Forest carbon assessment for REDD+ in the East & South Africa SERVIR region

"Exploring the variation in biomass in Zambia using ILUA I data"

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Lusaka, May 12-13th 2015

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SERVIR GLOBAL

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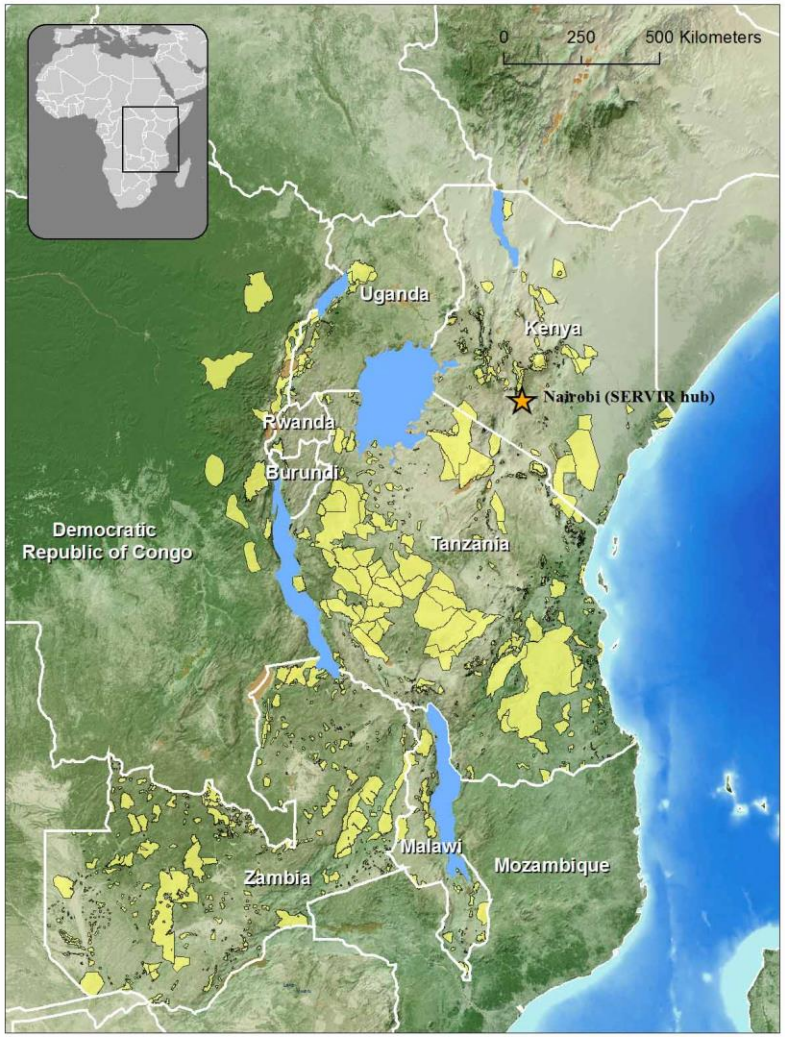
Forest Carbon Assessment for REDD+ in the East & South Africa SERVIR Region

Objectives

Our **Project demonstrates** how NASA Earth science products and derived models can assist East African countries, including the DR Congo, with their terrestrial carbon assessment and forest conservation strategy. The main focus of the project is:

- **Establishing forest carbon stock baselines and trends**, assessing historical and current carbon emissions from deforestation and degradation *(Gov/NGOs/Universities)*
- **Identifying corridors of high forest carbon stock** to be preserved and potential areas to be replanted in order to connect parks and protected areas and sustain biological diversity. *(Science WHRC-Implementation GOV/NGOs)*
- **Training and building capacity** in the use of maps, tools and models to be developed as part of this project *(SERVIR Hub, AMNH, JGI partners)*



Our project is assisting countries with developing strategies for reducing emissions from deforestation and forest degradation (REDD) to effectively decrease forest-based emissions.

Why explaining variation in tree biomass?

OBJECTIVES:

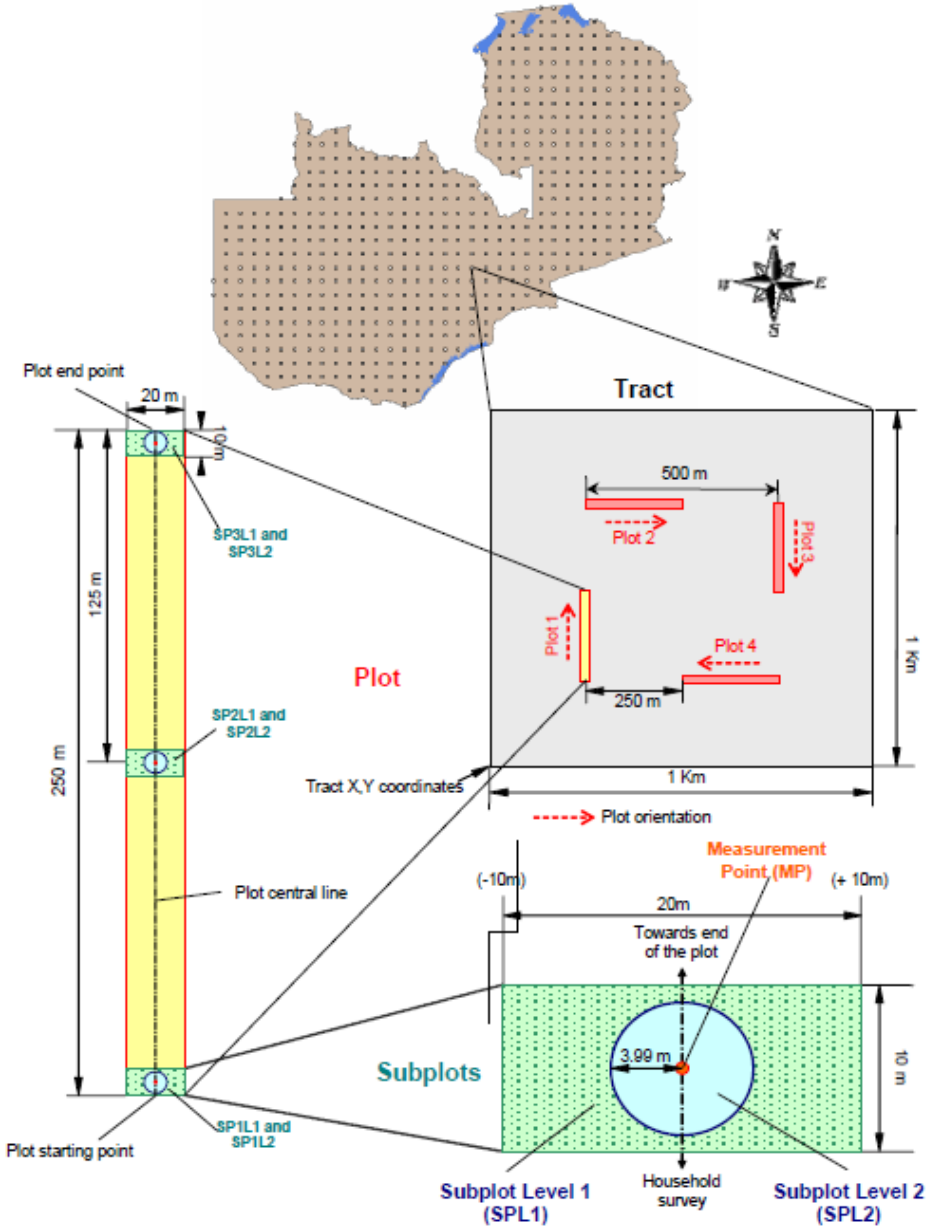
- Identify the key factors to explain the variation in forest tree biomass density looking at biophysical, social and biodiversity variables.

Results can contribute to plan intervention that takes into account this variation by reducing negative impacts or promoting practices that have a positive impacts on aboveground tree biomass.

Integrated Land Use Assessment I

SAMPLING DESIGN:

- 221 tracts out of 248 were accessed
- Biomass of each trees using Chave et al. (2014) allometric equation with 3 parameters
- Aggregating at different scale



Source: ILUA field manual (2005-2008)

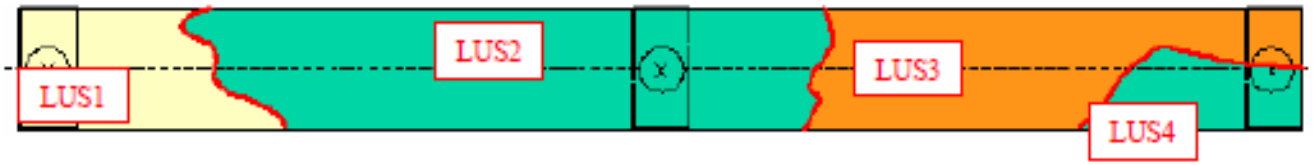
Integrated Land Use Assessment I

SAMPLING DESIGN:

4 different scales of analysis:

1. Tract level- Mean biomass density of 4 plots
2. Plot level- Biomass density (sum of tree biomass/ area)
3. Land Use type level- Biomass density (sum of tree biomass/ area)
4. Forest section level- (sum of tree biomass/ area)

Different scales were associated with a different set of variables



Example of the land-use/forest type sections distribution within a plot. Each tree measured was identified to belong to one land-use/forest type. Source: ILUA field manual (2005-2008).

Methods of Analysis

- Extraction of factors of influence: biodiversity index, climate variables, spatial variable
- Multiple regression analysis
- Variation partitioning
- Parametric and Non-parametric tests (Kruskral Wallis)

TRACT LEVEL

Factors tested:

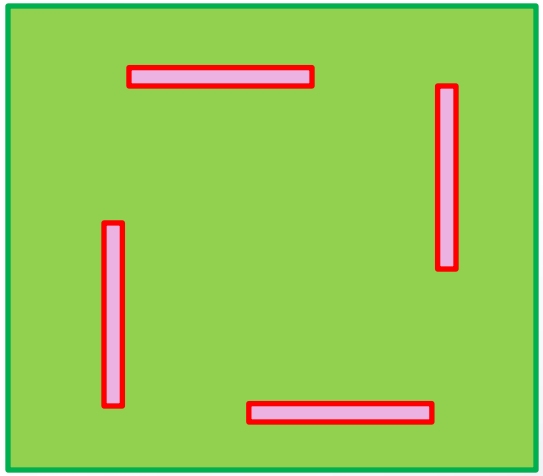
ENVIRONMENTAL FACTOR
- Presence-Absence of population
- Province
- Global Ecological Zone
- Elevation
- Population from household survey
- Distance to major town
- Total annual precipitation
- Mean minimum temperature
- Mean maximum temperature

LAND USE CATEGORY

BIODIVERSITY INDICES
- Species richness
- Shannon Entropy
- Simpson Index
- Shannon diversity number
- Simpson diversity number
- Pielou evenness
- Shannon evenness
- Simpson evenness

IDENTITY OF THE DOMINANT SPECIES (biomass)

SPATIAL VARIABLES from Moran Eigenvector Maps
- 71 positive spatial correlations

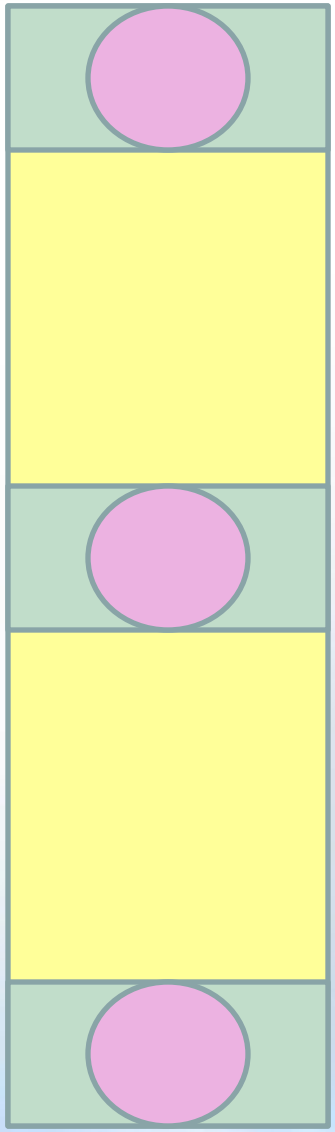


Tract

PLOT LEVEL

Factors tested:

ENVIRONMENTAL FACTOR
LAND USE CATEGORY
BIODIVERSITY INDICES
IDENTITY OF THE DOMINANT SPECIES (biomass)
SPATIAL VARIABLES from Moran Eigenvector Maps
    51 positive spatial correlations
BIOPHYSICAL VARIABLE in SUB-PLOTS
    Exposition
    Slope
    Relief
    Texture
    Drainage
    Soil Organic Matter

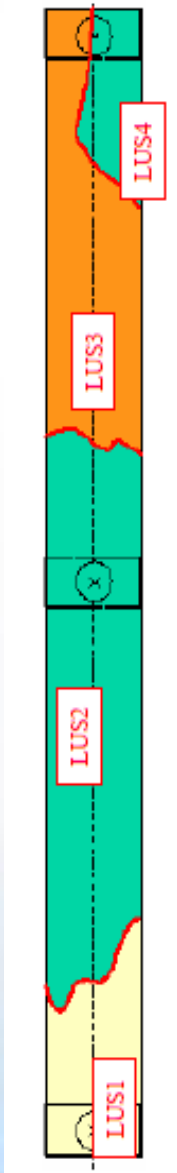


LAND USE TYPE LEVEL

Factors tested:

LAND USE CATEGORY
BIODIVERSITY INDICES
IDENTITY OF THE DOMINANT SPECIES (biomass)
MANAGEMENT CHARACTERISTICS

- Designation
- Land Tenure
- Fire Occurrence
- Fire Area
- Fire Type
- Tree Canopy Coverage



FOREST SECTION LEVEL

Factors tested:

LAND USE CATEGORY

BIODIVERSITY INDICES

IDENTITY OF THE DOMINANT SPECIES (biomass)

MANAGEMENT CHARACTERISTICS

STAND CHARACTERISTICS

- Stand Origin
- Stand Structure
- Shrub Coverage
- Shrub Height
- Management Plan
- Management Agreement
- Disturbances
- Timber Exploitation

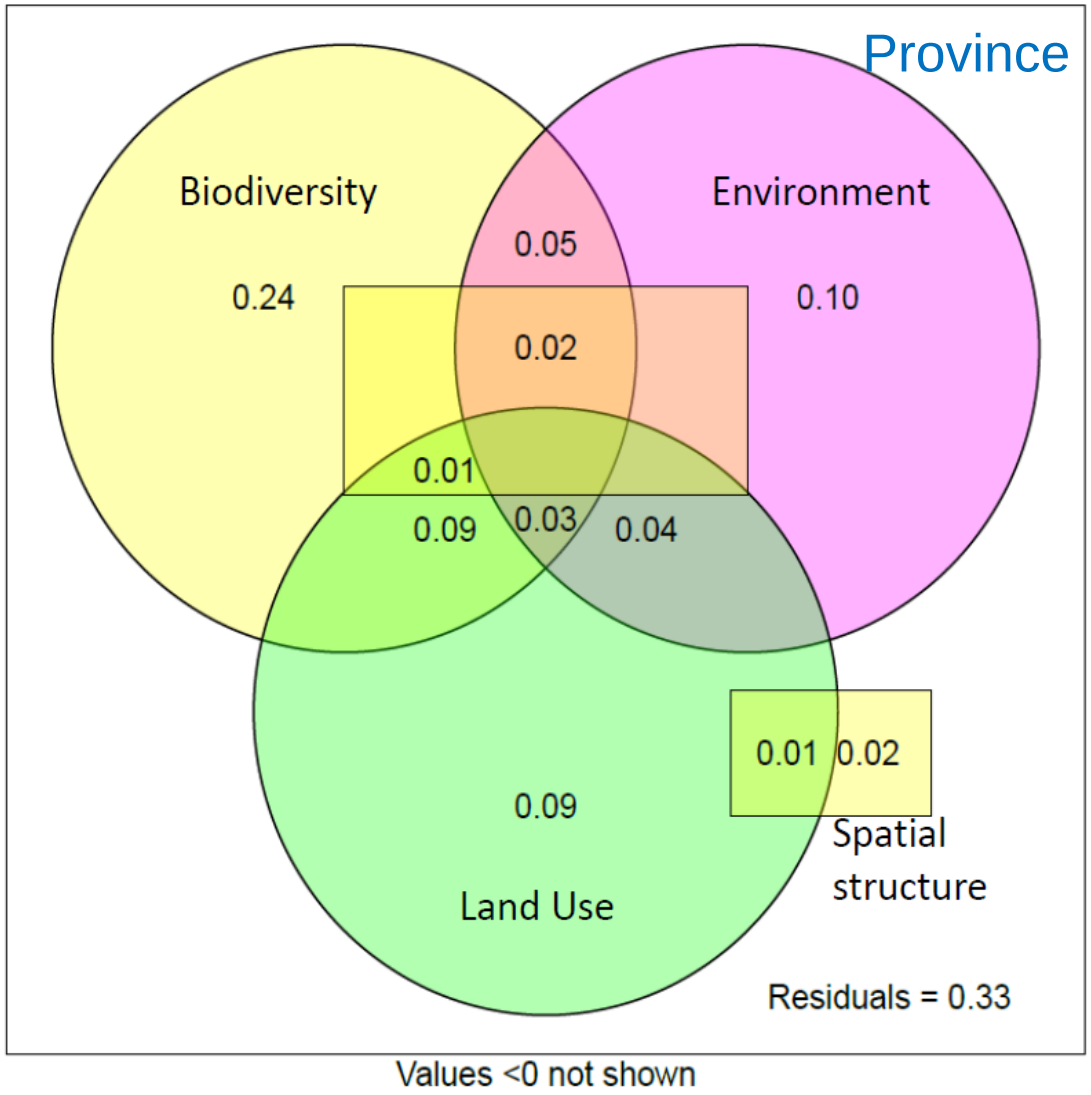
Preliminary results: TRACT

Table 1. Parsimonious multiple regression model of total above-ground tree biomass per tract in relation with explanatory variables after forward selection and reduction in collinearity (n = 198).

Variables	Coefficient	Std. Error	t value	Pr(>|t|)
(Intercept)	-10.59	2.64	-4.01	8.93E-05
Simpson evenness index	4.35	1.33	3.26	0.00132
Province- North-Western	1.64	0.38	4.35	2.29E-05
Province- Western	1.18	0.44	2.67	0.00838
Woody Grassland cc 5-10%	-0.42	0.09	-4.85	2.70E-06
Grassland	-0.43	0.13	-3.27	0.00131
Annual Crops	-0.34	0.08	-4.21	4.12E-05
Richness	0.06	0.02	4.13	5.54E-05
Difference of Pielou evenness (1-J)	18.63	2.79	6.68	2.89E-10
Simpson index	10.40	2.04	5.10	8.85E-07
Medium-scale spatial structure	-0.01	0.00	-2.60	0.01025
Broad-scale spatial structure	-0.01	0.00	-2.34	0.02061

Residual standard error: 1.279 on 178 degrees of freedom
Multiple R-squared: 0.7016, Adjusted R-squared: 0.6731
F-statistic: 24.61 on 17 and 178 DF, p-value: < 2.2e-16

Preliminary results: TRACT



Values <0 not shown

Biodiversity alone explains more of the variation in tree biomass density at the tract level

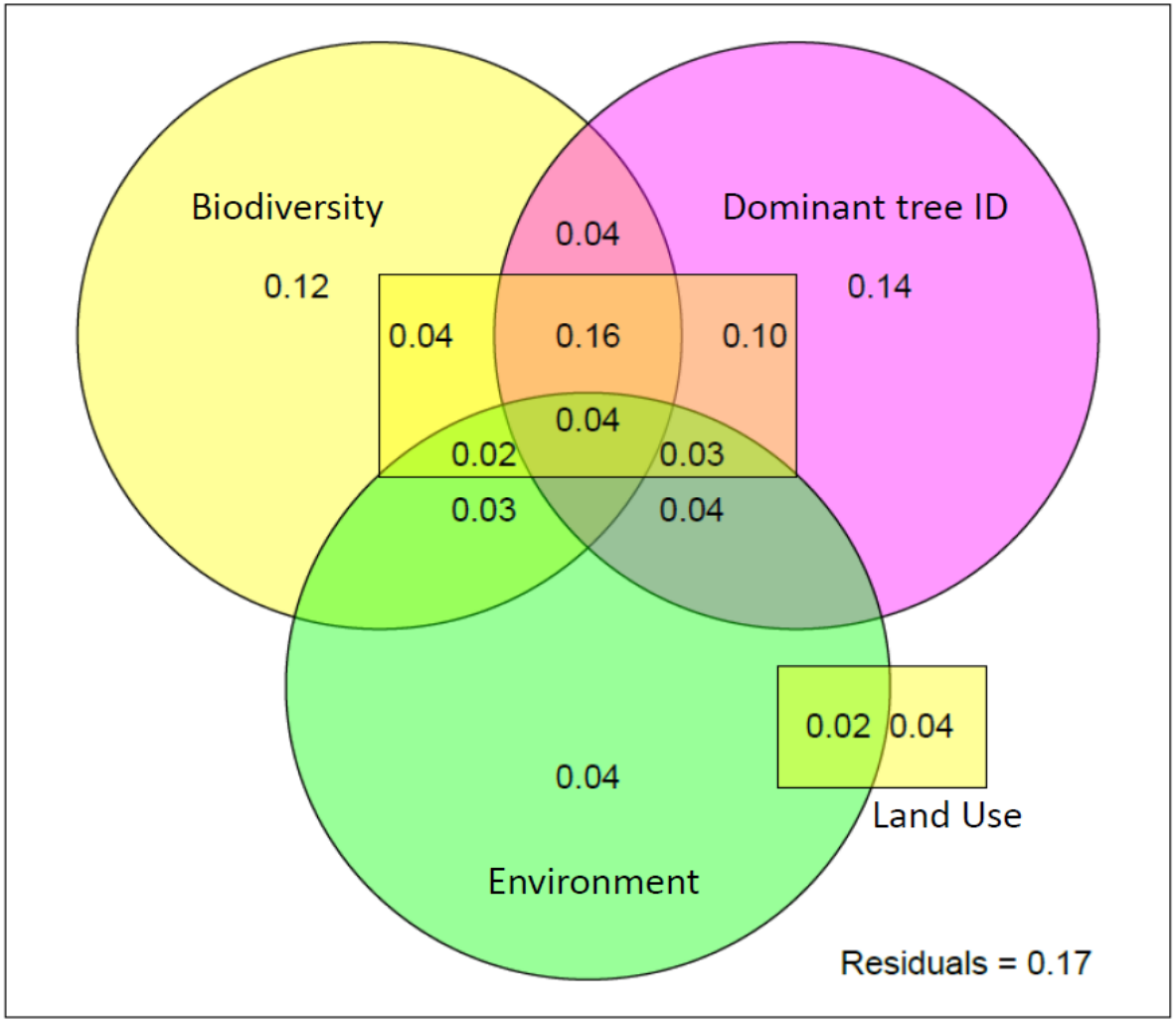
Preliminary results: PLOT

Table 2. Parsimonious multiple regression model of total above-ground tree biomass per plot in relation with explanatory variables after forward selection and reduction in collinearity (n = 798).

Variables	Coefficient	Std. Error	t value	Pr(>|t|)
(Intercept)	8.929	1.531	5.833	8.69E-09
Dominant ID$^{\alpha}$- Annona sp.	-1.311	0.437	-2.999	0.00281
Dominant ID- Azanza sp.	-1.452	0.535	-2.715	0.00681
Dominant ID- Brachystegia allenii	-1.417	0.672	-2.108	0.03543
Dominant ID- Euphorbia candelabrum	-1.517	0.667	-2.275	0.02324
Dominant ID- NoTree	-3.109	0.371	-8.391	3.18E-16
Simpson Evenness Index	-2.044	0.133	-15.36	< 2e-16
Shannon entropy index	0.456	0.043	10.608	< 2e-16
Province- Copperbelt	0.455	0.167	2.721	0.0067
Province- Eastern	-0.571	0.115	-4.973	8.50E-07
Province- North-Western	0.614	0.103	5.963	4.14E-09
Province- Northern	-0.074	0.095	-0.78	0.43584
Province- Southern	-0.446	0.112	-3.975	7.86E-05
Land Use- Shrubs and Woody Grassland	-0.474	0.079	-5.976	3.82E-09
Land Use- Grassland	-0.374	0.082	-4.56	6.16E-06
Land Use- Annual Crops	-0.266	0.064	-4.166	3.54E-05
Land Use- Fallows	-0.198	0.071	-2.789	0.00545
Land Use- Deciduous Forest	0.284	0.068	4.162	3.59E-05
Land Use- Semi-evergreen Forest	0.219	0.069	3.17	0.0016
Land Use- Evergreen and Other Forest lands	0.325	0.163	1.999	0.04605
Soil texture- Rock	-0.325	0.156	-2.079	0.03798
Altitude	-0.002	0.000	-6.111	1.74E-09
Average maximum temperature	-0.118	0.043	-2.771	0.00576

Residual standard error: 0.5713 on 630 degrees of freedom
Multiple R-squared: 0.8577, Adjusted R-squared: 0.826
F-statistic: 27.11 on 140 and 630 DF, p-value: < 2.2e-16

Preliminary results: PLOT



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Biodiversity and the dominant tree alone explains more of the variation in tree biomass density at the plot level; Combination of biodiversity, dominant tree & land use explains the highest share

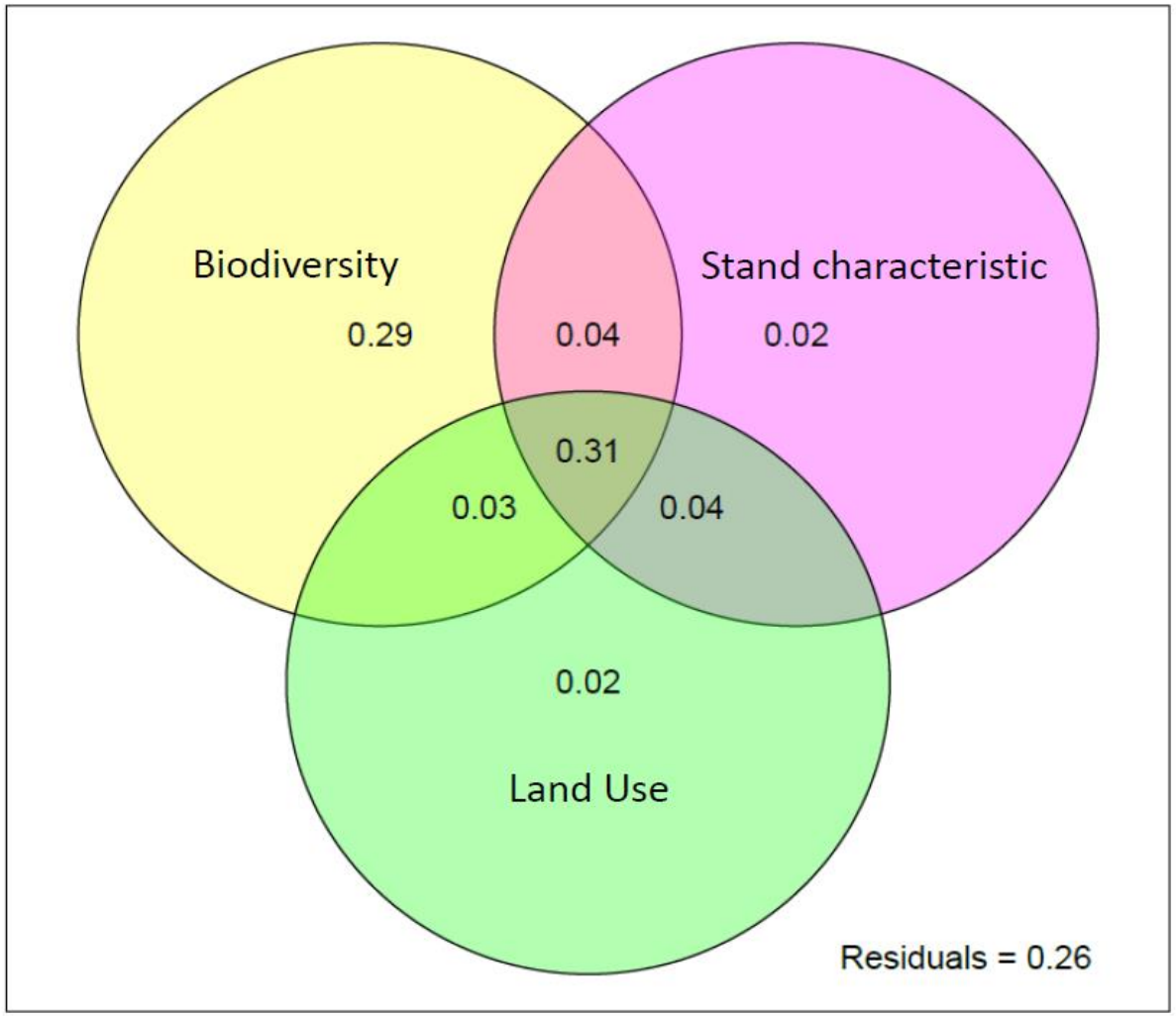
Preliminary results: LAND USE

Table 3. Parsimonious multiple regression model of total above-ground tree biomass per Land Use sections in relation with explanatory variables after forward selection and reduction in collinearity (n = 948).

Variables	Coefficient	Std. Error	t value	Pr(>|t|)
(Intercept)	5.18E-01	2.72E-01	1.905	5.70E-02
Shannon entropy index (H)	3.44E-01	5.86E-02	5.87	6.09E-09
Land Use- Shrubs	-7.40E-01	3.26E-01	-2.273	0.023237
Land Use-Woody Grassland cc:5-10%	-5.11E-01	2.68E-01	-1.903	0.057366
Tree Canopy Cover 40-70%	4.77E-01	1.35E-01	3.524	4.47E-04
Tree Canopy Cover > 70%	6.96E-01	1.67E-01	4.173	3.28E-05
Shannon evenness index	9.86E+00	6.89E-01	14.318	< 2e-16
Simpson evenness index	-8.86E+00	6.59E-01	-13.457	< 2e-16
Fire Area (m2)	-3.47E-05	1.50E-05	-2.31	0.021102

Residual standard error: 0.8157 on 925 degrees of freedom.
Multiple R-squared: 0.7408, Adjusted R-squared: 0.7347.
F-statistic: 120.2 on 22 and 925 DF, p-value: < 2.2e-16.

Preliminary results: LAND USE



Biodiversity alone explains uniquely explains 29% of the variation; The conjunction of stand characteristics, biodiversity and land use explains 31% of variation in tree biomass density

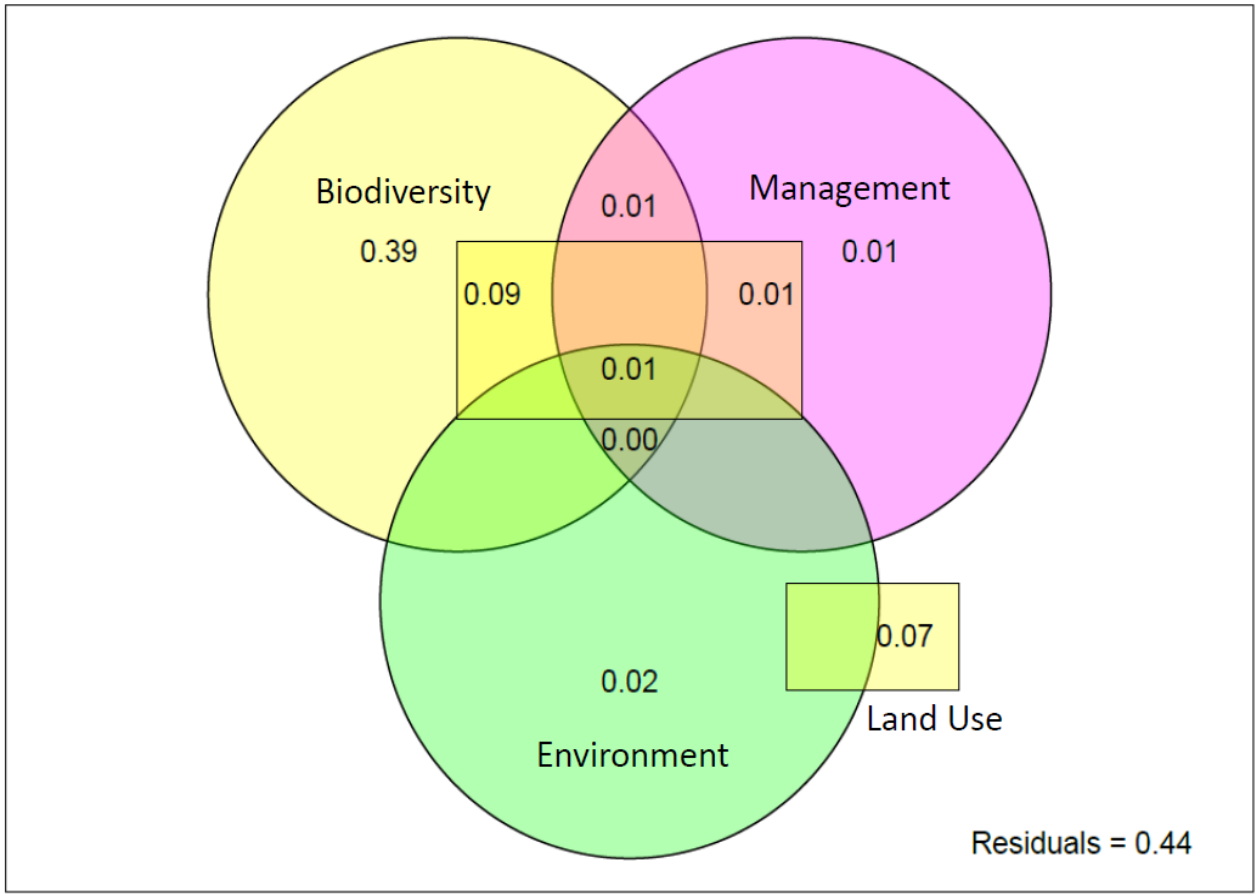
Preliminary results: FOREST

Table 4. Parsimonious multiple regression model of total above-ground tree biomass per Forest and Other wooded land sections in relation with explanatory variables after forward selection and reduction in collinearity (n = 557).

Variables	Coefficient	Std. Error	t value	Pr(>|t|)
(Intercept)	5.99E+00	3.43E-01	17.467	< 2e-16
Shannon evenness index	-6.86E+00	1.14E+00	-6.017	3.30E-09
Simpson evenness index	3.44E+00	9.31E-01	3.689	0.000248
Shannon entropy index	1.21E+00	1.33E-01	9.139	< 2e-16
Land Use- Shrubs	-1.37E+00	2.72E-01	-5.038	6.46E-07
Land Use-Woody Grassland cc: 5-10%	-1.21E+00	2.42E-01	-4.98	8.61E-07
Simpson index	-1.70E+00	3.79E-01	-4.498	8.40E-06
Fire Area (m2)	-6.94E-05	1.58E-05	-4.39	1.37E-05
Shrub Coverage 10-40%	-2.45E-01	9.21E-02	-2.662	0.008005
Management Plan- Traditional	-2.30E-01	8.47E-02	-2.712	0.00691
Management Agreement- Not known	1.61E-01	8.16E-02	1.97	0.049354

Residual standard error: 0.6482 on 535 degrees of freedom
Multiple R-squared: 0.5781, Adjusted R-squared: 0.5615
F-statistic: 34.9 on 21 and 535 DF, p-value:
<2.2e-16

Preliminary results: FOREST



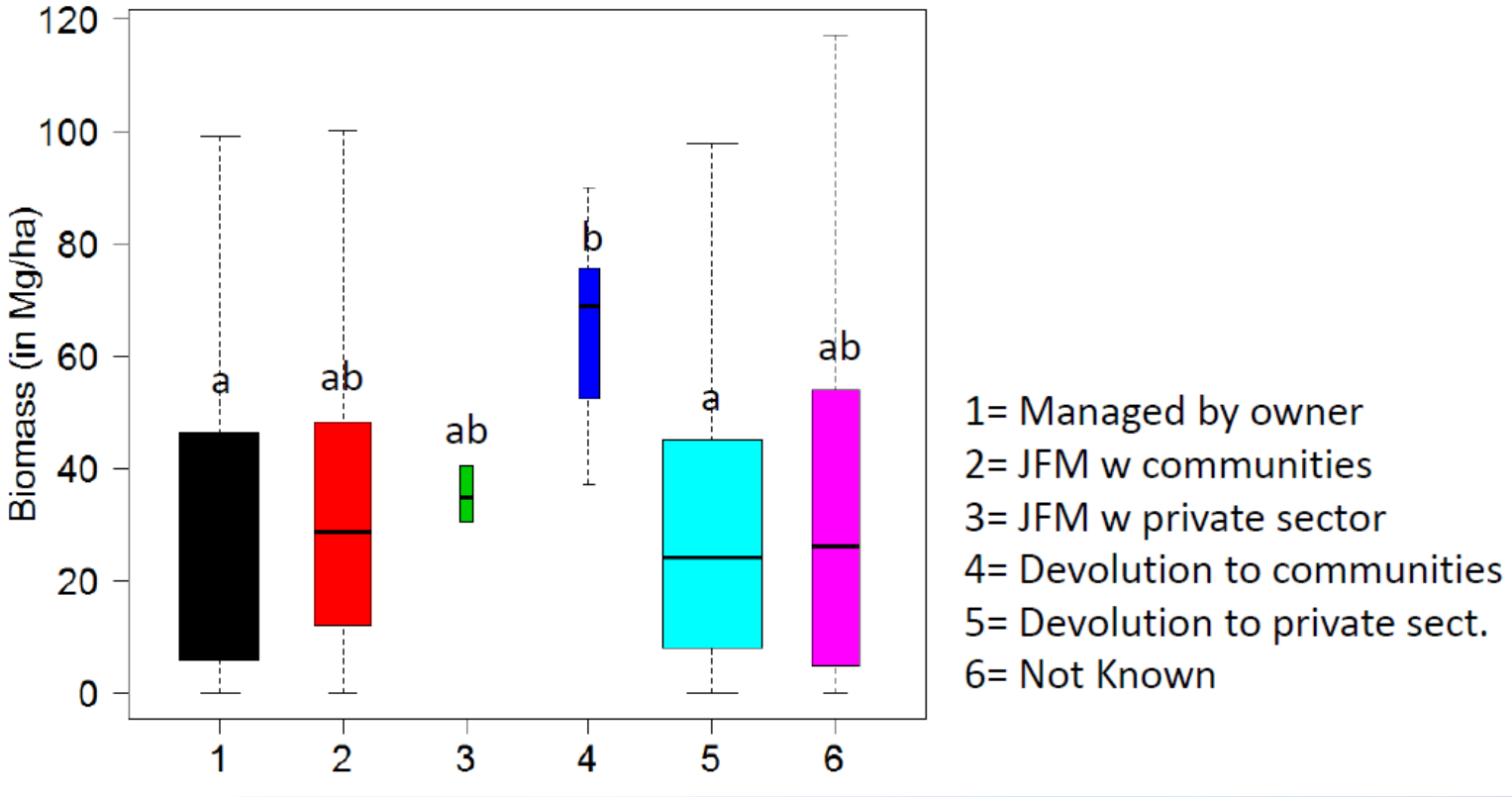
Values <0 not shown

Biodiversity alone explains uniquely explains 39% of the variation; and even more when including the share for land use

Types of management agreement

Forests devolved to communities hold significantly more biomass than other types of managed forest

Kruskal-Wallis chi-squared = 16.7433, df = 5, p-value = 0.005



Boxplot of the biomass density in forest lands under different types of management agreements

Synthesis of results

- **BIODIVERSITY** stands out as one of most important factors to explain variation in tree biomass density
- **LAND USE** contributes at all level but in conjunction with other factors

Biodiversity protection is included in the REDD+ safeguards: *promote actions that are consistent with the conservation of natural forests and biological diversity*

Biodiversity protection and reducing emissions have special synergy in Zambia