Global Land Cover Characteristics Data Base Version 2.0

PLEASE NOTE: This is the Version 2.0 release of the global land cover characteristics data base. The land cover information has been updated from Version 1.2. Please read section 9.0 for information about the revision process and what changes have been made to the database.

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1.0 Introduction

The U.S. Geological Survey's (USGS), the Earth Resources Observation and Science (EROS) Center, the University of Nebraska-Lincoln (UNL) and the Joint Research Centre of the European Commission have generated a 1-km resolution global land cover characteristics data base for use in a wide range of environmental research and modeling applications (Loveland and others, 2000). The land cover characterization effort is part of the National Aeronautics and Space Administration (NASA) Earth Observing System Pathfinder Program and the International Geosphere-Biosphere Programme-Data and Information System focus 1 activity. Funding for the project is provided by the USGS, NASA, U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, U.S. Forest Service, and the United Nations Environment Programme.

The data set is derived from 1-km Advanced Very High Resolution Radiometer (AVHRR) data spanning a 12-month period (April 1992-March 1993) and is based on a flexible data base structure and seasonal land cover regions concepts. Seasonal land cover regions provide a framework for presenting the temporal and spatial patterns of vegetation in the database. The regions are composed of relatively homogeneous land cover associations (for example, similar floristic and physiognomic characteristics) which exhibit distinctive phenology (that is, onset, peak, and seasonal duration of greenness), and have common levels of primary production.

Rather than being based on precisely defined mapping units in a predefined land cover classification scheme, the seasonal land cover regions serve as summary units for both descriptive and quantitative attributes. The attributes may be considered as spreadsheets of region characteristics and permit updating, calculating, or transforming the entries into new parameters or classes. This provides the flexibility for using the land cover characteristics data base in a variety of models without extensive modification of model inputs.

The analytical strategy for global land cover characterization has evolved from methods initially tested during the development of a prototype 1-km land cover characteristics data base for the conterminous United States (Loveland and others, 1991, 1995; Brown and others, 1993). In the U.S. study, multitemporal AVHRR data, combined with other ancillary data sets, were used to produce a prototype land cover characteristics data base.

2.0 Implementation Approach

The global land cover characteristics database was developed on a continent-by-continent basis. All continents in the global database share the same map projection (Interrupted Goode Homolosine), have 1-km nominal spatial resolution, and are based on 1-km AVHRR data spanning April 1992 through March 1993. (Please note that while the native projection for the global land cover database is the Interrupted Goode Homolosine, the land cover data are now available in a Geographic projection based on user requirements.) While each continental data base has unique elements based on the salient geographic aspects of the specific continent, there are a common set of derived thematic maps produced through the aggregation of seasonal land cover regions. The thematic maps include:

- Seasonal land cover regions
- Global Ecosystems (Olson, 1994a, 1994b)
- International Geosphere Biosphere Programme Land Cover Classification (Belward, 1996)
- USGS Land Use/Land Cover System (Anderson and others, 1976)
- Simple Biosphere Model (Sellers and others, 1986)
- Simple Biosphere 2 Model (Sellers and others, 1996)
- Biosphere-Atmosphere Transfer Scheme (Dickinson and others, 1986)
- Vegetation Lifeforms (Running and others, 1994)

Following the completion of the global data set, other attributes may be defined that would include region characteristics such as elevation (mean, median, mode, minimum, maximum, variance), representative soil characteristics, biome membership, and multitemporal NDVI statistics (mean, median, mode, minimum, maximum, variance) for each monthly composite period. All data used or generated during the course of the project (source, interpretations, attributes, and derived data), unless protected by copyrights or trade secret agreements, will be distributed.

3.0 Source Data

One-kilometer AVHRR NDVI composites are the core data set used in land cover characterization. In addition, other key geographic data include digital elevation data, ecoregions interpretations, and country or regional-level vegetation and land cover maps. See Brown and others (1993) for a detailed discussion of the role of ancillary data for land cover characterization.

3.1 AVHRR Data

The base data used are the International Geosphere Biosphere Programme (IGBP) 1-km AVHRR 10-day composites for April 1992 through March 1993 (Eidenshink and Faundeen, 1994). Multitemporal AVHRR NDVI data are used to divide the landscape into land cover regions, based on seasonality. While the primary AVHRR data used in the classification is NDVI, the individual channel data sets are used for postclassification characterization of certain landscape properties. A data quality evaluation was conducted and is reported by Zhu and Yang (1996).

3.2 Digital Elevation Model (DEM) Data

DEM data are used to model the ecological factors governing natural vegetation distribution, and are important for identifying land cover types and stratifying seasonal regions representing two or more disparate vegetation types.

3.3 Ecoregions Data

Ecological regions data are used to identify regions with disparate land cover types and for stratifying seasonal regions representing two or more disparate vegetation types. Both continental and country level ecoregions data are used in this process.

3.4 Map Data

Maps and atlases of ecoregions, soils, vegetation, land use, and land cover are used in the interpretation phase of the study and serve as reference data to guide class labeling.

4.0 Technical Description of Characterization Methods

The methods used can be described as a multitemporal unsupervised classification of NDVI data with post-classification refinement using multi-source earth science data. Monthly AVHRR NDVI maximum value composites for April, 1992 through March, 1993 are used to define seasonal greenness classes. Past investigations have demonstrated that classes developed from multitemporal NDVI data represent characteristic patterns of seasonality and correspond to relative patterns of productivity (Loveland and others, 1991; Brown and others, 1993).

The translation of the seasonal greenness classes to seasonal land cover regions require post-classification refinement with the addition of digital elevation, ecoregions data and a collection of other land cover/vegetation reference data. The interpretation is based on extensive use of computer-assisted image processing tools (Brown and others, 1998); however, the classification process is not automated and more closely resembles a traditional manual image interpretation philosophy. There is a reliance on the skills of the human interpreter to make the final decisions regarding the relationship between spectral classes defined using unsupervised methods and landscape characteristics that are used to make land cover definitions.

4.1 AVHRR Data Preparation

The initial step in the process involves the preparation of the AVHRR NDVI data for use in the unsupervised classification. This requires recompositing the 10day composites into monthly data sets. The use of monthly rather than 10-day composites represents a compromise between temporal frequency and the need for cloudfree data (Moody and Strahler, 1994). It also provides a means to reduce data volume while maintaining annual phenological information. Experience has shown that composites representing a longer period are more suitable for image classification due to the substantial improvement in composite quality (Zhu and Yang, 1996).

Masks representing water bodies, snow and ice, and barren or sparsely vegetated areas are developed to eliminate NDVI data from the composites for those areas where the meaning of the NDVI values is ambiguous. In addition, the masked data set has a reduced overall variance and the classes defined using unsupervised classifications are therefore more representative of landscape patterns. The water mask is developed through the interpretation of single-date AVHRR channel 2 (near-infrared) images supplemented with water body information taken from the Digital Chart of the World (Defense Mapping Agency, 1992). Snow and ice, barren, and sparsely vegetated masks are produced from a 12-month maximum value NDVI composite threshold values that vary according to continental characteristics.

4.2 Unsupervised Classification

The initial segmentation of the 12-month NDVI composites into seasonal greenness classes is performed using unsupervised clustering. This classification method is often used for studies in which the location and characteristics of specific classes are unknown. Unsupervised classification uses clustering to identify "natural" groupings of pixels with similar NDVI properties. In this case, the clusters correspond to annual sequences of greenup, peak, and senescence. The specific clustering algorithm used is CLUSTER, a variation of the K-Means algorithm that has been optimized for use with large data sets (Kelly and White, 1993). It is an iterative statistical clustering algorithm that defines clusters or groups of NDVI values with similar properties. The clustering is controlled by predetermined parameters for number of iterations and number of resulting clusters. The clusters are defined by channel mean vectors and covariance matrices. The specific number of clusters for each continent was based on an empirical evaluation of several clustering trials.

4.3 Preliminary Labeling

The purposes of the preliminary labeling step are to provide a general understanding of the characteristics of each cluster (or seasonal greenness class) and to determine which classes have two or more disparate land cover classes represented within their spatial distribution (e.g., a class may include a mixture of both broadleaf deciduous trees/shrubs and cropland). Preliminary labeling involves inspecting the spatial patterns and spectral or multitemporal statistics of each class, comparing each class to reference data, and making decisions concerning land cover types.

The preliminary labeling step includes two primary tasks. The first is the generation of statistics and graphics for each class, describing their relationship to the available ancillary data (for example, graphs profiling the temporal sequence of NDVI, graphs of class elevation ranges, and tabular summaries comparing the seasonal greenness classes to nominal data sets). The second task is the interpretation of the summaries, graphs, and reference data to determine the general land cover type or types associated with each seasonal greenness class and to identify the classes that represent two or more disparate land cover types. Typically, a minimum of three interpreters label each class. Where differences exist, the interpreters compare decisions and consult reference materials in order to arrive at a consensus.

4.4 Postclassification Stratification

Post-classification stratification is used to separate classes containing two or more disparate land cover types. Experience has shown that at least 70% of the seasonal greenness classes represent multiple land cover types (Brown and others, 1993; Running and others, 1995). Most of these types of problems are the result of spectral similarities between natural and agricultural land cover. These problems can usually be solved by developing criteria based on the relationship between the confused seasonal greenness classes and selected ancillary data sets. Elevation and ecoregions data have proven to be the most useful ancillary variables for post-classification stratification (Brown and others, 1993).

There are two tasks involved in the post-classification stratification step. The first is to determine the ancillary variables and preliminary decision rules that separate the classes identified in the preliminary labeling step as having multiple land cover types. The second task is to implement and refine the decision rules. Generally, this is an iterative process in which the initial criteria are tested, refined, and finally used to permanently modify the original class. This results in a number of new seasonal greenness classes, that through the following step, become the final map units (seasonal land cover regions). A complete history of the processing of each class is maintained.

4.5 Final Land Cover Characterization

Following the generation of the seasonal land cover regions in the postclassification stratification step, the remaining steps in data base development are: (1) generate final attributes; (2) determine the land cover type or types for each class; and (3) derive thematic data sets.

As with the preliminary labeling step, the final land cover characterization involves generating a suite of attributes that describe the characteristics of each seasonal land cover region. Both statistics and contingency tables are created between the final seasonal land cover regions layer and the respective ancillary variables (NDVI, AVHRR channels 15, elevation, ecoregions, etc.). The attributes are part of the global land cover characteristics database and, in addition, are used as evidence in the determining the final land cover types.

A convergence of evidence approach is used to determine the land cover type for each seasonal land cover class. All available documentation, including the region attributes, image maps, atlases, other existing land cover/vegetation maps, and any other relevant materials are consulted and compared to the spatial distribution of each region. As before, at least three interpreters are used to insure consistency.

The seasonal land cover regions are then translated into the Global Ecosystem framework (1994a, 1994b). Olson has defined 94 ecosystem classes that are based on their land cover mosaic, floristic properties, climate, and physiognomy. The Global Ecosystem framework provides a mechanism for tailoring data to the unique landscape conditions of each continent, while still providing a means for summarizing the data at the global level. The Global Ecosystem types have been cross-referenced to land cover classes in the Simple Biosphere Model (SiB), Simple Biosphere 2 Model, the Biosphere Atmosphere Transfer Scheme (BATS), International GeosphereBiosphere Programme (IGBP), and USGS/Anderson (see Table 1).

Table 1. Example translation table to derived data legends.

Cluster Label	Global Ecosystem	BATS Scheme	SiB Scheme	IGBP Scheme
Pine forest	Coniferous Evergreen Forest	Evergreen Needleleaf Tree	Evergreen Needleleaf Trees	Evergreen Needleleaf Forest
Oak/pine mixed forest	Mixed Forest	Mixed Deciduous Conifer Forest	Deciduous and Evergreen Trees	Mixed Forest

The final task associated with this step is the generation of the derived data sets, including land cover and seasonal measures. In this step, the seasonal land cover regions are aggregated (or renumbered) into the appropriate classes of the output classification legends. Urban areas, extracted from the Digital Chart of the World (Defense Mapping Agency, 1992)are added to three of the derived data sets: Global Ecosystems, IGBP Land Cover, and the USGS Land Use/Land Cover system.

5.0 Derived Data Sets

The following derived data sets are included in the global land cover data base:

- Global Ecosystems (Olson, 1994a, 1994b)
- IGBP Land Cover Classification (Belward, 1996)

- U.S. Geological Survey Land Use/Land Cover System (Anderson and others, 1976)
- Simple Biosphere Model (Sellers and others, 1986)
- Simple Biosphere 2 Model (Sellers and others, 1996)
- Biosphere Atmosphere Transfer Scheme (Dickinson and others, 1986)
- Vegetation Lifeform (Running and others, 1995)

The legends for each of these derived data sets can be found in Appendices 1-7.

6.0 Global Land Cover Validation Exercise

Accuracy statistics for one land cover layer from the version 1.2 Global Land Cover Characteristics Database (GLCC), the International Geosphere Biosphere Programme (IGBP) DISCover data set, was established by researchers at the University of California, Santa Barbara (UCSB). The UCSB validation was funded through the NASA Land Cover Land Use Change Program on behalf of the IGBP Land Cover Working Group (LCWG). While the results of this validation exercise do not provide conclusive evidence of the accuracy of the other land cover classifications included in either version 1.2 or version 2.0 GLCC, they provide a general indication of data quality.

IGBP DISCover accuracy figures were derived using a simple random sample stratified by land cover type (Belward and others, 1999). To determine the true cover type, three interpreters independently interpreted either Landsat TM or SPOT images covering each sample. In order for the AVHRR pixel to be called correct, the majority of the three interpreters (2 of 3) had to agree on the land cover type, as interpreted from Landsat or SPOT, for the sample point. Based on the original IGBP LCWG validation protocol, the overall accuracy figures are (Scepan, 1999):

Sample point accuracy 59.4%

Area-weighted accuracy 66.9%

The area-weighted accuracy weights the importance of each class accuracy based on the land area occupied by that class. These accuracy figures are based on the assumption that if the three people interpreting the Landsat or SPOT data could not reach a consensus on the "true" cover type (meaning there were three different answers), then the AVHRR classification was declared to be incorrect - event though there was no evidence that it actually was wrong. As a result, the LCWG developed a revised set of accuracy statistics. These figures, referred to as "Majority Rule' accuracy, is based on the assumption that if the "true" cover for a sample could not be determined by the interpreters, then the sample should be thrown out. Based on this assumption, the overall accuracy numbers are (Scepan, 1999):

Majority Rule Accuracy 73.5%

Area Weighted Majority Rule 78.7%

It must be noted that there is no statistical validity of these figures because of the reduction of the number of useful validation samples.

Another perspective on DISCover accuracy is provided by Defries and Los (1999). They investigated the impacts of the accuracy of DISCover for one application, climate modeling. In their study, they aggregated classes into groups corresponding to two key parameters used in climate models: leaf area index (LAI) and surface roughness. Based on this aggregation, the applications accuracy of DISCover for estimating those parameter are:

LAI Accuracy 84.5%

LAI Area Weighted Accuracy 90.2%

Surface Roughness Accuracy 82.4%

Surface Roughness Area Weighted Accuracy 87.8%

A comprehensive presentation of all aspects of the validation, including per class accuracy tables, can be found in the September 1999 volume of Photogrammetric Engineering and Remote Sensing: Special Issue on Global Land Cover Validation.

7.0 Details on Version 2.0 Database Revision

The first version of the global land cover database was completed and released to the public in November, 1997. We applied the feedback we received from the users of this database (Brown and others, 1999) and broad lessons learned from the validation exercise of the IGBP DISCover land cover data (Scepan, 1999; Muchoney and others, 1999) to the development of this revised version of the database. Version 2.0 of the Global Land Cover Database contains updated land cover and water classes. The revised version is based on the land cover regions that are found in Version 1.2. Consequently, this version of the database is still based on the 1992-1993 AVHRR time series, and therefore, represents the land cover patterns for that period. Detailed information about the revised seasonal land cover regions can be found in a set of ascii tab-delimited text files, one for each continental database:

- Africa Land Cover Database Table
- Australia/Pacific Land Cover Database Table
- Eurasia Land Cover Database Table
- North America Land Cover Database Table
- South America Land Cover Database Table

This graphic shows the areas that were revised in black. Land cover classes over 10% of the earth's land area were revised for Version 2.0. Key revision focus areas included:

- Boreal forest transition zone
- Forest/cropland separation in Europe
- Miombo forest in Africa
- Amazon rainforest

8.0 Data Format and Access

The global land cover characteristics data are in a flat, headerless raster format. The raster images contain class number values for each pixel that correspond to the appropriate land cover classification scheme legend. Data are distributed as compressed and uncompressed single-band images. The files can be obtained either by anonymous file transfer protocol (ftp) or downloaded from the LP Distributed Active Archive Center (DAAC) World Wide Web site. The instructions for accessing these files are contained in the following two sections.

8.2 Downloading from the Web

On the Global Land Cover page contains links to all documentation files and the image files (both compressed and uncompressed). NOTE: web browsers can vary in how the files will be downloaded. On PCs, some browsers will allow a user to interactively select the location where the file will be saved and to edit the file name. However, on certain browsers files may be automatically downloaded to a default storage location on the local system.

1. Select either button, compressed or uncompressed, for the file of interest.
2. A pop-up screen may appear, showing information on the download procedure. At this point, choose the directory in which to save the file.
3. For compressed files, the .gz extension must be added to the filename before downloading. However, if the browser will not accept adding an extension, continue with the download, and then rename the file with the .gz extension when the download is complete.
4. For uncompressed files, leave the .gz extension off. If a pop-up screen shows the filename with a .gz extension either edit the filename, or proceed with the download and rename the file without the extension after the procedure is complete.

9.0 Geometric Characteristics

The land cover characteristics data base is available for each of five continental areas and for the entire globe. The continental land cover characteristics data bases are available in two different map projections: the Interrupted Goode Homolosine and the Lambert Azimuthal Equal Area (see Steinwand, 1994 , and Steinwand and others, 1995, for a complete description of these projections). The geometric characteristics for each continent are described in the individual documentation files for each continental data set. The global data are now available in two projections--the Interrupted Goode Homolosine projection and the Geographic (or Plate Carre) projection.

9.1 Interrupted Goode Homolosine Projection Parameters

The data dimensions of the Interrupted Goode Homolosine projection for the global land cover characteristics data set are 17,347 lines (rows) and 40,031 samples (columns) resulting in a data set size of approximately 695 megabytes for 8-bit (byte) images. The following is a summary of the map projection parameters used for the Interrupted Goode Homolosine projection:

Projection Type: Interrupted Goode Homolosine

- Units of measure: meters
- Pixel Size: 1000 meters
- Radius of sphere: 6370997 m.
- XY corner coordinates (center of pixel) in projection units (meters):
  - Lower left: (-20015000, -8673000)
  - Upper left: (-20015000, 8673000)
  - Upper right: (20015000, 8673000)
  - Lower right: (20015000, -8673000)

9.2 Geographic Projection Parameters

The data dimensions of the Geographic projection for the global land cover characteristics data set are 21,600 lines (rows) and 43,200 samples (columns) resulting in a data set size of approximately 933 megabytes for 8-bit (byte) images. The following is a summary of the map projection parameters used for the Geographic projection:

Projection Type: Geographic

- Units of measure: arc seconds
- Pixel Size: 30 arc seconds
- Radius of sphere: 6370997 m.
- XY corner coordinates (center of pixel) in projection units (arc seconds):
    - Lower left: (-647985, -323985)
    - Upper left: (-647985, 323985)
    - Upper right: (647985, 323985)
    - Lower right: (647985, -323985)

Please Note: The geographic projection is not an equal-area projection, in contrast with the Interrupted Goode Homolosine projection. Users should be advised that area statistics calculated from data in the Geographic projection will not be correct because of the areal distortion inherent to this projection.

10.0 References

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Appendix 1.

Global Ecosystems Legend

Value	Description
1	Urban
2	Low Sparse Grassland
3	Coniferous Forest
4	Deciduous Conifer Forest
5	Deciduous Broadleaf Forest
6	Evergreen Broadleaf Forests
7	Tall Grasses and Shrubs
8	Bare Desert
9	Upland Tundra
10	Irrigated Grassland
11	Semi Desert
12	Glacier Ice
13	Wooded Wet Swamp
14	Inland Water
15	Sea Water
16	Shrub Evergreen
17	Shrub Deciduous
18	Mixed Forest and Field
19	Evergreen Forest and Fields
20	Cool Rain Forest

21	Conifer Boreal Forest
22	Cool Conifer Forest
23	Cool Mixed Forest
24	Mixed Forest
25	Cool Broadleaf Forest
26	Deciduous Broadleaf Forest
27	Conifer Forest
28	Montane Tropical Forests
29	Seasonal Tropical Forest
30	Cool Crops and Towns
31	Crops and Town
32	Dry Tropical Woods
33	Tropical Rainforest
34	Tropical Degraded Forest
35	Corn and Beans Cropland
36	Rice Paddy and Field
37	Hot Irrigated Cropland
38	Cool Irrigated Cropland
39	Cold Irrigated Cropland
40	Cool Grasses and Shrubs
41	Hot and Mild Grasses and Shrubs
42	Cold Grassland
43	Savanna (Woods)
44	Mire, Bog, Fen
45	Marsh Wetland
46	Mediterranean Scrub
47	Dry Woody Scrub
48	Dry Evergreen Woods
49	Volcanic Rock
50	Sand Desert
51	Semi Desert Shrubs
52	Semi Desert Sage
53	Barren Tundra
54	Cool Southern Hemisphere Mixed Forests

55	Cool Fields and Woods
56	Forest and Field
57	Cool Forest and Field
58	Fields and Woody Savanna
59	Succulent and Thorn Scrub
60	Small Leaf Mixed Woods
61	Deciduous and Mixed Boreal Forest
62	Narrow Conifers
63	Wooded Tundra
64	Heath Scrub
65	Coastal Wetland, NW
66	Coastal Wetland, NE
67	Coastal Wetland, SE
68	Coastal Wetland, SW
69	Polar and Alpine Desert
70	Glacier Rock
71	Salt Playas
72	Mangrove
73	Water and Island Fringe
74	Land, Water, and Shore (see Note 1)
75	Land and Water, Rivers (see Note 1)
76	Crop and Water Mixtures
77	Southern Hemisphere Conifers
78	Southern Hemisphere Mixed Forest
79	Wet Sclerophylic Forest
80	Coastline Fringe
81	Beaches and Dunes
82	Sparse Dunes and Ridges
83	Bare Coastal Dunes
84	Residual Dunes and Beaches
85	Compound Coastlines
86	Rocky Cliffs and Slopes
87	Sandy Grassland and Shrubs
88	Bamboo

89	Moist Eucalyptus
90	Rain Green Tropical Forest
91	Woody Savanna
92	Broadleaf Crops
93	Grass Crops
94	Crops, Grass, Shrubs
95	Evergreen Tree Crop
96	Deciduous Tree Crop
99	Interrupted Areas (Goodes Homolosine Projection)
100	Missing Data

Appendix 2.

IGBP Land Cover Legend

Value	Description
1	Evergreen Needleleaf Forest
2	Evergreen Broadleaf Forest
3	Deciduous Needleleaf Forest
4	Deciduous Broadleaf Forest
5	Mixed Forest
6	Closed Shrublands
7	Open Shrublands
8	Woody Savannas
9	Savannas
10	Grasslands
11	Permanent Wetlands
12	Croplands
13	Urban and Built-Up
14	Cropland/Natural Vegetation Mosaic
15	Snow and Ice
16	Barren or Sparsely Vegetated

17	Water Bodies
99	Interrupted Areas (Goodes Homolosine Projection)
100	Missing Data

Appendix 3.

USGS Land Use/Land Cover System Legend (Modified Level 2)

Value	Code	Description
1	100	Urban and Built-Up Land
2	211	Dryland Cropland and Pasture
3	212	Irrigated Cropland and Pasture
4	213	Mixed Dryland/Irrigated Cropland and Pasture
5	280	Cropland/Grassland Mosaic
6	290	Cropland/Woodland Mosaic
7	311	Grassland
8	321	Shrubland
9	330	Mixed Shrubland/Grassland
10	332	Savanna
11	411	Deciduous Broadleaf Forest
12	412	Deciduous Needleleaf Forest
13	421	Evergreen Broadleaf Forest
14	422	Evergreen Needleleaf Forest
15	430	Mixed Forest
16	500	Water Bodies
17	620	Herbaceous Wetland
18	610	Wooded Wetland
19	770	Barren or Sparsely Vegetated
20	820	Herbaceous Tundra
21	810	Wooded Tundra
22	850	Mixed Tundra
23	830	Bare Ground Tundra
24	900	Snow or Ice
99		Interrupted Areas (Goodes Homolosine Projection)

100		Missing Data

Appendix 4.

Simple Biosphere Model Legend

Value	Description
1	Evergreen Broadleaf Trees
2	Broadleaf Deciduous Trees
3	Deciduous and Evergreen Trees
4	Evergreen Needleleaf Trees
5	Deciduous Needleleaf Trees
6	Ground Cover with Trees and Shrubs
7	Groundcover Only
8	Broadleaf Shrubs with Perennial Ground Cover
9	Broadleaf Shrubs with Bare Soil
10	Groundcover with Dwarf Trees and Shrubs
11	Bare Soil
12	Agriculture or C3 Grassland
17	Persistent Wetland
18	Dry Coastal Complexes
19	Water
20	Ice Cap and Glacier
99	Interrupted Areas (Goodes Homolosine Projection)
100	Missing Data

Appendix 5.

Simple Biosphere 2 Model Legend

Value	Description
1	Broadleaf Evergreen Trees
2	Broadleaf Deciduous Trees
3	Broadleaf and Needleleaf Trees

4	Needleleaf Evergreen Trees
5	Needleleaf Deciduous Trees
6	Short Vegetation/C4 Grassland
7	Shrubs with Bare Soil
8	Dwarf Trees and Shrubs
9	Agriculture or C3 Grassland
10	Water, Wetlands
11	Ice/Snow
99	Interrupted Areas (Goodes Homolosine Projection)
100	Missing Data

Appendix 6.

Biosphere Atmosphere Transfer Scheme Legend

Value	Description
1	Crops, Mixed Farming
2	Short Grass
3	Evergreen Needleleaf Trees
4	Deciduous Needleleaf Tree
5	Deciduous Broadleaf Trees
6	Evergreen Broadleaf Trees
7	Tall Grass
8	Desert
9	Tundra
10	Irrigated Crops
11	Semidesert
12	Ice Caps and Glaciers
13	Bogs and Marshes
14	Inland Water
15	Ocean
16	Evergreen Shrubs
17	Deciduous Shrubs
18	Mixed Forest

19	Forest/Field Mosaic
20	Water and Land Mixtures
99	Interrupted Areas (Goodes Homolosine Projection)
100	Missing Data

Appendix 7.

Vegetation Lifeforms Legend

Value	Description
1	Evergreen Needleleaf Vegetation
2	Evergreen Broadleaf Vegetation
3	Deciduous Needleleaf Vegetation
4	Dedicuous Broadleaf Vegetation
5	Annual Broadleaf Vegetation
6	Annual Grass Vegetation
7	Non-Vegetated Land
8	Water Bodies
99	Interrupted Areas (Goodes Homolosine Projection)
100	Missing Data