Digging down to understand deforestation’s impacts on ecosystem services from soil.

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Aim: To influence the development and implementation of international ecosystem service payment schemes (e.g. REDD+) in the interests of poverty alleviation.
Slash & Burn Agriculture in E Madagascar

Upland Rice Yields t/ha

Indigenous Category: Ala Vadikatana Savoka / Dedeka Roranga Tany Maty

Fallow cycles after deforestation: 1st 2nd 3rd 4th 5th 6th 7th

Slash & Burn Agriculture in E Madagascar

SOILS AND LAND PLAY A FUNDAMENTAL AND CROSS-CUTTING ROLE IN ACHIEVING THE SDGs*

- **SDG 1:** End poverty
- **SDG 2:** Achieve food security
- **SDG 3:** Healthy lives for all
- **SDG 5:** Gender equality
- **SDG 6:** Water for all
- **SDG 7:** Energy for all
- **SDG 11:** Cities
- **SDG 13:** Combat climate change
- **SDG 15:** Protect terrestrial ecosystems

**Basic soil and land services that must be protected:**
- Carbon storage and contribution to climate change mitigation
- Water regulation
- Nutrient provision and cycling for crop/forest growth and other ecosystems
- Maintaining biodiversity

Changes in land use and cover, resulting in sustainable use
- Halting deforestation, land and soil degradation, and biodiversity loss
- Preventing soil sealing

Promoting sustainable agriculture and food systems
- Increased production and consumption of biomass for food, feed, fibre, and fuel
Study sites

- **ZOI 1** - Carbon Only
- **ZOI 2** - 11/21 sites
- **ZOI 3** - 9/9 sites
- **ZOI 4** - 0/15 sites
Biomass

BAU sites

Intervention sites

Time since closed canopy forest disturbance

Closed > < Tree Fallow
Dominated by trees, usually only one or two cycles

< < Shrub Fallow
Dominated by shrubs, declining biomass

< < Degraded Land
Dominated by grasses.

n=20 Sites
There will be 45
WP2: Hydrology Sampling
WP₄: Carbon Sampling
Site Level Sampling Design

Legend:
- * Entomology (small) and Herpetology (bucket) pitfall traps
- ▢ Butterfly traps
- ▲ Carbon soil samples
- — Carbon measurement circles
- — Nocturnal Herpetology transects
- ■ Leaf litter samples
- ◆ A, Soil cores, soil biodiversity and infiltration methods
- ▪ B, A + dye experiment

Dimensions given in metres
Hydrological Variables

- Transect aspect Degrees
- Transect slope Degrees
- Hydraulic Conductivity (Ksat) 0-10 cm [mm/hr]
- Bulk density [g/cm³] 12.5 to 17.5 cm
- Porosity [%] 12.5 to 17.5 cm
- Moisture content at field capacity [%] 12.5 to 17.5 cm
- Drainable porosity [%] 12.5 to 17.5 cm
- Root/litter layer cm above the soil surface
- Max. rooting depth cm below the soil surface
Below ground

Hydrology

Soil Surface Infiltration (m/day)

Carbon

Carbon Stock (MgC/ha⁻¹)

Biodiversity

No. of Soil Invertebrates

Land Use Codes
CC = Closed Canopy
TF = Tree Fallow
SF = Shrub Fallow
Deg = Degraded
RF = Reforested
When we have a lot of variables, we can use Multi-variate statistics to explore relationships between variables.
Example similarity matrix (20 sites x 20 sites)
Envl = Eclidian Distance
Bio = Bray Curtis Distance
Principal Component Analysis (PCA)

Determining principal components of the variation within individual multi-variate data sets

NOT A TEST OF SIGNIFICANCE
Principal Component Analysis Carbon (4 Variables)

**EIGENVECTORS**

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<th>PC1</th>
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<td>0.574</td>
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<td>-0.660</td>
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Principal Component Analysis Carbon (4 Variables)

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Principal Component Analysis Carbon (4 Variables)

EIGENVECTORS

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<tr>
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PC1 (51%) 
PC2 (29%)
Principal Component Ordination (PCO)

CAN USE PERMANOVA TO TEST FOR DIFFERENCES BETWEEN GROUPS AND INTERACTIONS
**Principal Component Ordination Carbon (4 Variables)**

**PERMANOVA RESULT**

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<thead>
<tr>
<th>Source</th>
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<th>MS</th>
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**LandUse**
- Closed Canopy
- Tree Fallow
- Shrub Fallow
- Degraded
- Reforested

**Normalise Resemblance: D1 Euclidean distance**
### Principal Component Ordination Hydrology (9 Variables)

**PERMANOVA RESULT**

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**LandUse**

- Closed Canopy
- Tree Fallow
- Shrub Fallow
- Degraded
- Reforested

**Normalise Resemblance: D1 Euclidean distance**
### Principal Component Ordination Biodiversity (17 Variables)

#### PERMANOVA RESULT

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<tr>
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Total 19 7023

#### LandUse

- Closed Canopy
- Tree Fallow
- Shrub Fallow
- Degraded
- Reforested

Transform: Square root
Resemblance: S17 Bray-Curtis similarity
Exploring relationships between two multi-variate data sets

A) Test (“Relate”) Patterns in 2 Similarity Matrices
Example similarity matrix (20 sites x 20 sites)

*Envl = Eclidian Distance*

*Bio = Bray Curtis Distance*
Exploring relationships between two multi-variate data sets

A) Test ("Relate") Patterns in 2 Similarity Matrices
B) Distance Based Linear Models of Biological Data from Physical Data
Distance Based Linear Model: Relationship between Biodiversity and Carbon

Spearman’s Rank Correlation
Rho 0.267 (weak)
Significance 0.04% (significant)

Three variables identified as significant individual predictors

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<thead>
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Best model is a 1 variable model including
SOC 0-30  Trial  AIC=138.63

Spearman’s Rank Correlation
Rho 0.267 (weak)
Significance 0.04% (significant)
Distance Based Linear Model: Relationship between Biodiversity and Hydrology

Spearman’s Rank Correlation
Rho 0.224 (weak)
Significance 1.2% (significant)

Only one of 9 variables identified as significant individual predictor
Max. rooting depth cm below the soil surface \( P=0.003 \)

Best model is a 2 variable model including
Bulk density [g/cm³] 12.5 to 17.5 cm
Max. rooting depth cm below the soil surface \( AIC = 115.19 \)
Annual Report: The importance of soils and soil processes is being recognised in a growing number of projects.
Species loss as a driver of global environmental change
Next steps

▪ Include more sites (from 20 to 45)
▪ Account for spatial autocorrelation
▪ Split sites into degrading/recovering
▪ Explore above <> below ground relationships
▪ Include more carbon variables (e.g. dead wood)
▪ Higher resolution on biodiversity (meta-genomics)
▪ Functional diversity
Acknowledgements