# *Building a GEO Forest Carbon Tracking Database*

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Measurement, Verification and Reporting Joint Workshop

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**U.S. Geological Survey**
**U.S. Department of Interior**

# National Demonstrator Annual Products

a. Forest and land cover maps
b. Biomass estimations
c. Carbon stock estimates
d. Future carbon stock scenarios

# What will it take to get there?

# Steps to Comprehensive FCT

1. Creation of a CEOS Virtual Technical Center (VTC) for Forest Cover and Carbon Assessment, Monitoring and Verification
2. Data Outreach and Training: Methods, Tools, and Capacity
3. Sampling and Sampling Frames
4. Earth Observation Data Provision, Pre-processing and Distribution
5. *In situ* Data Management and Protocols
6. Classification and Mapping Support

# 1. A Virtual Technical Center (VTC) for Forest Cover and Carbon Assessment, Monitoring and Verification

**Action 1:**

Create a “virtual” center of specialists to provide training, to provide expert advice on mapping procedures, and to support carbon accounting and verification methods.

Undertake the following actions:

# **2.** Data Outreach and Training: Methods, Tools, and Capacity

USGS and GOFC-GOLD have been holding training sessions at the EROS Data Center, training international users and providing them with data from the EROS archive.

**Action 2:**

This program should be **continued and expanded** and it should include **more specific training on forest and land cover mapping** as well as the **provisioning of hardware and software as well as data**.

# 3. Sampling and Sampling Frames

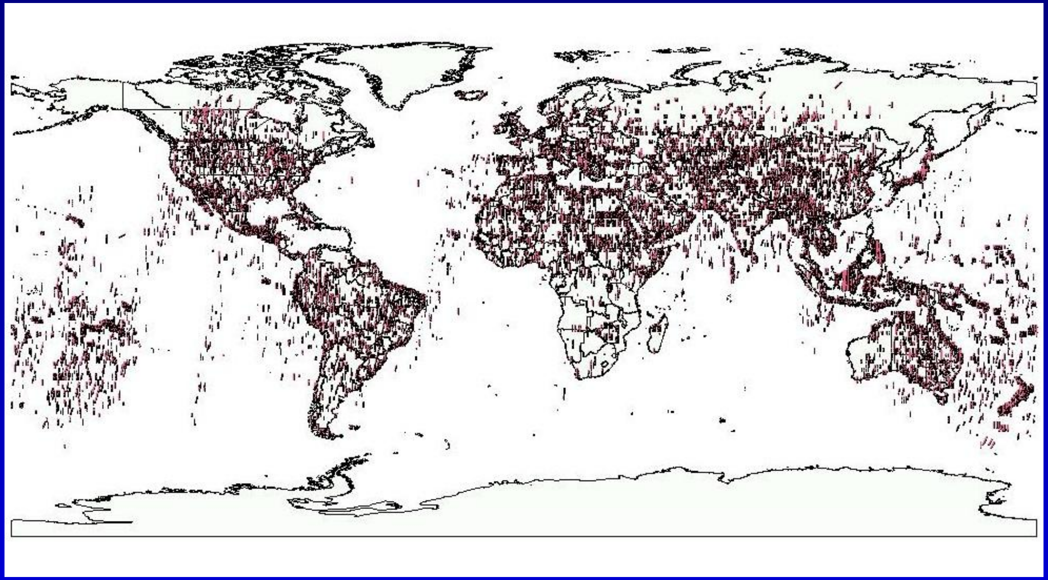
**Action 3:**

Conduct a study on the distribution of current field sites and field campaigns; develop a global multi-stage and multi-scale sampling frame along with a database of global sites and *in situ* data to better coordinate field data collection, aerial surveys, and satellite acquisitions with existing research sites.

# Test Site Analysis Datasets – Satellite

- OrbView-3 Footprints
- Hyperion
- Optical and Radar Assets (Table below)

# OrbView-3 Data Archive



- Spatial Area
  - The collection occupies much of the land masses of the world
- Temporal Range
  - The images were acquired between 2003 and 2007.
  - The collection is being offered in its entirety of 530,424 records.

# Test Site Analysis Datasets – Aerial

- Lidar
- Radar
- Hyperspectral
- Photography / Videography

# Test Site Analysis Datasets – In situ

- ILTER
- TEAM
- FluxNet
- Smithsonian
- American Cordillero
- Other

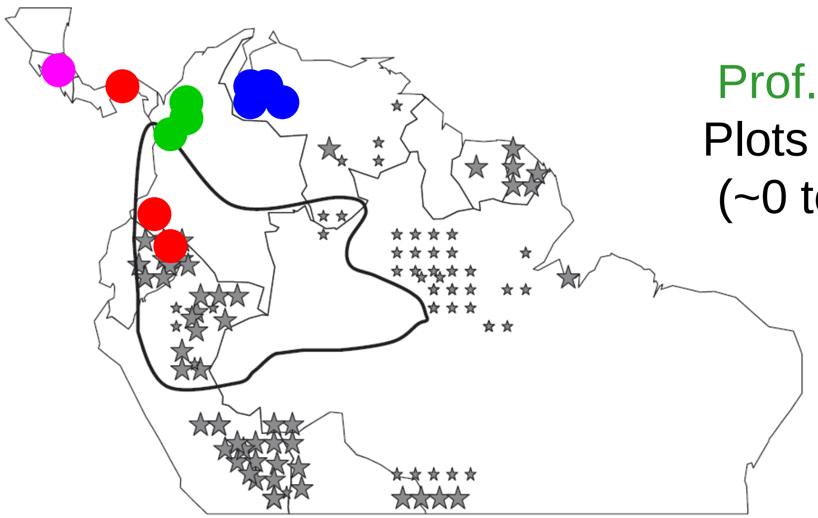
# Build on Existing in situ Networks

# Some examples from South America

The CTFS plot network
http://www.ctfs.si.edu/
(130 to 1780 m elevation; mean = 715 m)

Prof. J. P. Veillon *et al.*
Plots measured 1961 to 1985?
(<180 to >2450 m elevation)

Dr. D. Lieberman *et al.*
Plots measured
1969 to 1985?
(32 to 71 m elevation)



Prof. A. J. Duque M. *et al.*
Plots are being established
(~0 to ~3000 m elevation)

The RAINFOR plot network
http://www.geog.leeds.ac.uk/projects/rainfor/
(35 to 800 m elevation; mean = 250 m)

# Let’s not forget aerial ….

especially, a resource for identifying upcoming missions for sharing….

# 4. Earth Observation Data Provision, Pre-processing and Distribution

**Action 4a:**

- Development of robust, spatially integrated primary datasets for the FCT National Demonstrators (ND). These data would include an appropriate array of Essential Climate Variables (ECVs) as defined by CEOS, as well as supporting documentation, and would be distributed to National FCT/UN REDD lead institutions on hard disks considering the data volume.

**Action 4b:**

- Process MODIS 250m time series vegetation index data on 16-day intervals, and generate temporal metrics (length of growing season, start of growing season etc.) which will be included as part of the national data bundles.

# Core Data Resources

1. Satellite
2. Digital Terrain Data: slope, aspect, elevation
3. Landforms
4. Land cover
5. Land use/Land cover change
6. Hydrology / Hydrography
7. Geology
8. Ecosystems Maps (GEO Ecosystems)
9. Soils
10. Climate Data
11. Protected Area Data (WDPA)
12. Plot-based Measurements

# FCT National Demonstrator Metadata

| Data | Source | Pre-processing Institution | Product(s) | Product Type / Name | Product Processing Institution | Spatial Resolution (m) | Timestep | Date(s) | File Format | Projection | Datum | Spheroid | Projection Parameters | Atmospheric Correction | Terrain Correction |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Terrain Model** | | | | | | | | | | | | | | | |
| **ALOS-PALSAR** | JAXA | | | | | 10, 50 | | | | | | | | | |
| **ASAR** | | | | | | | | | | | | | | | |
| **ASTER** | JAXA | | | | | 30 | | | | | | | | | |
| **AVHRR** | | | | | | 1000 | | | | | | | | | |
| **CBERS 2B CCD** | Brazil/China | INPE | | Level 1T | | 20 | | | GEO-TIFF | UTM | WGS84 | | | ? | SRTM |
| **COSMO-SkyMed** | | | | | | | | | | | | | | | |
| **ENVISAT ASAR** | ESA | | | | | | | | | | | | | | |
| **IRS** | India | | | | | | | | | | | | | | |
| **Landsat INPE** | Brazil/China | INPE | | Level 1G | | 30 | | | GEO-TIFF | UTM | WGS84 | | | ? | |
| **Landsat USGS** | USGS | USGS | Forest cover and change | Landsat TM/ETM Level 1T | TBD | 15, 30, 60 | | | GEO-TIFF | UTM | WGS84 | | | yes | SRTM (GTOPO-30) |
| **LIDAR - aerial** | | | | | | | | | | | | | | | |
| **Meris** | ESA | | | | | 300 | | | | | | | | | |
| **MODIS** | NASA/USGS | USGS | Phenology | | USGS | 250 | 8/16-day composites | | HDF-EOS | ISG | | | | | |
| **Radarsat-2** | | | | | | | | | | | | | | | |
| **SPOT-4 TPM** | SPOT | | | | | | | | | | | | | | |
| **SPOT-4/5** | SPOT Image | | | | | | | | | | | | | | |
| **SPOT-VGT** | SPOT | | | | | 10000 | | | | | | | | | |
| **TerraSAR-X** | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| **Terrain Model** | | | | | | | | | | | | | | | |
| **ASTER DEM** | JAXA | | derivatives | | | 30 | | | | | | | | | |
| **SRTM** | NGA | | derivatives | | | 30 | | | | | | | | | |
| **SRTM** | NGA | | derivatives | | | 90 | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| **Ancillary Data** | | | | | | | | | | | | | | | |
| **GEO Ecosystems** | USGS | N/A | Ecosystems | | USGS | | | 2010 | | | | | | | |
| **Soils** | | | | | | | | | | | | | | | |
| **Geology** | | | | | | | | | | | | | | | |
| **Lithology** | | | | | | | | | | | | | | | |
| **Climate** | | | T, Precip. | | | | monthly | term | | | | | | | |

# National Data Standards

| Country | Lead National Insitution | FCT Lead (s) | File Format | Projection | Datum | Spheroid | Projection Parameters | Atmospheric Correction | Terrain Correction | Resampling | National Demonstrator | UN-REDD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Africa** | | | | | | | | | | | | |
| **Cameroon** | | ESA | | | | | | | | | yes | |
| **Democratic Republic of Congo** | | Congo Basin Forest Fund (Norway + UK) | | | | | | | | | | yes |
| **Ghana** | | Australia TBC | | | | | | | | | | |
| **Tanzania** | Div. of Forestry and Beekeeping | Norway, Australia? | | UTM | ARC1960 | | | | | | yes | yes |
| **Zambia** | | | | | | | | | | | | yes |
| | | | | | | | | | | | | |
| **Asia and Pacific** | | | | | | | | | | | | |
| **Australia (Tasmania)** | | Australia | | | | | | | | | yes | |
| **Cambodia** | | Australia, Japan, USA (TBC) | | UTM | Indian 1954 | Everest Adjustment 1937 | | | | | | |
| **China** | | China, Australia | | | | | | | | | | |
| **Indonesia (Borneo)** | TBD | Australia, Japan, Indonesia | | | | | | | | | yes | yes |
| **Papua New Guinea** | | Australia | | | | | | | | | | |
| **Vietnam** | | | | | | | | | | | | yes |
| | | | | | | | | | | | | |
| **North and Central America** | | | | | | | | | | | | |
| **Mexico** | | | | | | | | | | | yes | |
| **Panama** | | | | | | | | | | | | yes |
| | | | | | | | | | | | | |
| **South America** | | | | | | | | | | | | |
| **Bolivia** | | EU, ESA | | | | | | | | | | |
| **Brazil** | | Brazil, Norway, USA | | | | | | | | | yes | |
| **Brazil - Xingu** | | Brazil, Norway, USA | | | | | | | | | | |
| **Colombia** | Colombia | TBD | | | | | | | | | | |
| **Guyana** | Guyana Forestry Commission | Norway | | | | | | | | | yes | |
| **Paraguay** | | | | | | | | | | | | yes |
| **Peru** | | | | | | | | | | | | |

# Test Site Analysis Datasets – Sites

- FAO FRA Remote Sensing Survey
- Confluences
- Protected Areas (WDPA)
- KBAs, IBAs

# 5. *In situ* Data Management and Protocols

Action 5:

Develop a best practices set of guidelines for field sampling, and produce a field methods manual with accompanying forms, hand-helds, and databases.

# Why a plot model and database?

- Calibration and validation of remote sensing models
- Direct parameterization: the ability to directly predict plot variables rather than map categorical classification systems
- Direct mapping and cross-walking of multiple classification systems
- Mixture modeling: allows understanding the relationship of plot composition and structure to remote sensing parameters
- Permanent and standardized to permit monitoring and continuity of descriptions across plots, sites and regions

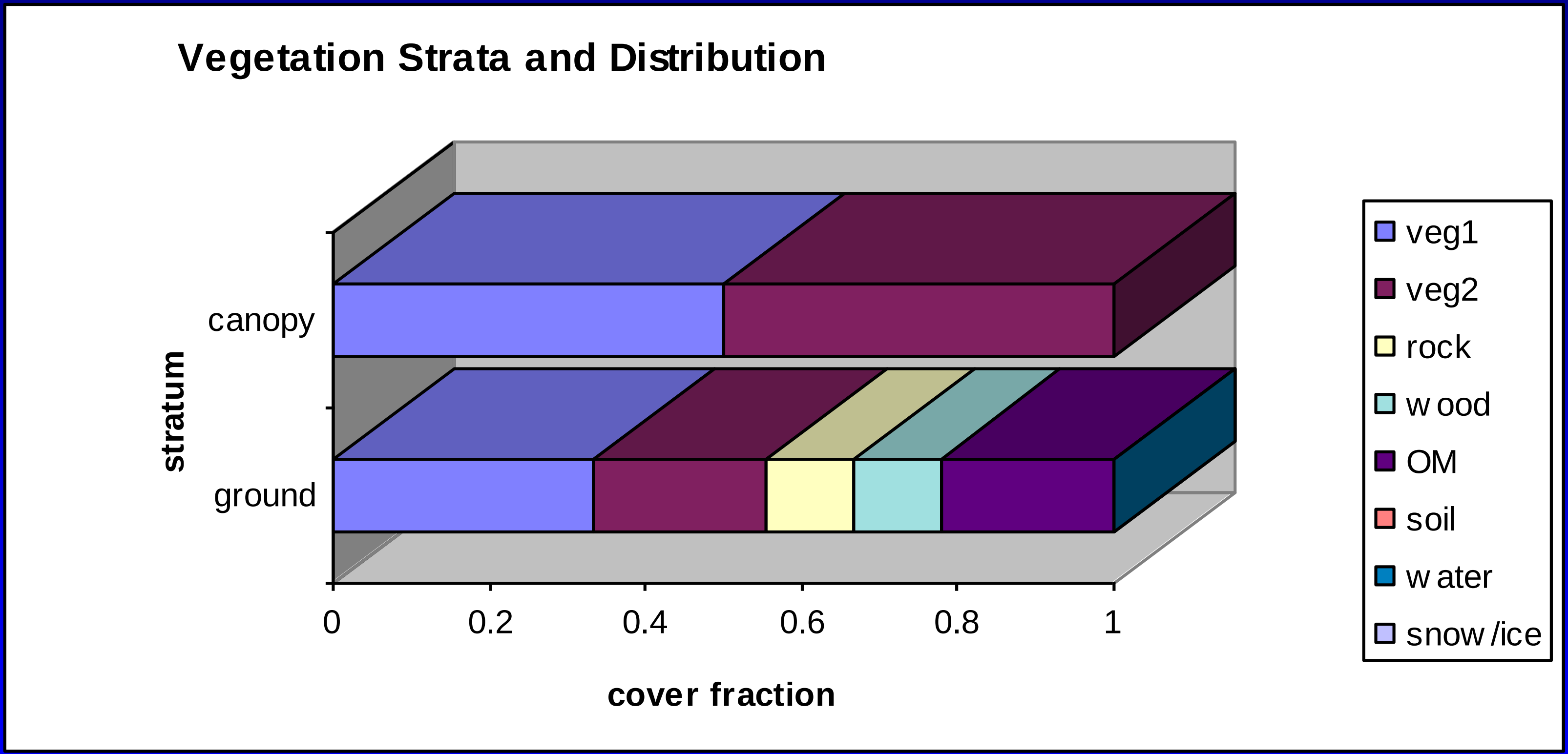
# Site/Environmental Data Variables

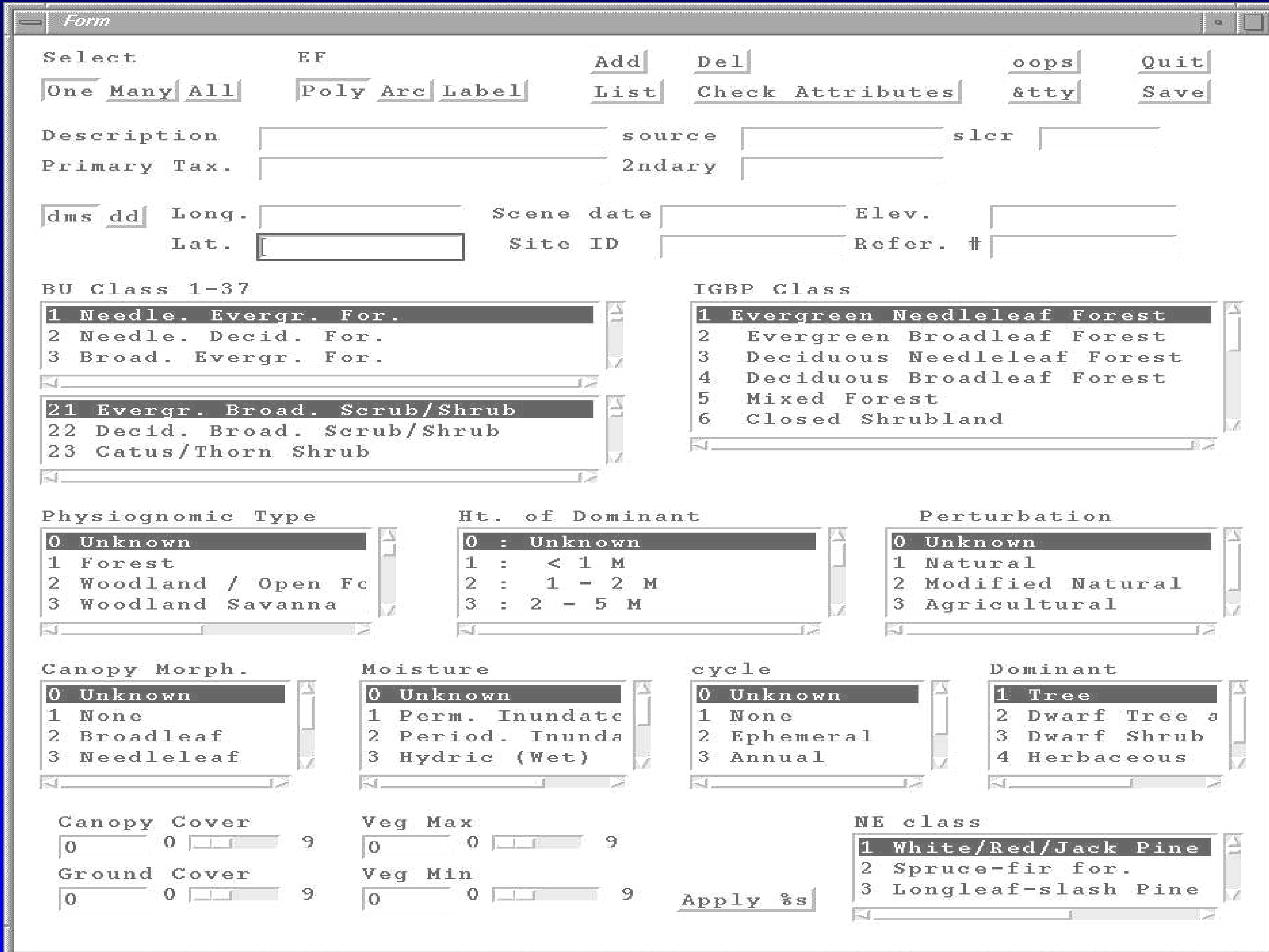
| feature | variable name | data type | data range | data units |
|---|---|---|---|---|
| latitude | X | ratio | 71.35-91.56 | dec. degrees |
| longitude | Y | ratio | 8.01-19.52 | dec. degrees |
| moisture | MOIST | categorical | 1-8 | class |
| disturbance | PERT | categorical | 0-4 | class |
| physiognomic formation | PHYS | categorical | 1-13 | class |
| IGBP | IGBP | categorical | 1-17 | class |
| STEP-Vegetation | VEGCLASS | categorical | 1-37 | class |
| polygon site ID | SITEID | categorical | 1-300 | class |
| canopy cover fraction (%) | CCOV | ordinal | 0-9 | percent class |
| canopy cover leaf morphology | CMORPH | categorical | 0-6 | class |
| canopy cover phenology | CPHEN | categorical | 0-6 | class |
| vegetation cycle (periodicity) | CYCLE | categorical | 0-6 | class |
| vegetation distribution | DIST | categorical | 1-4 | class |
| dominant lifeform | DOM | categorical | 0-4 | class |
| cover of dominant lifeform | DOMCOV | ordinal | 0-9 | percent class |
| height of dominant lifeform | DOMHT | ordinal | 0-8 | height class |
| groundcover leaf morphology | GCMORPH | categorical | 0-7 | class |
| groundcover phenology | GCPHEN | categorical | 0-7 | class |
| vegetated ground fraction (%) | GCVEG | ordinal | 0-9 | percent class |
| leaf type | LTYPE | categorical | 0-8 | class |
| percent max. vegetation cover | VEGMAX | ordinal | 0-9 | percent class |
| percent min. vegetation cover | VEGMIN | ordinal | 0-9 | percent class |
| month of max. vegetation | MONTHMAX | categorical | 1-12 | month |
| month of min. vegetation | MONTHMIN | categorical | 1-12 | month |

# Remote Sensing / Environmental Variables

| feature class | feature | variable name | data type | data range | data units | source |
|---|---|---|---|---|---|---|
| VI | daily NDVI | c1_vi - c365_vi | interval | 0-255 | index | NDVI |
| temporal NDVI | max. monthly NDVI | x_max | interval | 0-255 | index | NDVI |
| | min. monthly NDVI | x_min | interval | 0-255 | index | NDVI |
| | month of max. NDVI | mo_max | categorical | 1-12 | month | NDVI |
| | month of min. NDVI | mo_min | categorical | 1-12 | month | NDVI |
| | mean annual NDVI | xndvi | interval | 0-255 | index | NDVI |
| | NDVI range | x_range | interval | 0-100 | index | NDVI |
| | NDVI prinicpal components | PCA_1-6 | interval | 0-255 | index | DEM |
| topography | slope | SLOPE | ratio | 0-25 | degrees | DEM |
| | aspect | ASP | interval | 0-255 | degrees | DEM |
| | elevation | ELEV | ratio | 0-255 | meters | DEM |
| temperature | 12 monthly temp.means | t1_x - t12_x | interval | 0-255 | degrees K | AVHRR |
| temporal Temp. | max. monthly temperature | tmax | interval | 0-255 | index | AVHRR |
| | min. monthly temperature | tmin | interval | 0-255 | index | AVHRR |
| | month of max. temperature | mtmax | categorical | 1-12 | month | AVHRR |
| | month of min.temperature | mtmin | categorical | 1-12 | month | AVHRR |

# Vegetation Structure and Distribution

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Select
One Many All
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Poly Arc Label
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2ndary
dms dd
Long.
Lat.
Scene date
Site ID
Elev.
Refer. #
BU Class 1-37
1 Needle. Evergr. For.
2 Needle. Decid. For.
3 Broad. Evergr. For.
21 Evergr. Broad. Scrub/Shrub
22 Decid. Broad. Scrub/Shrub
23 Catus/Thorn Shrub
IGBP Class
1 Evergreen Needleleaf Forest
2 Evergreen Broadleaf Forest
3 Deciduous Needleleaf Forest
4 Deciduous Broadleaf Forest
5 Mixed Forest
6 Closed Shrubland
Physiognomic Type
0 Unknown
1 Forest
2 Woodland / Open Fc
3 Woodland Savanna
Ht. of Dominant
0 : Unknown
1 : < 1 M
2 : 1 - 2 M
3 : 2 - 5 M
Perturbation
0 Unknown
1 Natural
2 Modified Natural
3 Agricultural
Canopy Morph.
0 Unknown
1 None
2 Broadleaf
3 Needleleaf
Moisture
0 Unknown
1 Perm. Inundate
2 Period. Inunda
3 Hydric (Wet)
cycle
0 Unknown
1 None
2 Ephemeral
3 Annual
Dominant
1 Tree
2 Dwarf Tree a
3 Dwarf Shrub
4 Herbaceous
Canopy Cover
0 0 9
Ground Cover
0 0 9
Veg Max
0 0 9
Veg Min
0 0 9
Apply %s
NE class
1 White/Red/Jack Pine
2 Spruce-fir for.
3 Longleaf-slash Pine

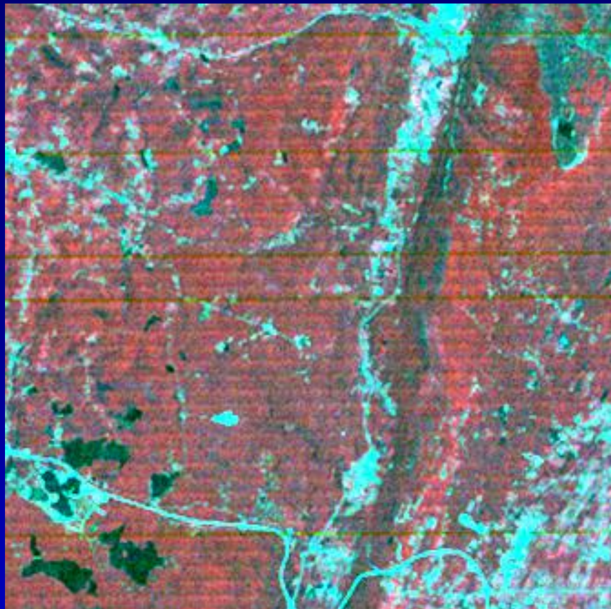
# 6. Classification and Mapping Support

Action 6a:

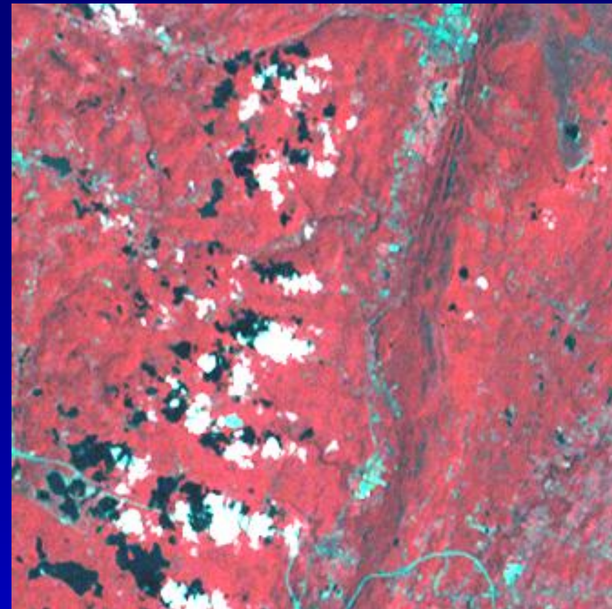
- Provide best practice methods and training on MRV and FCT dataset development, and mapping methods.

Action 6B:

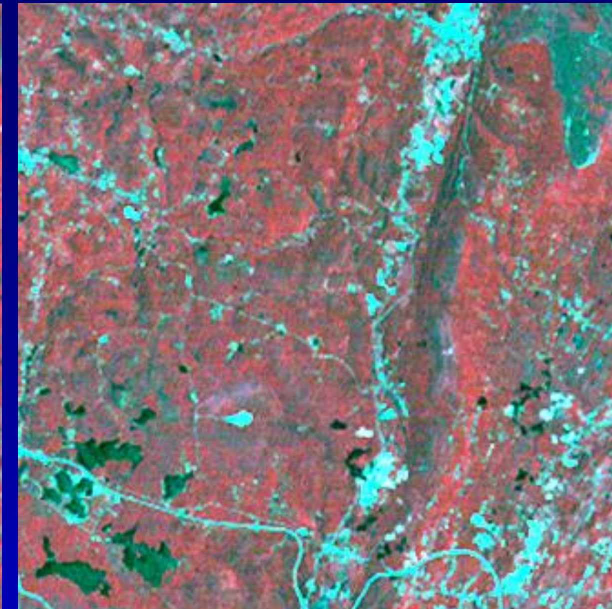
- Derive a global 30 m forest and land cover map using the GLS data.



Landsat MSS 1972



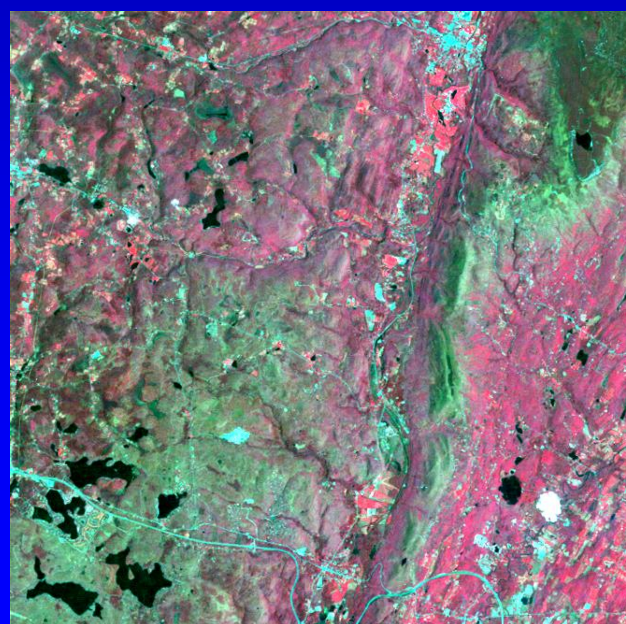
Landsat MSS 1980



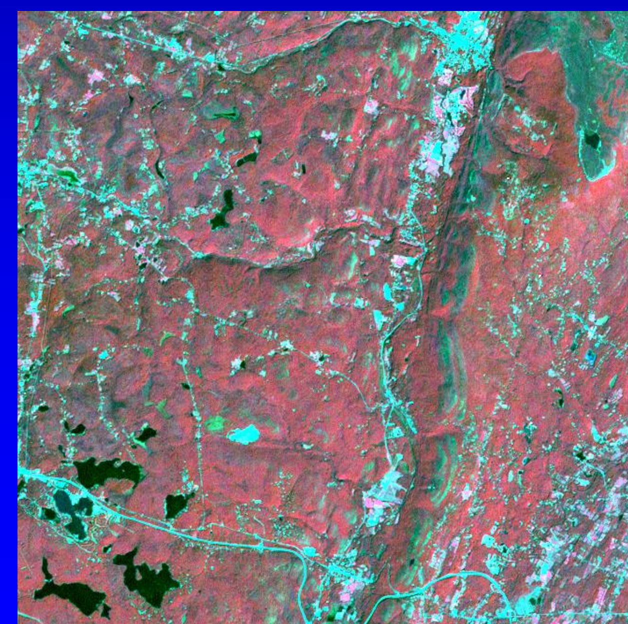
Landsat MSS 1986

# Landsat

# Time Series

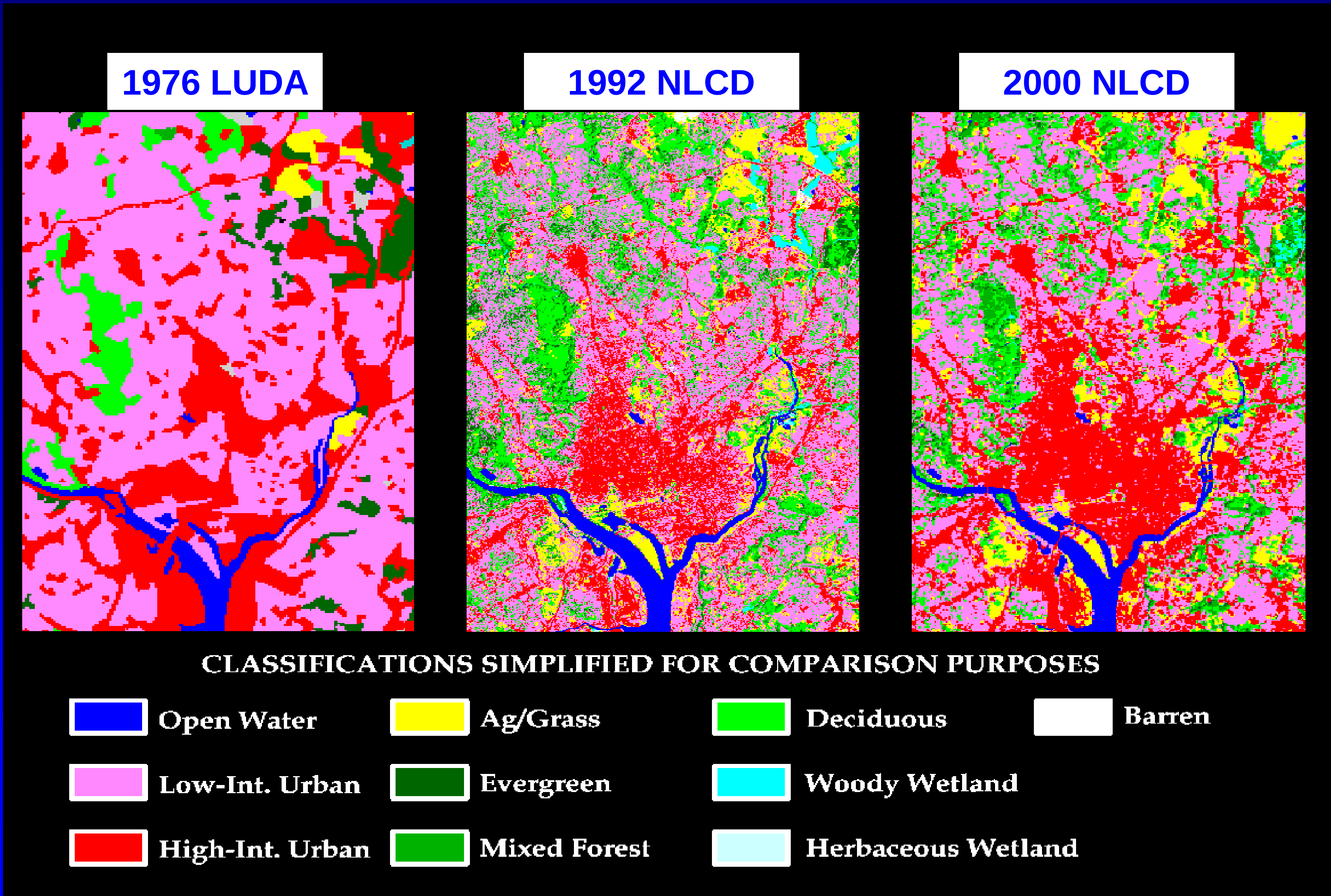


Landsat TM 1992

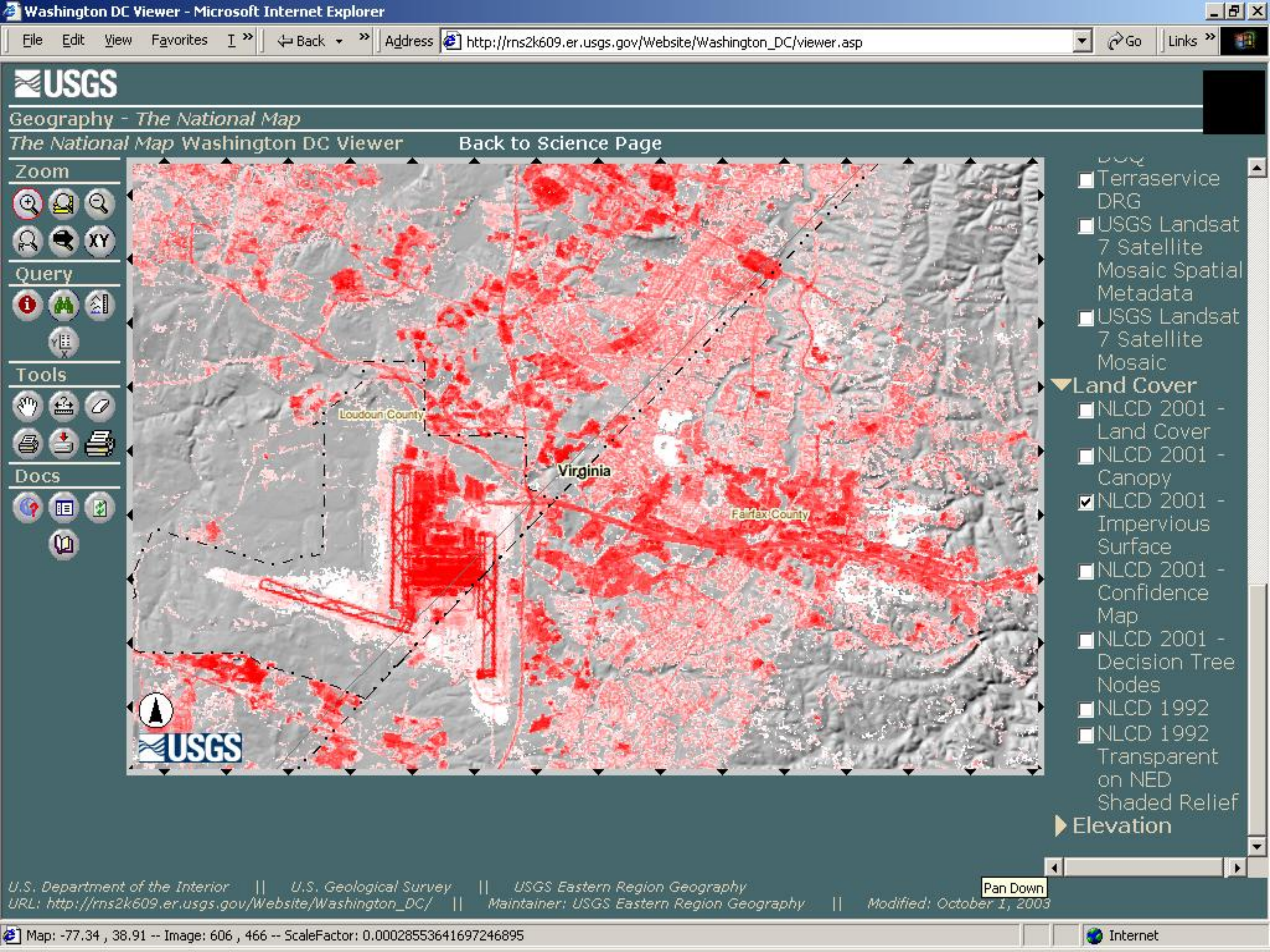


Landsat ETM+ 2000

# Land Cover



1976 LUDA
1992 NLCD
2000 NLCD
CLASSIFICATIONS SIMPLIFIED FOR COMPARISON PURPOSES
Open Water
Ag/Grass
Deciduous
Barren
Low-Int. Urban
Evergreen
Woody Wetland
High-Int. Urban
Mixed Forest
Herbaceous Wetland



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USGS
Geography - The National Map
The National Map Washington DC Viewer
Back to Science Page
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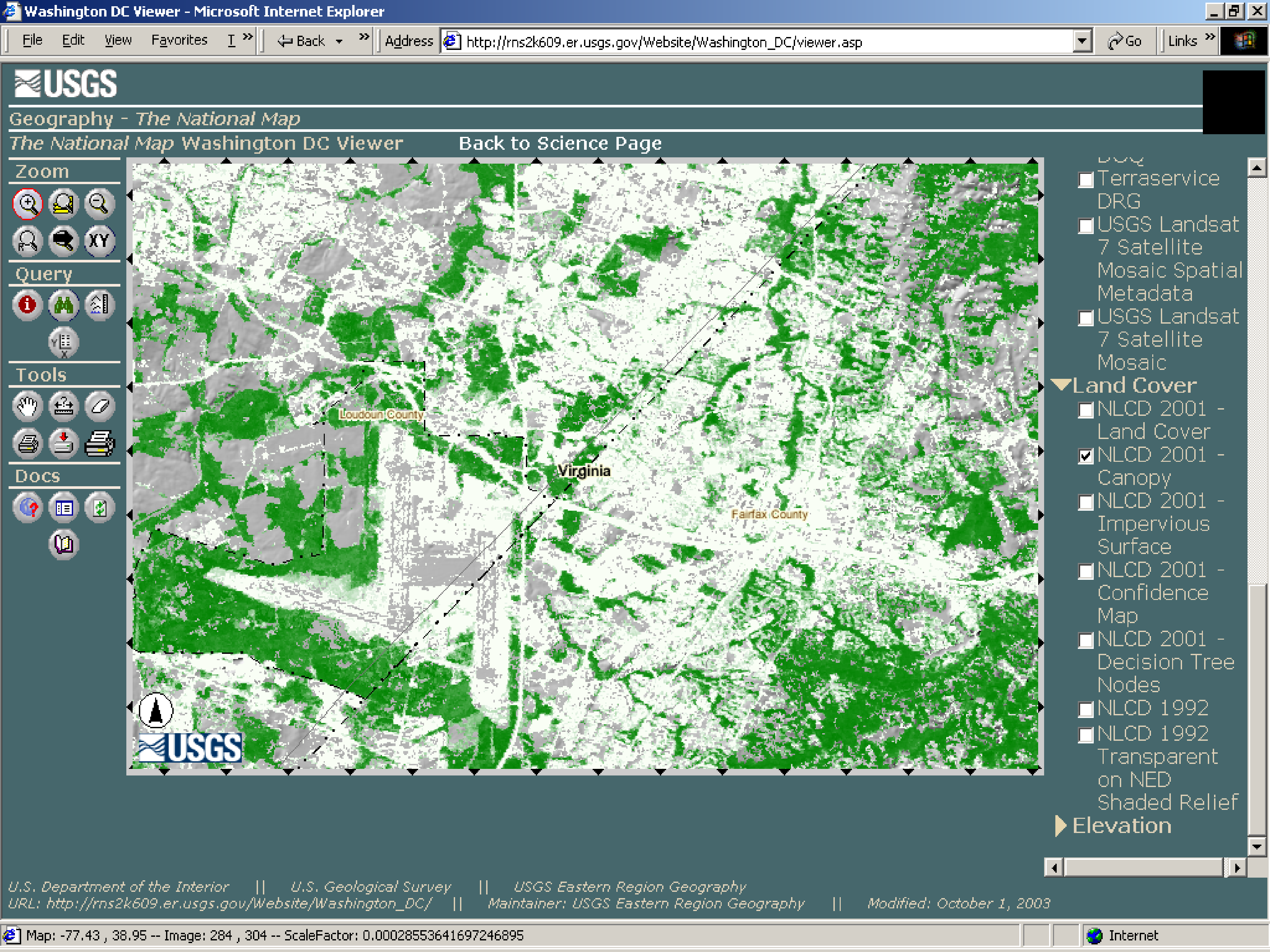
Query
Tools
Docs
Loudoun County
Virginia
Fairfax County
USGS
Terraservice DRG
USGS Landsat 7 Satellite Mosaic Spatial Metadata
USGS Landsat 7 Satellite Mosaic
Land Cover
NLCD 2001 - Land Cover
NLCD 2001 - Canopy
NLCD 2001 - Impervious Surface
NLCD 2001 - Confidence Map
NLCD 2001 - Decision Tree Nodes
NLCD 1992
NLCD 1992 Transparent on NED Shaded Relief
Elevation
U.S. Department of the Interior || U.S. Geological Survey || USGS Eastern Region Geography
URL: http://rns2k609.er.usgs.gov/Website/Washington_DC/ || Maintainer: USGS Eastern Region Geography || Modified: October 1, 2003
Pan Down
Map: -77.34 , 38.91 -- Image: 606 , 466 -- ScaleFactor: 0.000285536416972468953
Internet



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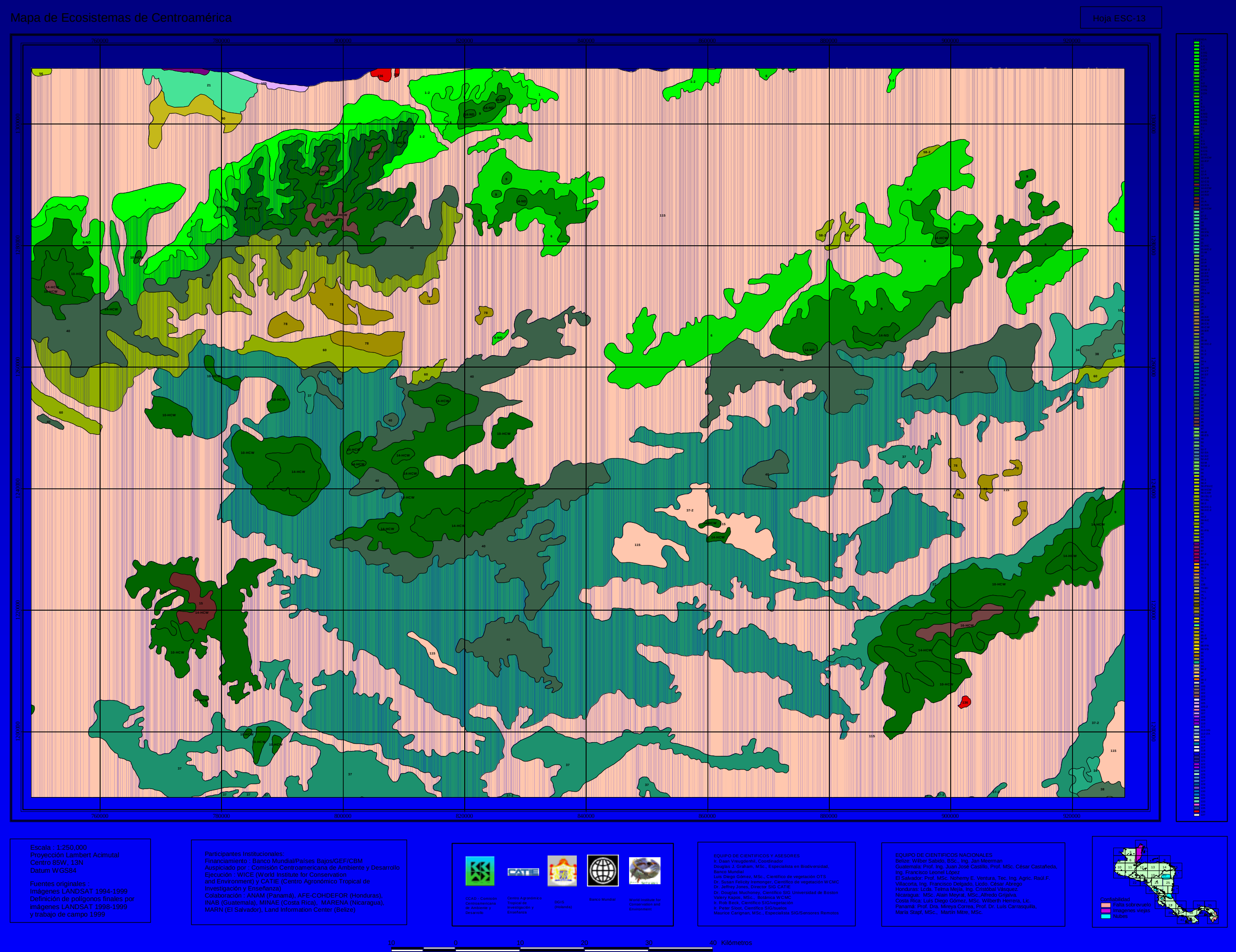
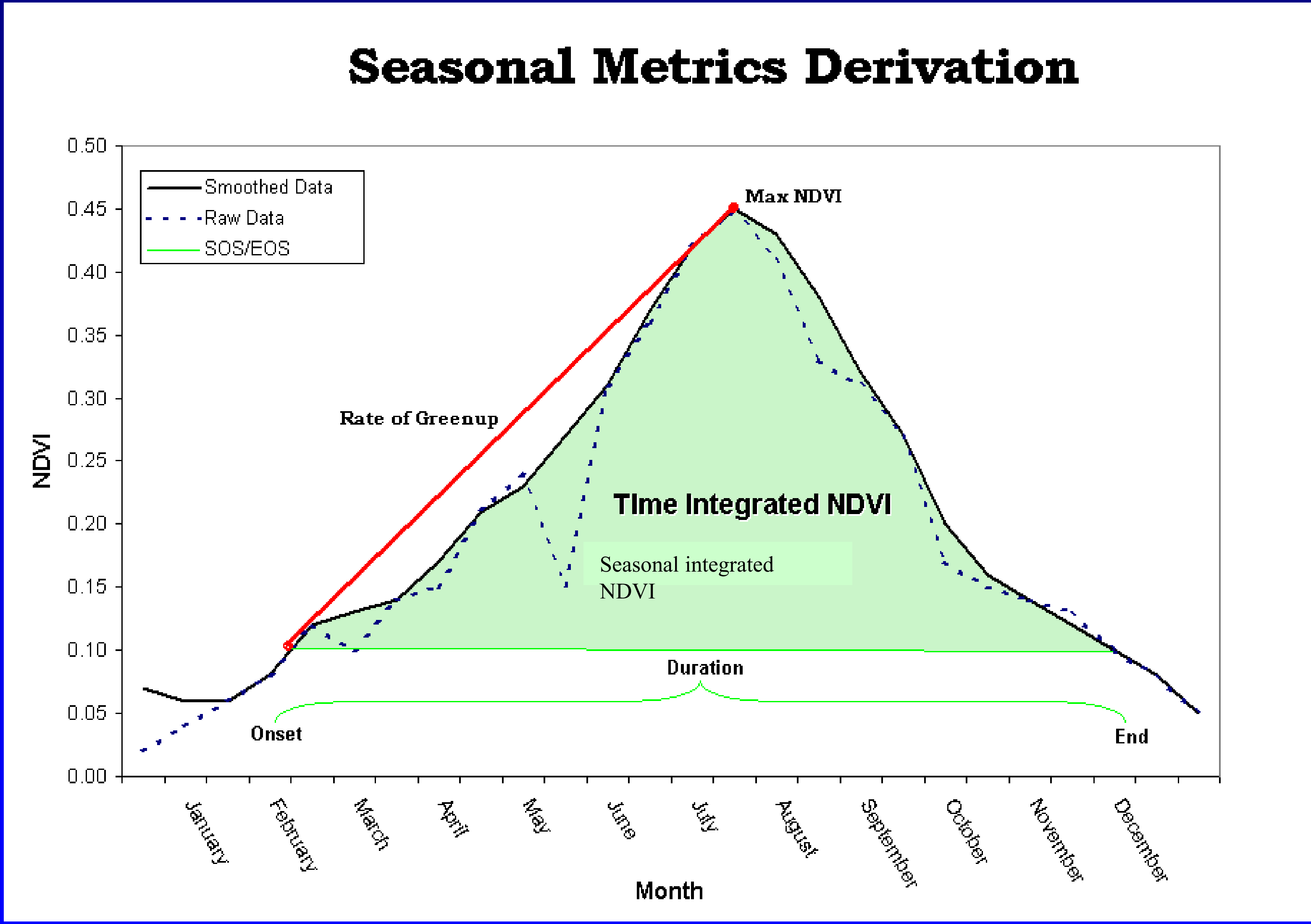
Docs
Loudoun County
Virginia
Fairfax County
USGS
Terraservice DRG
USGS Landsat 7 Satellite Mosaic Spatial Metadata
USGS Landsat 7 Satellite Mosaic
Land Cover
NLCD 2001 - Land Cover
NLCD 2001 - Canopy
NLCD 2001 - Impervious Surface
NLCD 2001 - Confidence Map
NLCD 2001 - Decision Tree Nodes
NLCD 1992
NLCD 1992 Transparent on NED Shaded Relief
Elevation
U.S. Department of the Interior || U.S. Geological Survey || USGS Eastern Region Geography
URL: http://rns2k609.er.usgs.gov/Website/Washington_DC/ || Maintainer: USGS Eastern Region Geography || Modified: October 1, 2003
Map: -77.43 , 38.95 -- Image: 284 , 304 -- ScaleFactor: 0.00028553641697246895
Internet

# Central American Ecosystems



# Temporal / Phenologic Vegetation Metrics



# Scientific and operational challenges

- Optical data acquisition in the tropics
- Data Integration: in situ, optical, radar and lidar
- Database management
- Accurately estimating forest cover, volume, biomass, and carbon stocks and flows
- Land cover change modeling for future scenarios
- Long-term operations in developing countries
- Accuracy requirements traded against costs and benefits
- Accuracy assessments
- Requirements for verification

# 30-Month Timeline

| Task | Duration (Months) | Month | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| **VTC Logistical Support** | 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Training** | 24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Sampling Design and Protocols** | 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| STEP Manual | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Data Collection** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cartographic | 24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| In Situ | 24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Remote Sensing | 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Landsat | 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MODIS | 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Radar | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aerial Photography | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| LiDAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Database Development** | 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Database Management** | 22 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Algorithm Development** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Forest and Land Cover | 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Biomass | 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Phenology | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Disturbance History | 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Data Processing** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Forest and Land Cover | 24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Carbon Estimates | 24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Disturbances | 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Land Cover Change | 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Carbon Verification** | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Transition to Operations** | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Reporting** | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Thank you

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