BARREN LANDS

Lands not capable for agriculture or very limited in their use, sometimes covered with small native species of vegetation; these areas, for various environmental or cultural reasons, are poor, unproductive lands.

61 Salt Flats (salar)
Extensive and deserted areas covered with natural salt

62 Playas and Dunes
Playas are shallow basins, without surface drainage, in arid areas that occasionally may be transformed into a temporary lake. Dunes are accumulations of sand with regular forms molded by wind.

63 Exposed Rock
Areas with a predominance of gauging rocks, steep talus slopes, volcanic material, or other rock zones without vegetation.

64 Surface mines and quarries
Open mine sites resulting form the surface extraction of rocks, gravel, and/or minerals, and slag piles and other features associated with surface and surface mining activities.

65 Saline lands
Improductive areas caused by the formation of accumulations of salt minerals.

66 Badlands
Areas where the surface has a strongly dissected relief, preferentially developed in arid conditions, characterized by the presence of pinnacles and profound gullies.

67 Other
Other undifferentiated zones of barren lands.

7 PERMANENT SNOW AND ICE

Natural permanent accumulations of snow in the high mountains including those areas that for reasons of temperature and pressure may be transformed into permanent ice.

71 Fields with permanent snow
72 Glaciers
Masses of ice located in high mountains that slowly slip by gravity action.

8 TUNDRA

Periglacial areas, with soil that may be frozen most of the year; with vegetation predominantly of grassy species, commonly in the form of "bunch grass" or cushioned. The flora has a limited number of species with small development and low density.

81 Wet Tundra
Tundra located in areas with saturated soils, generally resulting from inadequate drainage.

82 Dry Tundra
Tundra areas in arid environments.

9 URBAN AREAS

Places of human habitation that constitute a nucleus of population with the requirements for human life in all of their manifestations. (Urban areas have priority for classification when they coincide with two or more categories.) Included are (1) cities, (2) towns, and (3) areas of transportation and communication facilities.

91 Cities
Large areas used for the habitation and functional activities of a large and concentrated human population. Cities contain a variety of sub-areas, providing housing and basic service and employment activities. Their location may be based directly by images or with supplementary information.

92 Towns and Villages (Pueblos)
A group of inhabitants in a place or region that has only limited basic services and employment activities. Their location may be based directly by images or with supplementary information.

93 Transporation and Communication
Facilities and features, characterized by linear landscape expressions, that provide for the movement of people, information, goods, etc.

931 Airports and landing fields
932 Railroads and roads
933 Others, pipelines, power lines, etc.