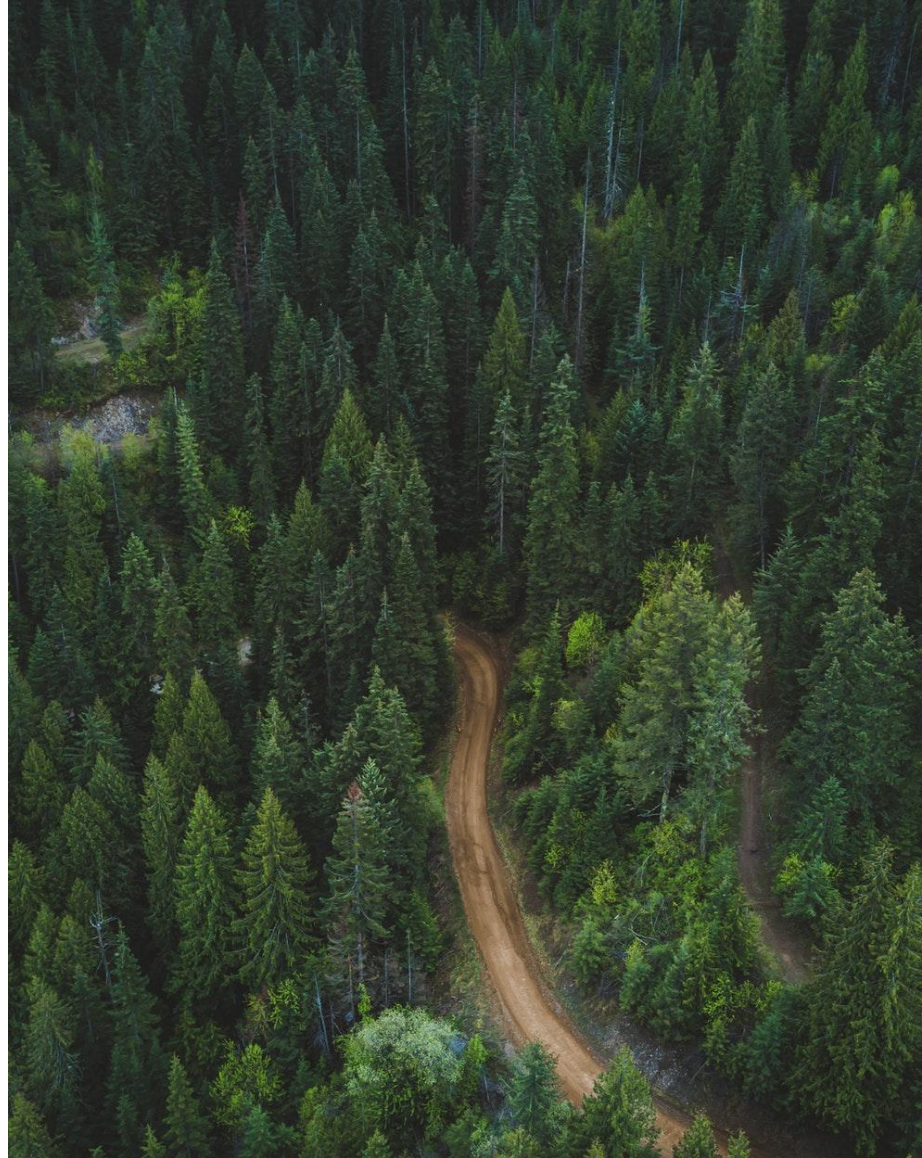


Carbon model



bc³
BASQUE CENTRE
FOR CLIMATE CHANGE
Klima Aldaketa Ikergai

International Spring University
**on Ecosystem
Services Modeling**



springuniversity.bc3research.org

Overview

- Multiple components related to climate stability:
 - Carbon storage in biomass
 - Carbon storage in soils
 - Carbon sequestration
 - Emissions of other GHGs: methane, N_2O , etc.
- Initial ARIES Tier 1 strategy: general global models of first two, supplement with ecosystem-specific models where possible



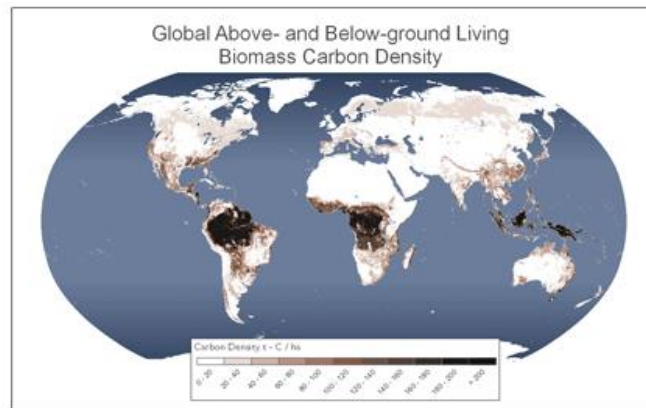
+



IPCC method Tier 1 (Ruesch & Gibbs 2008)



New IPCC Tier-1 Global Biomass Carbon Map for the Year 2000



Submitted to ORNL-CDIAC by Aaron Ruesch and Holly K. Gibbs*

*Corresponding author: hgibbs@stanford.edu

Authors' affiliation at the time of publication:
Center for Sustainability and the Global Environment ([SAGE](#))
Nelson Institute for Environmental Studies,
University of Wisconsin-Madison

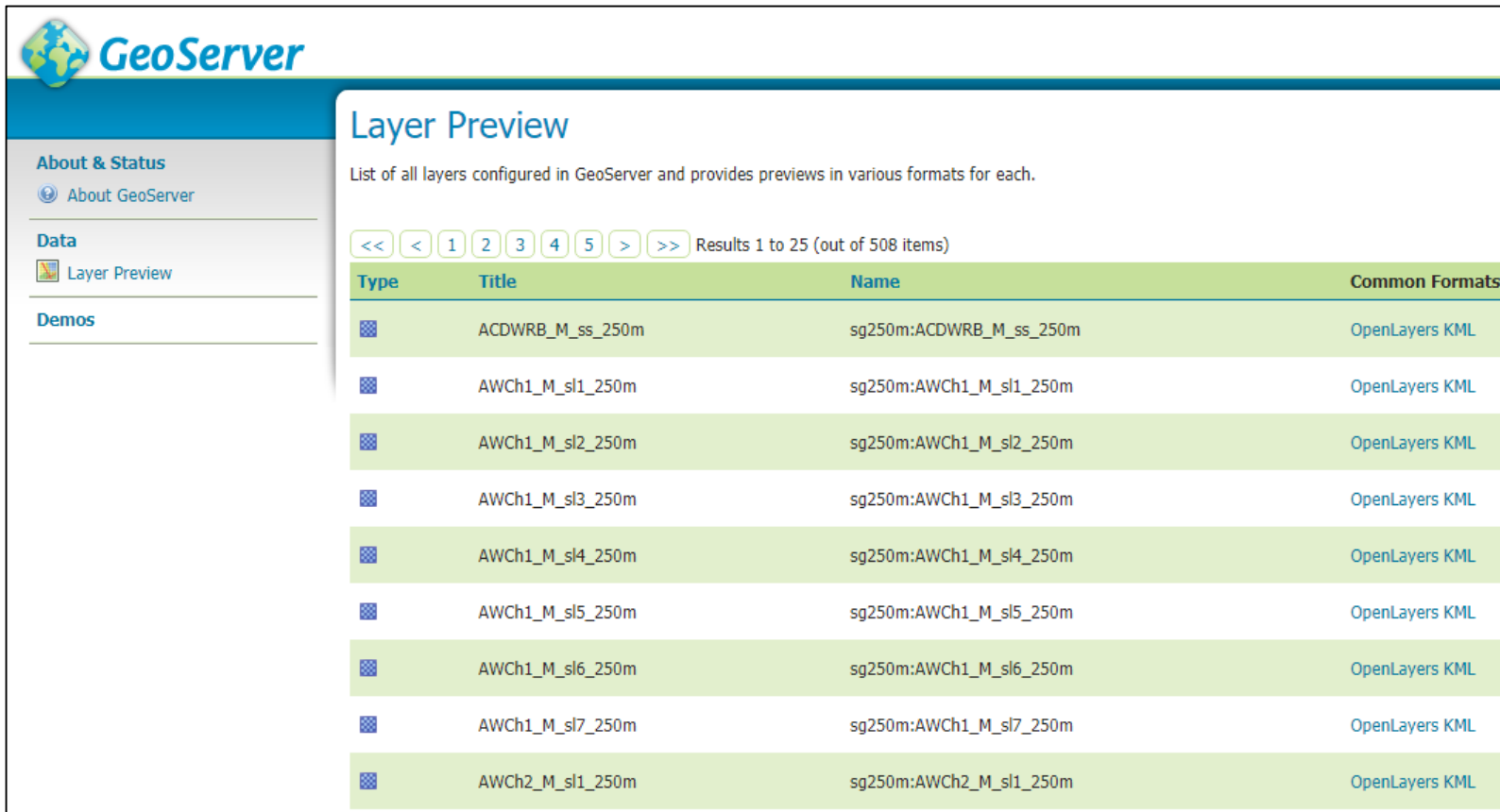
IPCC method Tier 1 (Ruesch & Gibbs 2008)

- Vegetation carbon storage – above & belowground
- Massive (900+ row) lookup table

landcover	ecofloristicregion	continental_region	f_forest	burned	vegetationcarbon
landcover:BroadleafForest	ecology:TropicalRainforest	geography:AfricanRegion	*	false	200
landcover:BroadleafForest	ecology:TropicalRainforest	geography:NorthAmericanRegion	*	false	193
landcover:BroadleafForest	ecology:TropicalRainforest	geography:SouthAmericanRegion	*	false	193
landcover:BroadleafForest	ecology:TropicalRainforest	geography:AsianRegion	*	false	180
landcover:BroadleafForest	ecology:TropicalRainforest	geography:InsularAsianRegion	*	false	225
landcover:BroadleafForest	ecology:TropicalRainforest	geography:AustralianRegion	*	false	199.5
landcover:BroadleafForest	ecology:TropicalMoistDeciduousForest	geography:AfricanRegion	*	false	152
landcover:BroadleafForest	ecology:TropicalMoistDeciduousForest	geography:NorthAmericanRegion	*	false	128
landcover:BroadleafForest	ecology:TropicalMoistDeciduousForest	geography:SouthAmericanRegion	*	false	128
landcover:BroadleafForest	ecology:TropicalMoistDeciduousForest	geography:AsianRegion	*	false	105
landcover:BroadleafForest	ecology:TropicalMoistDeciduousForest	geography:InsularAsianRegion	*	false	169
landcover:BroadleafForest	ecology:TropicalMountainSystem	geography:AfricanRegion	*	false	69
landcover:BroadleafForest	ecology:TropicalMountainSystem	geography:NorthAmericanRegion	*	false	87
landcover:BroadleafForest	ecology:TropicalMountainSystem	geography:SouthAmericanRegion	*	false	87
landcover:BroadleafForest	ecology:TropicalMountainSystem	geography:AsianRegion	*	false	81
landcover:BroadleafForest	ecology:TropicalDryForest	geography:InsularAsianRegion	*	false	122

Soil carbon storage

- Abundant soils data, including carbon, available from ISRIC SoilGrids 250 m global dataset



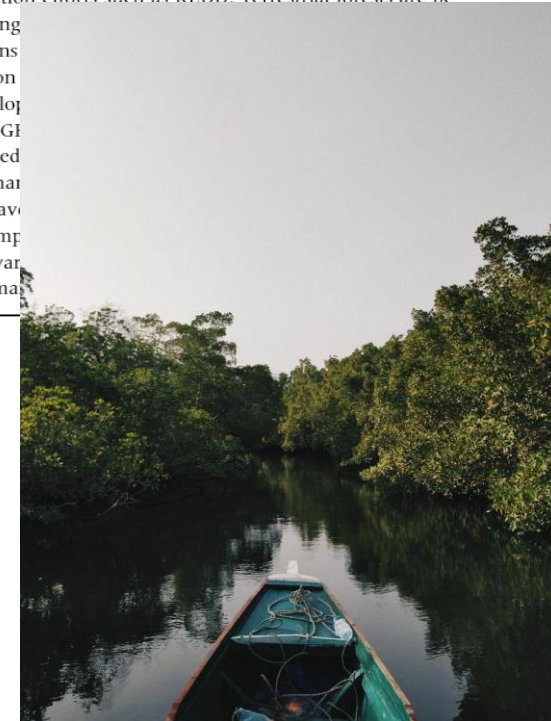
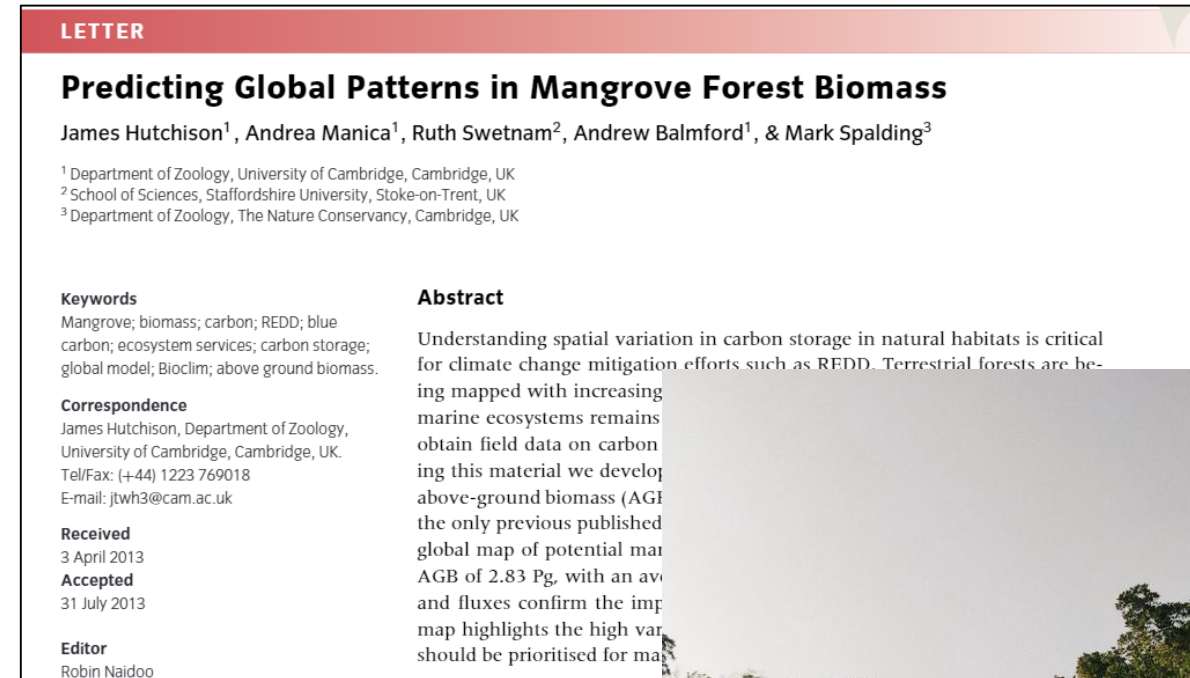
The screenshot displays the GeoServer web interface. On the left is a sidebar with navigation links: 'About & Status' (with a sub-link 'About GeoServer'), 'Data' (with a sub-link 'Layer Preview'), and 'Demos'. The main content area is titled 'Layer Preview' and includes a description: 'List of all layers configured in GeoServer and provides previews in various formats for each.' Below this is a pagination control showing 'Results 1 to 25 (out of 508 items)' with buttons for navigation. A table lists the layers, with columns for 'Type', 'Title', 'Name', and 'Common Formats'. The table contains 9 rows of data, all of which are soil data layers from the ISRIC SoilGrids dataset.

Type	Title	Name	Common Formats
☒	ACDWRB_M_ss_250m	sg250m:ACDWRB_M_ss_250m	OpenLayers KML
☒	AWCh1_M_sl1_250m	sg250m:AWCh1_M_sl1_250m	OpenLayers KML
☒	AWCh1_M_sl2_250m	sg250m:AWCh1_M_sl2_250m	OpenLayers KML
☒	AWCh1_M_sl3_250m	sg250m:AWCh1_M_sl3_250m	OpenLayers KML
☒	AWCh1_M_sl4_250m	sg250m:AWCh1_M_sl4_250m	OpenLayers KML
☒	AWCh1_M_sl5_250m	sg250m:AWCh1_M_sl5_250m	OpenLayers KML
☒	AWCh1_M_sl6_250m	sg250m:AWCh1_M_sl6_250m	OpenLayers KML
☒	AWCh1_M_sl7_250m	sg250m:AWCh1_M_sl7_250m	OpenLayers KML
☒	AWCh2_M_sl1_250m	sg250m:AWCh2_M_sl1_250m	OpenLayers KML

Ecosystem-specific carbon storage example:

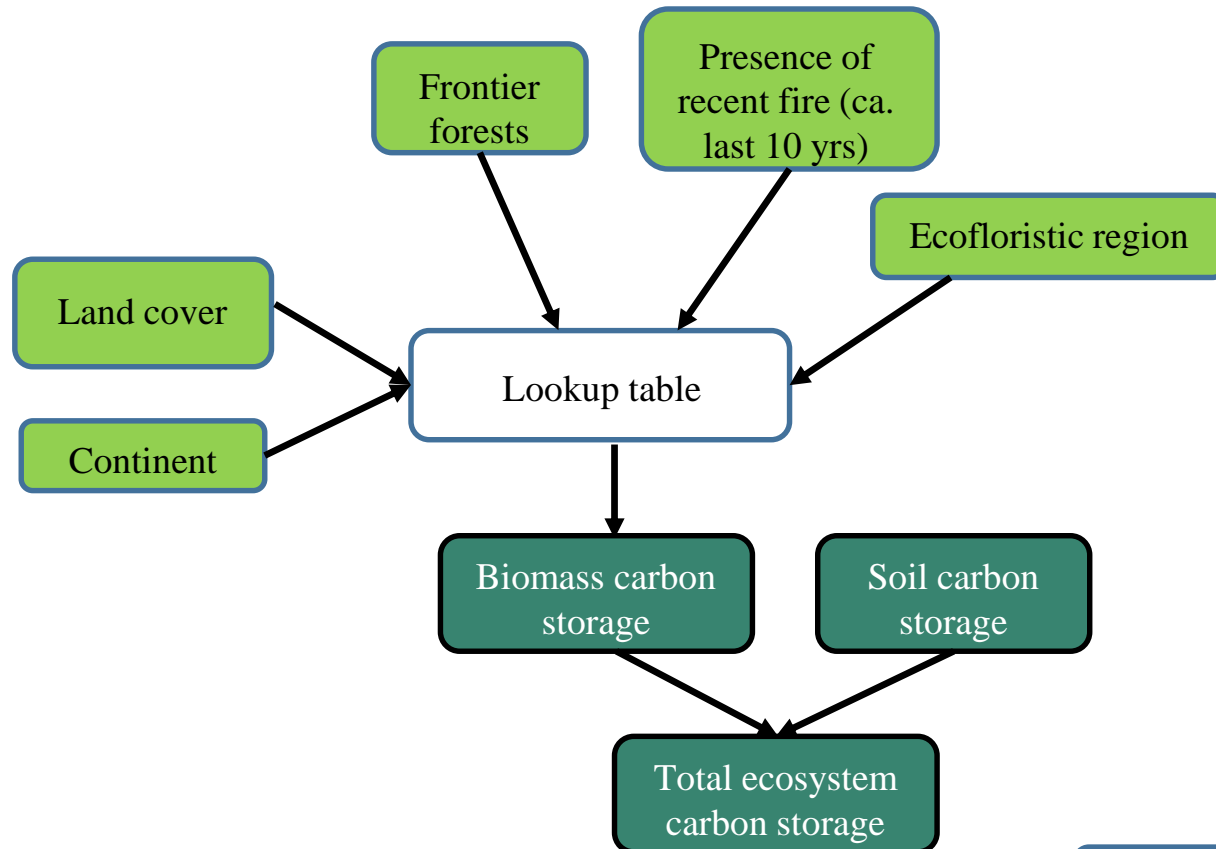
Mangroves (not yet available)

- Use a trusted ecosystem-specific model when available (could do the same for grasslands, wetlands, seagrass, etc.)
 - This one predicts aboveground biomass as function of climate, and belowground biomass based on aboveground

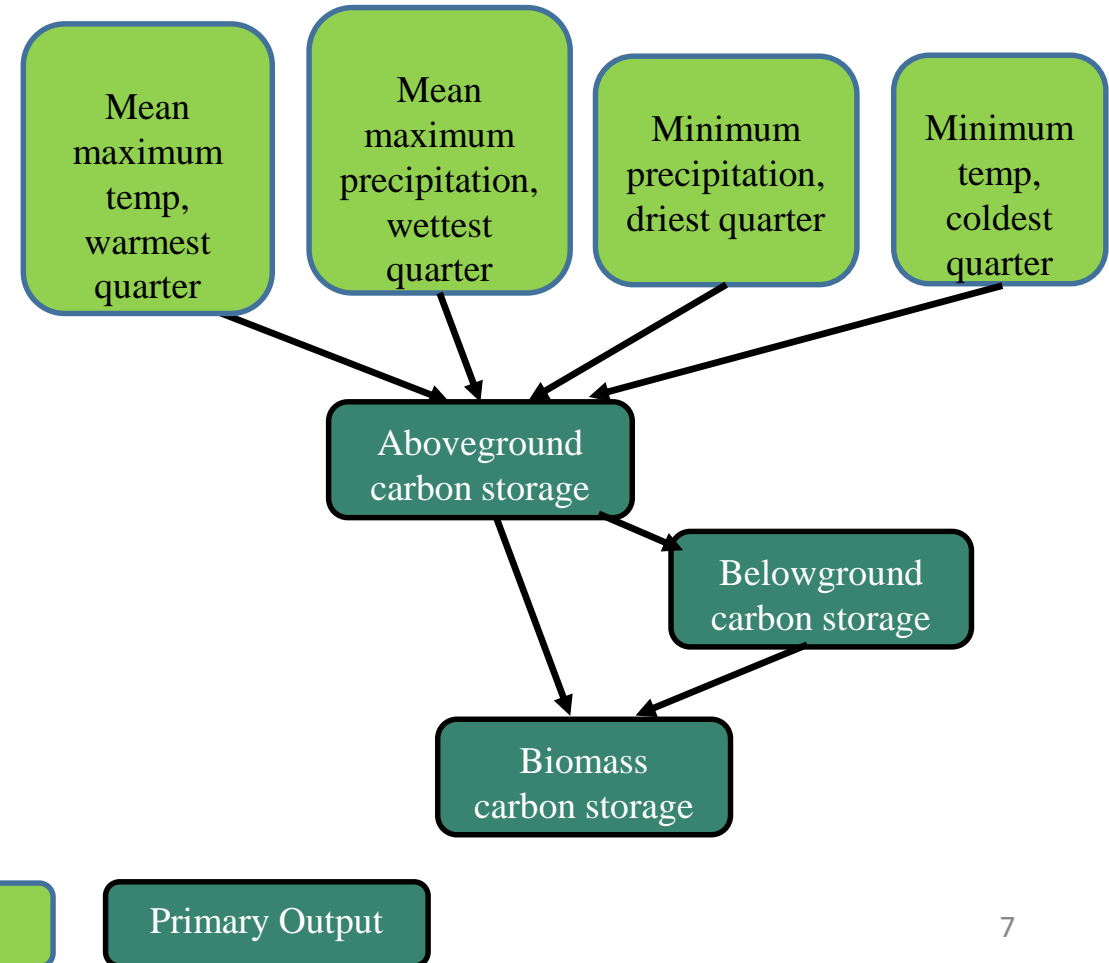


Flowchart

General Tier 1 terrestrial carbon storage model



Mangrove-specific carbon storage model



Primary input

Primary Output

Model code

```
@documented(carbon.global.totalstorage)
model chemistry:Organic chemistry:Carbon im:Mass in t/ha
  observing
    ecology:Vegetation chemistry:Carbon im:Mass in t/ha named vegetation_carbon_storage,
    soil:Soil chemistry:Organic chemistry:Carbon im:Mass in t/ha named soil_carbon_storage
  set to
    [vegetation_carbon_storage + soil_carbon_storage];

@documented(carbon.global.vegetation)
model ecology:Vegetation chemistry:Carbon im:Mass in t/ha
  observing
    landcover:LandCoverType named land_cover_type,
    presence of chemistry:Burned earth:Region named burned_land,
    geography:ContinentalRegion named continental_region,
    presence of im:Critical (conservation:Pristine ecology:Forest earth:Region) named frontier_forest,
    ecology:EcoFloristicRegionType named ecofloristic_region
  lookup (land_cover_type, ecofloristic_region, continental_region, frontier_forest, burned_land, ?)
  into VEGETATION_CARBON_TABLE;
```



Carbon lookup table

landcover	ecofloristicregion	continental_region	f_forest	burned	vegetationcarbon
landcover:BroadleafForest	ecology:TropicalRainforest	geography:AfricanRegion	*	false	200 ,
landcover:BroadleafForest	ecology:TropicalRainforest	geography:NorthAmericanRegion	*	false	193 ,
landcover:BroadleafForest	ecology:TropicalRainforest	geography:SouthAmericanRegion	*	false	193 ,
landcover:BroadleafForest	ecology:TropicalRainforest	geography:AsianRegion	*	false	180 ,
landcover:BroadleafForest	ecology:TropicalRainforest	geography:InsularAsianRegion	*	false	225 ,
landcover:BroadleafForest	ecology:TropicalRainforest	geography:AustralianRegion	*	false	199.5 ,
landcover:BroadleafForest	ecology:TropicalMoistDeciduousForest	geography:AfricanRegion	*	false	152 ,
landcover:BroadleafForest	ecology:TropicalMoistDeciduousForest	geography:NorthAmericanRegion	*	false	128 ,
landcover:BroadleafForest	ecology:TropicalMoistDeciduousForest	geography:SouthAmericanRegion	*	false	128 ,
landcover:BroadleafForest	ecology:TropicalMoistDeciduousForest	geography:AsianRegion	*	false	105 ,
landcover:BroadleafForest	ecology:TropicalMoistDeciduousForest	geography:InsularAsianRegion	*	false	169 ,
landcover:BroadleafForest	ecology:TropicalMountainSystem	geography:AfricanRegion	*	false	69 ,
landcover:BroadleafForest	ecology:TropicalMountainSystem	geography:NorthAmericanRegion	*	false	87 ,
landcover:BroadleafForest	ecology:TropicalMountainSystem	geography:SouthAmericanRegion	*	false	87 ,
landcover:BroadleafForest	ecology:TropicalMountainSystem	geography:AsianRegion	*	false	81 ,
landcover:BroadleafForest	ecology:TropicalDryForest	geography:InsularAsianRegion	*	false	122 ,

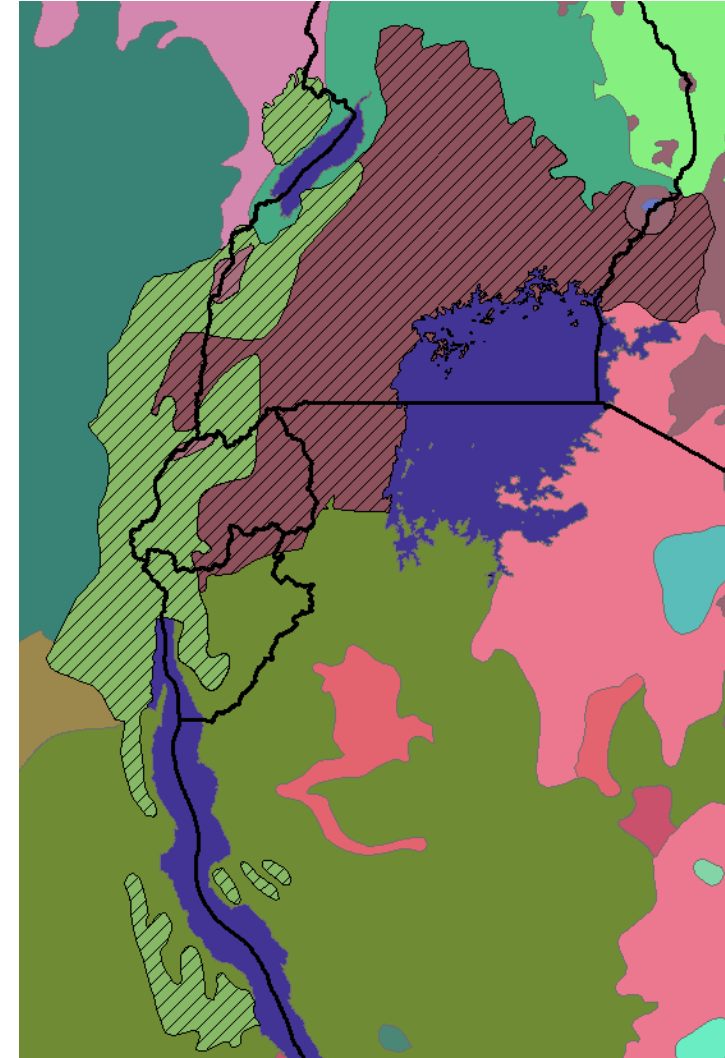


Examples of model customization

- Local data for land cover, recent fires, etc.
- Local carbon storage lookup tables:
 - Rwanda: Bagstad et al. (2018) – replaces the IPCC method entirely by providing local biomass & soil carbon data by land cover type
 - For all customizations, code in the conditions under which the customization should take place (Rwanda, East Africa, tropical rainforests, cities, temperate zones, etc...)



WWF Ecoregions; cross-hatched include ecosystems relevant from Rwanda carbon storage literature review



Example: Rwanda custom lookup table

```
model local:im:kbagstad:af.rw.landcover:rwanda_landcover_servir_2010
  as landcover:LandCoverType classified into
    landcover:ClosedMixedForest      if 1,
    landcover:OpenMixedForest         if 2,
    landcover:SparseTreeCover         if 3,
    landcover:TransitionalWoodlandScrub if 4,
    landcover:NaturalGrassland         if in (5 14),
    landcover:SparseHerbaceousCover   if 6,
    landcover:MoorAndHeathland         if 7,
    landcover:SparseShrubCover        if 8,
    landcover:PermanentCropland       if 9,
    landcover:ArableLand              if 10,
    landcover:Wetland                 if 11,
    landcover:WaterBody               if 12,
    landcover:ArtificialSurface       if 13;
```

```
define VEGETATION_CARBON_TABLE_RWANDA as {{
```

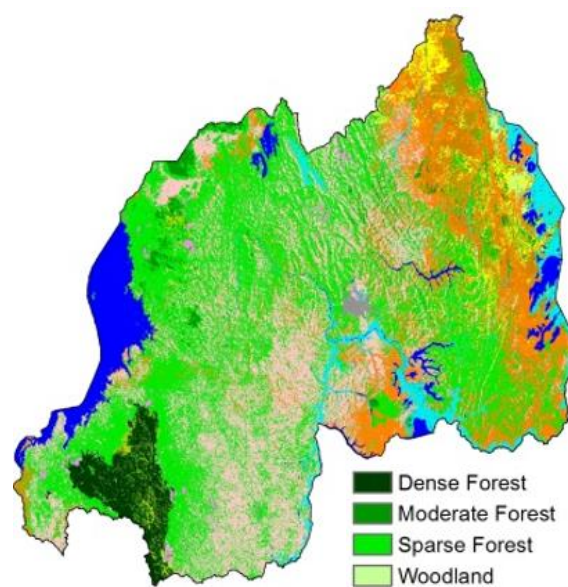
landcover	vegetationcarbon
landcover:ClosedMixedForest	230.5 ,
landcover:ClosedDeciduousBroadleafForest	230.5 ,
landcover:OpenMixedForest	160.1 ,
landcover:OpenDeciduousBroadleafForest	160.1 ,
landcover:DeciduousBroadleafForest	160.1 ,
landcover:EvergreenBroadleafForest	160.1 ,
landcover:SparseTreeCover	98.8 ,
landcover:TransitionalWoodlandScrub	94.2 ,
landcover:HeterogeneousAgriculturalLand	94.2 ,
landcover:NaturalGrassland	27.8 ,
landcover:SparseHerbaceousCover	27.8 ,
landcover:MoorAndHeathland	60.7 ,
landcover:SparseShrubCover	60.7 ,
landcover:PermanentCropland	2.9 ,
landcover:ArableLand	2.9 ,
landcover:Wetland	72.7 ,
landcover:WaterBody	0 ,
landcover:ArtificialSurface	0 };

```
model ecology:Vegetation chemistry:Carbon im:Mass in t/ha
  observing
    landcover:LandCoverType named land_cover_type
  lookup (land_cover_type) into VEGETATION_CARBON_TABLE_RWANDA
  over space(urn = 'local:ariesteam-global-geography-biomes:im_ariesteam_global_geography_biomes_wwf_terr_ecos#eco_code=AT0101, AT1013, AT0721');
```

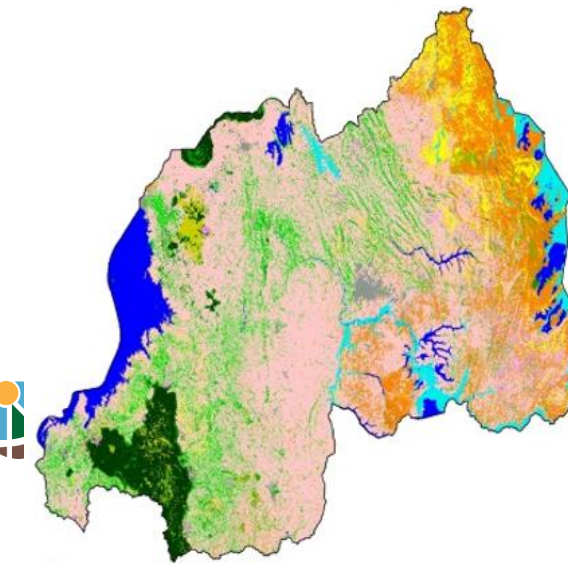
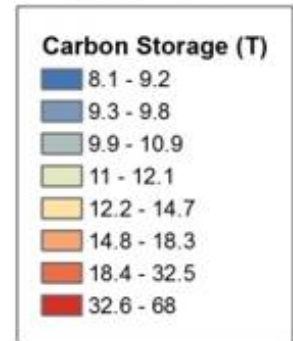
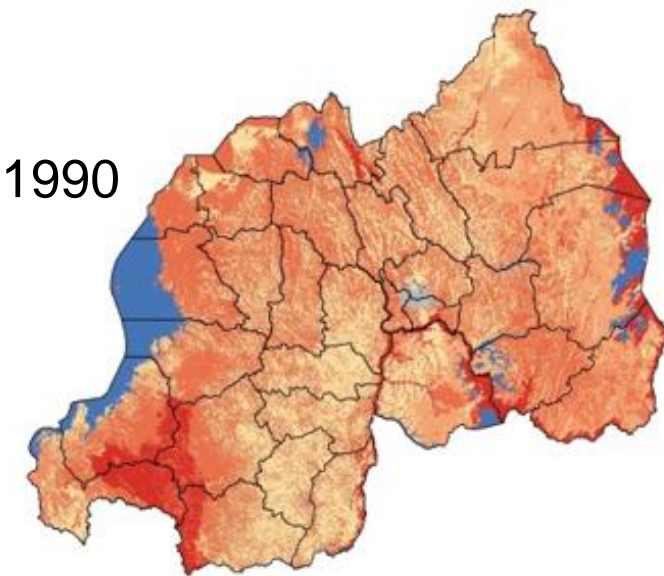
Example: Rwanda custom lookup table

```
define VEGETATION_TABLE_RWANDA as {{
```

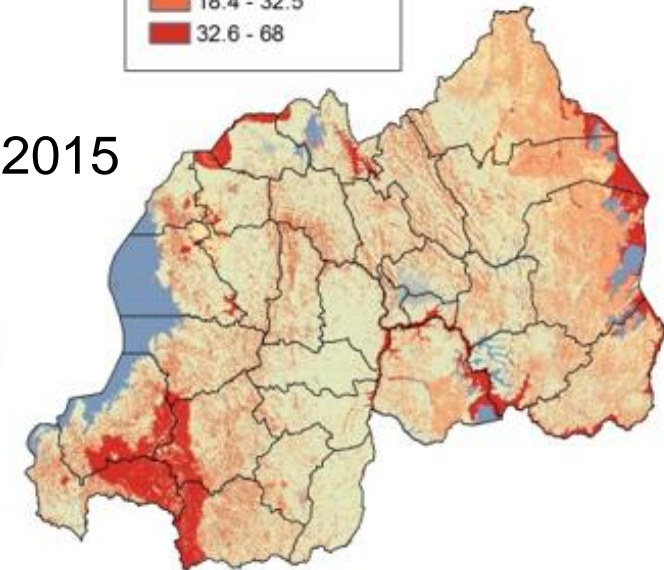
landcover	vegetationcarbon
landcover:ClosedMixedForest	230.5 ,
landcover:ClosedDeciduousBroadleafForest	230.5 ,
landcover:OpenMixedForest	160.1 ,
landcover:OpenDeciduousBroadleafForest	160.1 ,
landcover:DeciduousBroadleafForest	160.1 ,
landcover:EvergreenBroadleafForest	160.1 ,
landcover:SparseTreeCover	98.8 ,
landcover:TransitionalWoodlandScrub	94.2 ,
landcover:HeterogeneousAgriculturalLand	94.2 ,
landcover:NaturalGrassland	27.8 ,
landcover:SparseHerbaceousCover	27.8 ,
landcover:MoorAndHeathland	60.7 ,
landcover:SparseShrubCover	60.7 ,
landcover:PermanentCropland	2.9 ,
landcover:ArableLand	2.9 ,
landcover:Wetland	72.7 ,
landcover:WaterBody	0 ,
landcover:ArtificialSurface	0 }};



1990

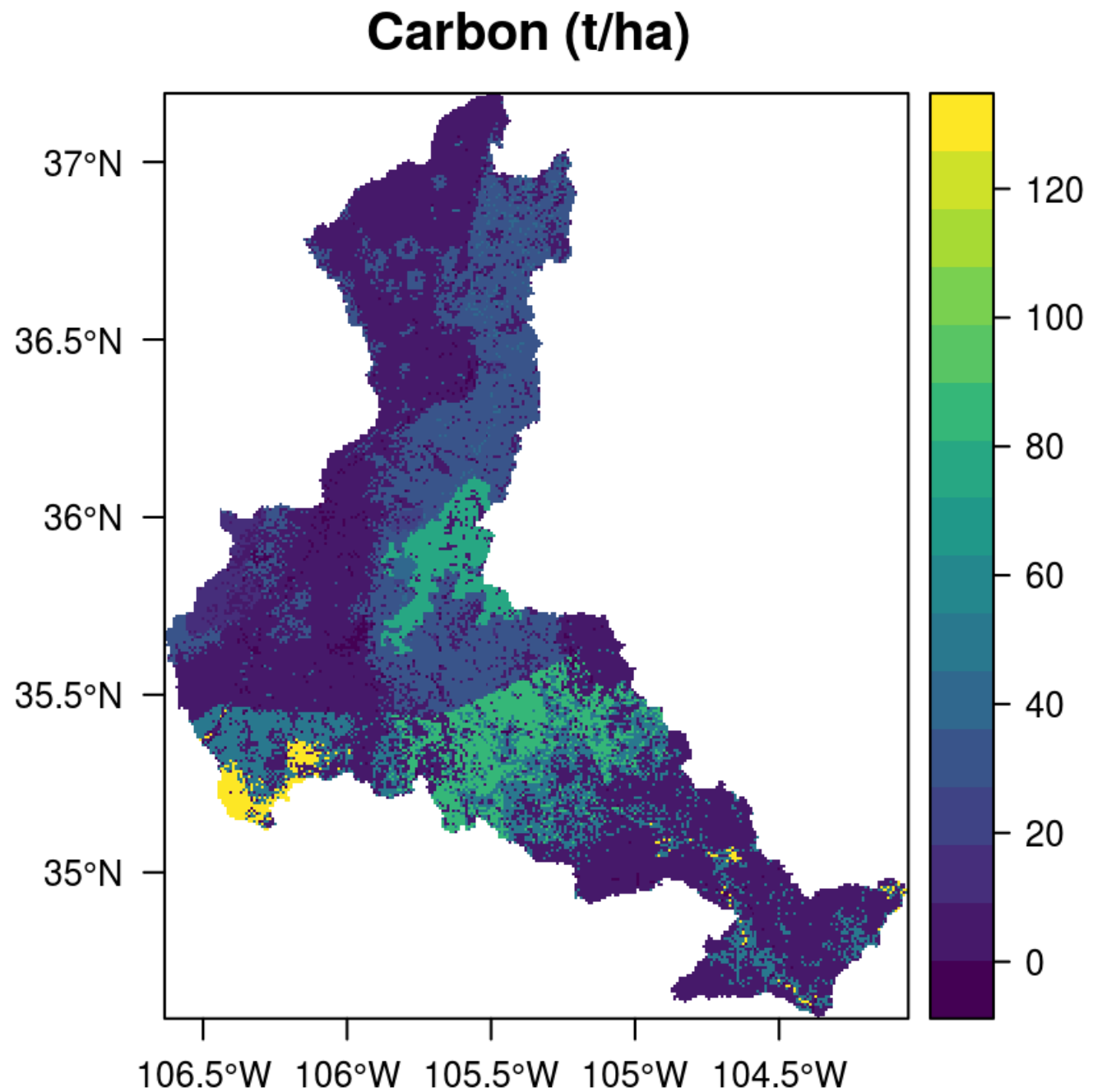


2015



Example: Santa Fe, NM

Ruesch & Gibbs
(2008) lookup table
method



About those land cover types...

Data source

SERVIR

SERVIR

ESA-CCI

GlobeLand

SERVIR-Rw

Dense fores

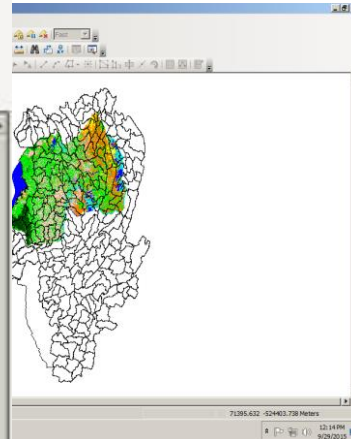
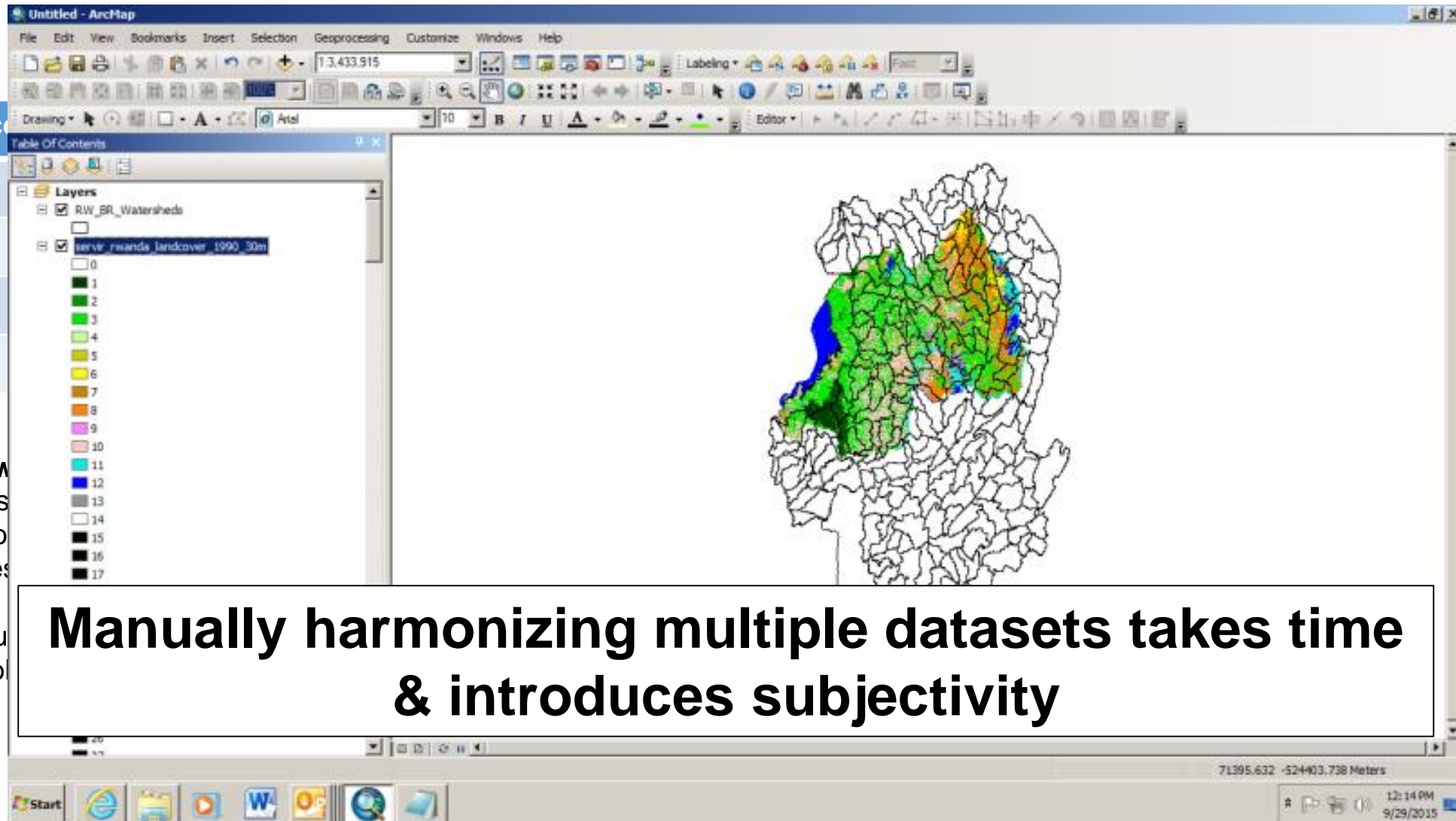
Moderate fo

Sparse fores

Woodland

Closed shrub

Open shrub



About those land cover types...

```
(NaturalVegetation has children
  ( Forest
    has children
      ( BroadleafForest with metadata { im:corine-encoding 311 im:nlcd-1992-encoding 41 im:nlcd-2001-encoding 41 }
        has children
          ( EvergreenBroadleafForest with metadata { im:cci-encoding 50 }
            ),
          ( DeciduousBroadleafForest with metadata { im:cci-encoding 60 im:globcover-encoding 40 }
            has children
              ( ClosedDeciduousBroadleafForest with metadata { im:cci-encoding 61 im:globcover-encoding 50 })),
```

We're working on ways to cross-walk common land cover types using semantics, but it's complicated

```

    ),
    ( MixedForest with metadata { im:corine-encoding 313 im:cci-encoding 90 im:nlcd-1992-encoding 43 im:nlcd-2001-encoding 43 im:globcover-encoding 100 } ),
    ( ConiferousForest with metadata { im:corine-encoding 312 im:nlcd-1992-encoding 42 im:nlcd-2001-encoding 42 }
      has children
        ( EvergreenConiferousForest with metadata { im:cci-encoding 70 im:globcover-encoding 90 }
          has children
            ( ClosedEvergreenConiferousForest with metadata { im:globcover-encoding 70 im:cci-encoding 71 } ),
            ( OpenEvergreenConiferousForest with metadata { im:cci-encoding 72 } )
          ),
        ( DeciduousConiferousForest with metadata { im:cci-encoding 80 }
          has children
            ( ClosedDeciduousConiferousForest with metadata { im:cci-encoding 81 } ),
            ( OpenDeciduousConiferousForest with metadata { im:cci-encoding 82 } )
          )
        )
    ),
    ( ScrubHerbaceousVegetation
      has children
        ( NaturalGrassland with metadata { im:corine-encoding 321 im:cci-encoding 130 im:nlcd-1992-encoding 71 im:nlcd-2001-encoding 71 im:globcover-encoding 140 } ),

```