1. TITLE

1.1 Data Set Identification

ISLSCP II University of Maryland Global Land Cover Classifications, 1992-1993

1.2 Database Table Name(s)

Not applicable to this data set.

1.3 File Name(s)

The data sets in this directory are provided at three spatial resolutions of 0.25, 0.5 and 1.0 degrees lat./long. For each spatial resolution there is a land cover type classification layer (with numbers from 0 to 14) and 15 associated layers that provide the fraction, from 0 to 100, of each land cover type per cell. The land cover type files are named **umd_landcover_class_XX.asc**, where XX is qd, hd, or 1d, denoting a spatial resolution of 1/4, 1/2 or 1.0 degrees, respectively. The fractional files are called **umd_landcover_XX_cZZ.asc**, where XX is the same as above, and ZZ is a number from 00 to 14 which represents the land cover type code as described in Section 8.2. As an example, the file named **umd_landcover_qd_c02.asc** is the fraction of Evergreen Broadleaf Forest at a quarter degree spatial resolution. This file is associated with the **umd_landcover_class_qd.asc** land cover type file.

1.4 Revision Date of this Document

February 12, 2010

2. INVESTIGATOR(S)

2.1 Investigator(s) Name and Title

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2.2 Title of Investigation
University of Maryland (UMD) Global Land Cover Classifications.

2.3 Contacts (For Data Production Information)

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2.4 Data Set Citation

DeFries, R.S. and M. Hansen. 2010. ISLSCP II University of Maryland Global Land Cover Classifications, 1992-1993. In Hall, Forrest G., G. Collatz, B. Meeson, S. Los, E. Brown de Colstoun, and D. Landis (eds.). ISLSCP Initiative II Collection. Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A. doi:10.3334/ORNLDAAC/969

2.5 Requested Form of Acknowledgment

Users of the International Satellite Land Surface Climatology (ISLSCP) Initiative II data collection are requested to cite the collection as a whole (Hall et al. 2006) as well as the individual data sets. Please cite the following publications when these data are used:

Hall, F.G., E. Brown de Colstoun, G. J. Collatz, D. Landis, P. Dirmeyer, A. Betts, G. Huffman, L. Bounoua, and B. Meeson, The ISLSCP Initiative II Global Data sets: Surface Boundary Conditions and Atmospheric Forcings for Land-Atmosphere Studies, *J. Geophys. Res.*, 111, doi:10.1029/2006JD007366, 2006.

Hansen, M. C., DeFries, R.S., Townshend, J.R.G., and Sohlberg, R., 2000, Global land cover classification at 1km spatial resolution using a classification tree approach, *International Journal of Remote Sensing*, 21, 1331-1364.

3. INTRODUCTION

3.1 Objective/Purpose

The objective of this study was to create a land cover map derived from 1 kilometer Advanced Very High Resolution Radiometer (AVHRR) data using all available bands and derived Normalized Difference Vegetation Index (NDVI) and a full year of data (April 1992-March 1993). This thematic map was then resampled to 0.25, 0.5 and 1.0 degree grids for the International Satellite Land Surface Climatology Project (ISLSCP) data initiative II. This map was generated for use by modelers of global biogeochemical cycles and others in need of an internally consistent, global depiction of land cover. The original 1km land cover map was also one of the MODIS (Moderate Resolution Imaging Spectroradiometer) at-launch land cover maps.

3.2 Summary of Parameters

The data set describes the geographic distributions of 13 classes of vegetation cover (plus water and unclassified classes) based on a modified International Geosphere-Biosphere Programme (IGBP) legend (Rasool 1992). The data set also provides the fraction of each of the 15 classes within the coarser resolution cells. The data set is provided at three spatial resolutions of 0.25, 0.5 and 1.0 degrees in latitude and longitude.

3.3 Discussion

Building on the 8 km map and methodology of DeFries et al. (1998), a 1km land cover data set based on the individual spectral bands as well as NDVI values of the AVHRR was derived (Hansen et al. 2000). The approach involved a supervised method where the entire globe was classified using a classification tree algorithm. The tree predicted class memberships from metrics derived from the same AVHRR data employed by Loveland et al. (2000), except here all 5 spectral bands as well as NDVI were used. The application of the tree classifier utilized an imposed hierarchy of vegetation form similar to that proposed and implemented by Running et al. (1995), except that the relationships between multi-spectral data and vegetation type were empirically derived. Subsequently, this map was degraded to 0.25, 0.5 and 1.0 degree resolutions using a weighted resampling method. Classes with common dominant vegetation traits, such as open and closed shrubland, were weighted together based on their mean cover definitions and then resampled. Because the land/water boundaries of these resampled maps did not always agree with those of the ISLSCP II land/water masks, both the thematic land cover type files and the land cover fraction files have been modified to agree with the land and water fractions of the ISLSCP II land/water mask.

4. THEORY OF ALGORITHM/MEASUREMENTS

Coarse resolution data allow for nearly daily capture of imagery for the entire land surface. In this way, the annual greening and senescing of vegetation, or its phenology, can be captured in the satellite record. This multi-temporal information can be used to identify different land cover types. For example, evergreen forests are green and dark throughout the year. Conversely, bare ground is always bright and often extremely hot or cold. By labeling training sites around the globe with their appropriate land cover class, algorithms can be used to identify characteristic multi-spectral/multi-temporal signatures for each land cover type.

5. EQUIPMENT

5.1 Instrument Description

The global land cover data set was based on AVHRR maximum monthly composites for 1992-93 bands 1-5 and derived NDVI at approximately 1 km resolution (see Eidenshink and Faundeen 1994).

5.1.1 Platform (Satellite, Aircraft, Ground, Person)

The AVHRR instrument is flown on the National Oceanic and Atmospheric Administration (NOAA) series of satellite platforms.

5.1.2 Mission Objectives

AVHRR was designed for the instantaneous observation of clouds, ocean, land, ice and snow cover for weather analysis purposes. The multi-spectral measurements have been proven to be suitable for the quantitative measurement of a number of parameters that AVHRR was originally not designed for. The long data record also allows the use of AVHRR data for climate analysis purposes.

5.1.3 Key Variables

All 5 spectral bands of the AVHRR were used as inputs: channel 1 (visible red reflectance, 0.58-0.68 microns), channel 2 (near infrared reflectance, 0.725-1.1 microns), channel 3 (thermal infrared, 3.55-3.93 microns), channel 4 (thermal, 10.3-11.3 microns), channel 5 (thermal, 11.5-12.5 microns) and the NDVI (channel 2- channel 1)/(channel 2 + channel 1).

5.1.4 Principles of Operation

AVHRR, a scanning radiometer, is operated and maintained by the National Environmental Satellite Data and Information Service (NOAA/NESDIS).

5.1.5 Instrument Measurement Geometry

AVHRR operates with a cross-track scanning system with a maximum of 55.4° scan angle from the nadir. The nominal resolution of the sub-satellite point is 1.1 km for Local Area Coverage (LAC) and 4 km for Global Area Coverage (GAC) data. The spatial resolution decreases substantially towards the edges of the orbital swath.

5.1.6 Manufacturer of Instrument

ITT.

5.2 Calibration

5.2.1 Specifications

5.2.1.1 Tolerance

See Eidenshink and Faundeen (1994) for more details on the production of the global 1km AVHRR data set.

5.2.2 Frequency of Calibration

See Eidenshink and Faundeen (1994) for more details.

5.2.3 Other Calibration Information

None.

6. PROCEDURE

6.1 Data Acquisition Methods

The AVHRR 1km data set was processed at the EROS Data Center (EDC) under the guidance of the IGBP (Eidenshink and Faundeen 1994).

6.2 Spatial Characteristics

6.2.1 Spatial Coverage

The coverage is global. Data in files are ordered from North to South and from West to East beginning at 180 degrees West and 90 degrees North.

6.2.2 Spatial Resolution

The data are given in an equal-angle lat/long grid that has three spatial resolutions of 0.25 x 0.25, 0.5 x 0.5 and 1.0 x 1.0 degree lat/long.

6.3 Temporal Characteristics

6.3.1 Temporal Coverage

The data set is derived from data collected from April 1992 to March 1993.

6.3.2 Temporal Resolution

This data set represents the land cover types present during the period from April 1992 to March. The temporal resolution is thus one year.

7. OBSERVATIONS

7.1 Field Notes

Not applicable to this data set

8. DATA DESCRIPTION

8.1 Table Definition with Comments

Not applicable to this data set.

8.2 Type of Data

8.2.1 Parameter/ Variable Name	8.2.2 Parameter/ Variable Description	8.2.3 Data Range	8.2.4 Units of Measurement	8.2.5 Data Source
Land Cover Classes	Dominant land cover class within each grid cell. See class definitions below	Min=0 Max=14	See class codes below	Hansen et al. (2000)
Land Cover Fractions	Fraction of each land cover class contained within each grid cell. There is one layer each for each land cover class listed below.	Min=0 Max=100	Percent	Hansen et al. (2000)

*****NOTE:** There are no cells with a value of 13 (Urban and Built-up) in the 1.0 degree land cover type file.

Land Cover Type Codes and Definitions (Abbreviations):

0=Water bodies (Watr): oceans, seas, lakes, reservoirs, and rivers. Can be either fresh or salt water. Note that this class is derived from a land/water mask.

1=Evergreen Needleleaf Forests (ENeF): lands dominated by trees with a percent canopy cover >60% and height exceeding 5m. Almost all trees remain green all year. Canopy is never without green foliage.

2=Evergreen Broadleaf Forests (EBrF): lands dominated by trees with a percent canopy cover > 60% and height exceeding 5m. Almost all trees remain green all year. Canopy is never without green foliage.

3=Deciduous Needleleaf Forests (DNeF): lands dominated by trees with a percent canopy cover >60% and height exceeding 5m. Trees shed their leaves simultaneously in response to cold seasons.

4=Deciduous Broadleaf Forests (DBrF): lands dominated by trees with a percent canopy cover >60% and height exceeding 5m. Trees shed their leaves simultaneously in response to dry or cold seasons.

5=Mixed Forests (MixF): lands dominated by trees with a percent canopy cover >60% and height exceeding 5m. Consists of tree communities with interspersed mixtures or mosaics of needleleaf and deciduous forest types. Neither type has <25% or >75% landscape coverage.

6=Woodlands (Wdld): lands with herbaceous or woody understories and tree canopy cover of >40% and <60%. Trees exceed 5m in height and can be either evergreen or deciduous.

7=Wooded Grasslands/Shrublands (WdGr): lands with herbaceous or woody understories and tree canopy cover of >10% and <40%. Trees exceed 5m in height and can be either evergreen or deciduous.

8=Closed Bushlands or Shrublands (ClSh): lands dominated by bushes or shrubs. Bush and shrub percent canopy cover is >40%. Bushes do not exceed 5m in height. Shrubs or bushes can be either evergreen or deciduous. Tree canopy cover is <10%. The remaining cover is either barren or herbaceous.

9=Open Shrublands (OpSh): lands dominated by shrubs. Shrub canopy cover is >10% and <40%. Shrubs do not exceed 2m in height and can be either evergreen or deciduous. The remaining cover is either barren or of annual herbaceous type.

10=Grasslands (Gras): lands with continuous herbaceous cover and <10% tree or shrub canopy cover.

11=Croplands (Crop): lands with >80% of the landscape covered in crop-producing fields. Note that perennial woody crops will be classified as the appropriate forest or shrubs land cover type.

12=Barren (Bare): lands of exposed soil, sand, rocks, snow or ice which never have more than 10% vegetated cover during any time of year.

13=urban and Built-up (Urban): lands covered by buildings or other man-made structures. Note that this class is not mapped from the AVHRR imagery but is developed from the populated places layer that is part of the Digital Chart of the World (Danko 1992).

14=Unclassified (Uncl): Points where the ISLSCP II land/sea mask was labeled as land and the UMD original data had sea and which could not be filled in from a 3 by 3 average of surrounding cells (See Section 9.2 for a description of methods used).

8.3 Sample Data Record

Not Applicable to this data set.

8.4 Data Format

All of the files in the ISLSCP Initiative II data collection are in the standard ArcGIS ASCII grid, or text format. The file format consists of numerical fields of varying length, which are delimited by a single space and arranged in columns and rows. The values in the land cover class type files are written as integers from 0 to 14. All values in the land cover fraction files are written as real numbers.

The files at different spatial resolutions each contain the following numbers of columns and rows:

1 degree: 360 columns by 180 rows
1/2 degree: 720 columns by 360 rows
1/4 degree: 1440 columns by 720 rows

All files are gridded to a common equal-angle lat/long grid, where the coordinates of the upper left corner of the files are located at 180 degrees W, 90 degrees N and the lower right corner coordinates are located at 180 degrees E, 90 degrees S. Data in the files are ordered from North to South and from West to East beginning at 180 degrees West and 90 degrees North.

8.5 Related Data Sets

For other global land cover data sets, see (DeFries and Townshend, 1994, DeFries et al. 1998, DeFries et al. 1999, Loveland et al. 2000). Other land cover data sets in the ISLSCP II collection include the EROS Data Center (EDC) Classifications, the MODIS classification, and the C_4 vegetation fraction data set. Related data sets can also be obtained at http://daac.ornl.gov/ISLSCP_II/islscpii.html.

9. DATA MANIPULATIONS

9.1 Formulas

9.1.1 Derivation Techniques/Algorithms

A decision tree was used to classify the dependent variable of class membership using the independent variables of AVHRR metrics. Trees are a non-parametric, hierarchical classifier which predicts class membership by recursively partitioning a data set into more homogeneous subsets. This procedure is followed until a perfect tree (one in which every pixel is discriminated from pixels of other classes, if possible) is created with all pure terminal nodes or until preset conditions are met for terminating the tree's growth. The method used here is that of the Splus statistical package (Clark and Pergibon 1992), which employs a deviance measure to split data into nodes which are more homogeneous with respect to class membership than the parent node. The reduction in deviance, (*D*) is calculated as:

$$D = D_s - D_t - D_u \quad (1)$$

where *s* is the parent node, and *t* and *u* are the splits from *s*. Right and left splits along the digital counts for all metrics are examined. When *D* is maximized, the best split has been found, and the data are divided at that digital count and the process repeated on the two new nodes of the tree. The deviance for nodes is calculated from the following:

$$D_i = -2\Sigma\, n_{ik} \log p_{ik} \quad (2)$$

where *n* is the number of pixels in class *k* in node *i* and *p* is the probability distribution of class *k* in node *i*. (Hansen et al. 2000)

9.2 Data Processing Sequence

9.2.1 Processing Steps and Data Sets

The majority of the training data were derived via the method described in DeFries et al. (1998), using an overlay of co-registered coarse resolution and interpreted high-resolution data sets. Core areas for each class were derived from classification and interpretations of the high-resolution imagery. Based on the interpretation of over 200 Landsat Thematic Mapper and Multi-Spectral Scanner data sets, 37,249 training pixels were delineated. These sites for all 13 land cover classes were then input to the classification tree as the dependent variables. The independent variables used to predict class membership were multi-temporal AVHRR metrics. A set of 41 metrics was created for input into the decision tree. The first 29 metrics were created from values associated with the 8 greenest months of the year. Snow cover, especially relating to the distribution and number of training pixels within and without the snow area, can produce undesired results. By binning all metrics on only the 8 greenest months, snow effects are largely limited to those places with perpetual snow and ice cover and very high-latitudes, while still retaining most of the seasonal variability associated with vegetation phenology. The 8 greenest months are not necessarily consecutive, but represent the 8 months with the clearest view of green vegetation. In this manner, globally applicable, timing insensitive metrics with minimized cloud presence are created. The metrics used included maximum, minimum, mean and amplitudes for all bands associated with the eight greenest months. Individual band values associated with peak greenness were also derived. The application of the tree followed a nested two-class hierarchy where dominant vegetation forms were successively identified until all 13 classes were depicted. For more information, refer to Hansen et al. (2000).

To create coarser scale land cover maps, the original 13 classes were grouped by common vegetation traits and averaged over output grid cells. During the aggregation process, the fraction of each land cover type contained within the coarser cell was produced and used to determine the principal cover type at the coarse scale. Note that this aggregation did not assign a label based on a simple dominant fraction but used voting rules based on the land cover class definitions given in Section 8.2. In that legend, ranges of cover are given for tree cover and shrub cover classes. The specific rules that were used are given below using conditional statements (class abbreviations are given in Section 8.2):

If (totalforest >= 60%) then
[If totalbroadleaf > (0.75*totalforest) then
If (EBrF > DBrF) then
EBrF
Else
DBrF

If totalneedleleaf > (0.75*totalforest) then
If (ENeF > DNeF) then
ENeF
Else
DNeF]
Else
MixF

If (totalforest >= 40% and totalforest < 60%) then
Wdld

If (totalforest >= 10% and totalforest < 40%) then
WdGr

For the above statements totalforest = ENeF+EBrF+DNeF+DBrF+MixF, totalbroadleaf = EBrF+ DBrF and totalneedleleaf = ENeF+ DNeF.

If (Gras+Crop) > 0 and (Gras+Crop) > (ClSh+OpSh) and (Gras+Crop) > Bare then
If (Crop > Gras) then
Crop
Else
Gras

If (ClSh+OpSh) > 0 and (ClSh+OpSh) > (Gras+Crop) and (ClSh+OpSh) > Bare then
If (ClSh > OpSh) then
ClSh
Else
OpSh

If Bare > 0 and Bare > (ClSh+OpSh) and Bare > (Gras+Crop) then
Bare

If Urbn >= 50% then
Urbn

If Uncl > 50% then
Uncl

If Watr >= 50%
Watr

9.2.2 Processing Changes

None.

9.2.3 Additional Processing by the ISLSCP II Staff

Some discrepancies were found between the ISLSCP II land/water mask and the water/land values in the UMD land cover products. To address these issues, the original UMD products were made to match with the water fractions of the ISLSCP II land/water mask and a new land cover type map was derived using the rules given in Section 9.2.1. Two general cases were addressed: 1) The ISLSCP II mask is water and the UMD map is land, 2) The ISLSCP II mask is land and the UMD product is water. For 1), the original UMD fractions for each land cover category were adjusted using the land fractions of the ISLSCP II mask. For all cells in this category, the original UMD land cover type was replaced with a value of 0 (water). For cases in 2), if the UMD water fraction was less than 100%, the existing UMD fractions were adjusted as in 1). In cases were the UMD water fraction was 100% in 2), the cell in all land cover fraction files was filled from an average of all surrounding cells in a 3 by 3 window. In a few instances such as small islands, no land values were available in the 3 by 3 window and the cell was given a value of 14 (Unclassified). The land cover types were then derived using the new fraction files and the rules given in Section 9.2.1

9.3 Calculations

9.3.1 Special Corrections/Adjustments

None.

9.4 Graphs and Plots

See Hansen et al. (2000).

10. ERRORS

10.1 Sources of Error

Sources of error include the data inputs (misplaced swaths, noise, misregistration, cloud contamination, missing data, etc...), training data labels (unreliable ancillary map sources, misinterpretations, incomplete class sampling) and the inseparablility of class signature. The data filling procedures described in Section 9.2.3 also introduce some errors.

10.2 Quality Assessment

10.2.1 Data Validation by Source

The data set has not been systematically validated. However, comparisons with higher resolution data, as well as ancillary land cover products are made in Hansen et al. (2000) and Hansen and Reed (2000).

10.2.2 Confidence Level/Accuracy Judgment

The training accuracy of the original map is 69 percent, with well over half of the errors associated with mixed assemblage woodland and wooded grassland classes. There is relatively little confusion between core classes representing dominant vegetation forms and forest types. For example, the training agreement when viewing the confusion between only the classes of evergreen needleleaf and broadleaf forests, deciduous needleleaf and broadleaf forests, shrubland, grassland, cropland and bare ground is 88 percent (positively identified pixels of these classes/(positively identified pixels of these classes + errors only across these classes)).

A number of conclusions can be drawn based on comparisons made between regional databases and the UMD product. The basic distinction between forest and non-forest shows good agreement with other sources, ranging from 81 to 92 percent. One area of possible improvement for the UMD map is the mapping of pastures within heavily agricultural areas. Future iterations of this product must include better training for this cover sub-type. Atmospheric degradation of the remote sensing signal in central Africa is difficult to handle in the global context and suggests the possible value of fusing other data sources such as radar in these areas. Landscape heterogeneity found in high-resolution data sets is reduced in the 1km multi-temporal UMD product. Favoring the dominant classes when using coarser resolution data, especially the greener classes due to multi-temporal NDVI compositing, is present in this product. However, most of these problems are greatly reduced in the aggregation of the 1 kilometer map to 0.25, 0.5 and 1.0 degree resolution maps.

10.2.3 Measurement Error for Parameters and Variables

None.

10.2.4 Additional Quality Assessment Applied

None.

11. NOTES

11.1 Known Problems with the Data

See section 10.2.

11.2 Usage Guidance

When aggregating the 1km maps to coarser scales, many errors are reduced, such as the limitation in depicting spatial heterogeneity. Users should note that the land cover type file is consistent with the ISLSCP II binary land/water mask while the land cover fraction files are consistent with the land and water fraction files of the ISLSCP II land/water mask. Users can utilize the land cover fraction files to generate different land cover products with different rules than those given in Section 9.2.1

11.3 Other Relevant Information

None.

12. REFERENCES

12.1 Satellite/Instrument/Data Processing Documentation

None.

12.2 Journal Articles and Study Reports

Clark, L. A., and Pergibon, D., 1992, *Tree-based models*. In Statistical Models in S, edited by T. J. Hastie (Pacific Grove, CA: Wadsworth and Brooks).

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Running, S. W., Loveland, T. W., Pierce, L. L., Nemani, R. R. and Hunt, E. R., Jr., 1995, A remote sensing based vegetation classification logic for global land cover analysis, *Remote Sensing of Environment*, 51, 39-48.

13. DATA ACCESS

13.1 Data Access Information

The ISLSCP Initiative II data are archived and distributed through the Oak Ridge National Laboratory (ORNL) DAAC for Biogeochemical Dynamics at http://daac.ornl.gov.

13.2 Contacts for Archive

E-mail: uso@daac.ornl.gov
Telephone: +1 (865) 241-3952

13.3 Archive/Status/Plans

The ISLSCP Initiative II data are archived at the ORNL DAAC. There are no plans to update these data.

14. GLOSSARY OF ACRONYMS

AVHRR	Advanced Very High Resolution Radiometer
CD-ROM	Compact Disk (optical), Read Only Memory
DAAC	Distributed Active Archive Center
EOS	Earth Observing System
EDC	EROS Data Center
GAC	Global Area Coverage
GCM	General Circulation Model of the atmosphere
GSFC	Goddard Space Flight Center
IDS	Inter-disciplinary Science
IGBP	International Geosphere-Biosphere Programme
ISLSCP	International Satellite Land Surface Climatology Project
LAC	Local Area Coverage
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NESDIS	National Environmental Satellite Data and Information Service (NOAA)
NOAA	National Oceanic and Atmospheric Administration
ORNL	Oak Ridge National Laboratory
UMD	University of Maryland