# Estimating ecosystem carbon stocks under different land-use and land-use changes at tropical forest margins-Developing simple models

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# Methodology

- Deriving simple relationships of carbon stocks with climate and soil variables under different LU/LU changes by

    1. Using secondary data (from literature)

    2. Using a process-based model (PALM)

# Secondary data

| Country | Location | Landuse (age) | MAT (°C) | MAP (mm) | Altitude (m) | Clay (%) | References |
|---|---|---|---|---|---|---|---|
| Colombia | Porce | PF, SF(8) | 22.70 | 2078 | 900-1500 | | Sierra et al.(2007); Sierra et al. (2009) |
| Brazil | Rondônia/ Santa Barbara | PF; SC (1); SF 6); SF (12); P (14) | 25.2 | 2354 | | 27, 51,16, 44, 23 | Hughes (2002); Guild (1998) |
| Peru | Manu National park | PF | 11.0 | 2200 | 3345 | | Gibbon et al. (2010); Zimmermann et al. (2010); Malhi et al. (2004) |
| | | P | 11.0 | 2200 | 3540 | | |
| China | Menglun | PF | 21.70 | 1539 | 730 | | Lü et al. (2010) |
| | Mengla | PF | 21.70 | 1539 | 581 | | |
| | Manyang | PF | 21.70 | 1539 | 643 | | |
| Mexico | Veracruz/ (LTBS) | PF ; P (8, 9, 33); C (5,32,45) | 27.0 | 4700 | | | Hughes et al. (2000) |
| Venezuela | Cero El Coco | PF | 27.00 | 800 | 130 | | Delaney et al. (1997) |
| | Caimital& Ticoporo | PF | 26.00 | 1500 | 150 | | |
| | Rio Grande& KM92 | PF | 25.50 | 2850 | 210-270 | | |
| | Carbonera | PF | 15.00 | 1480 | 2310-2450 | | |
| | Mucuy | PF | 10.50 | 1970 | 2640-3000 | | |

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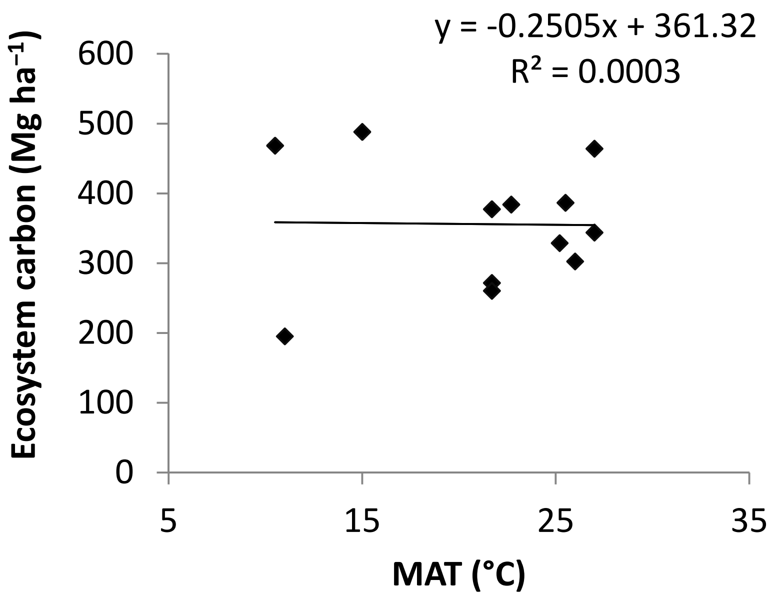
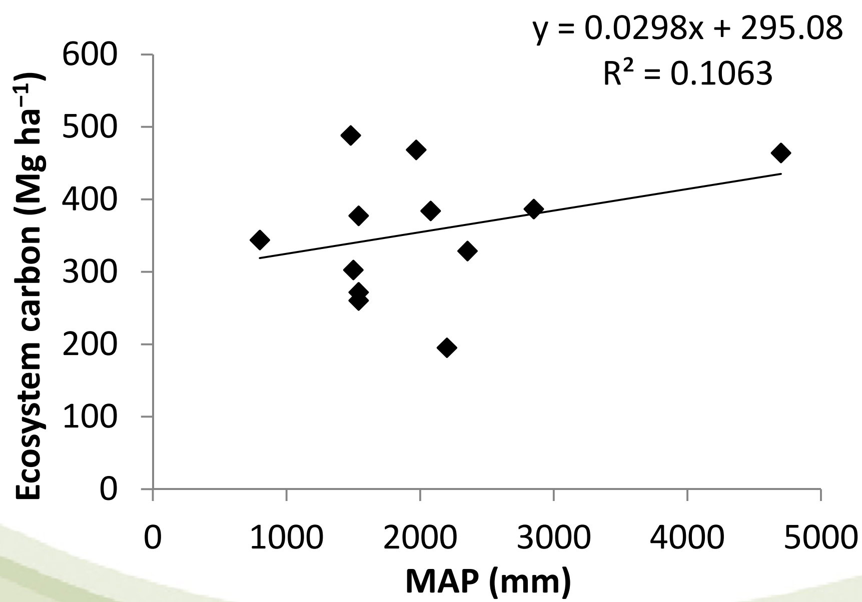
# Ecosystem carbon stock-Primary Forest

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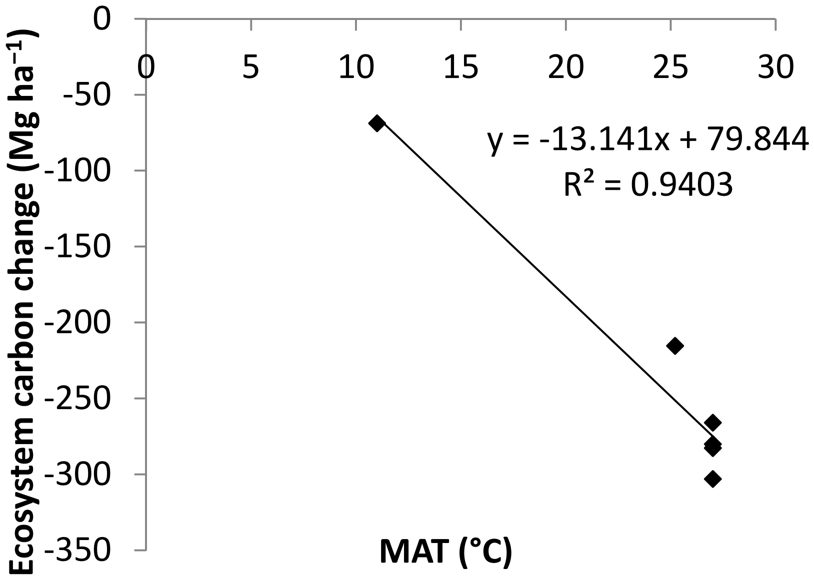
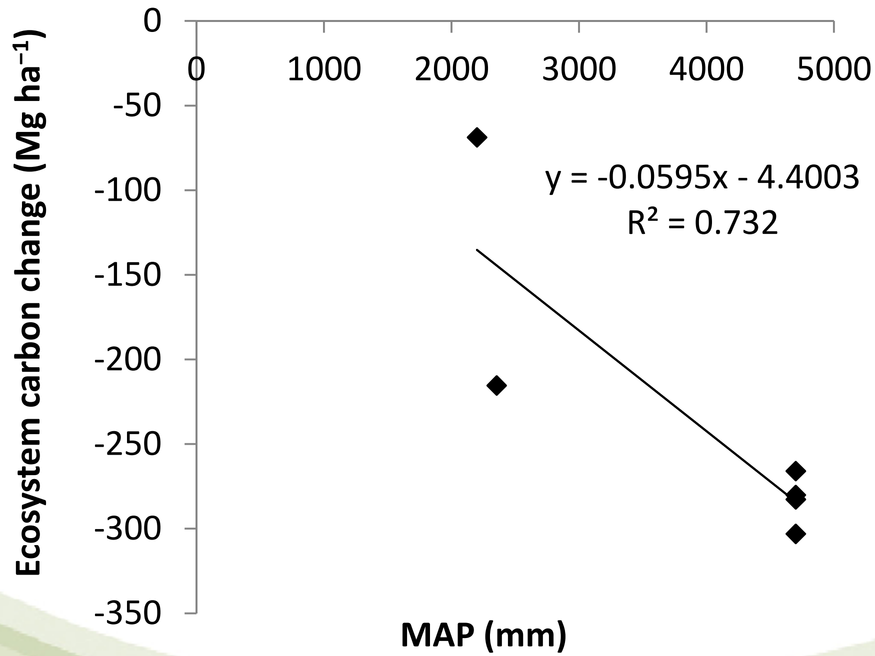
# Carbon stock change

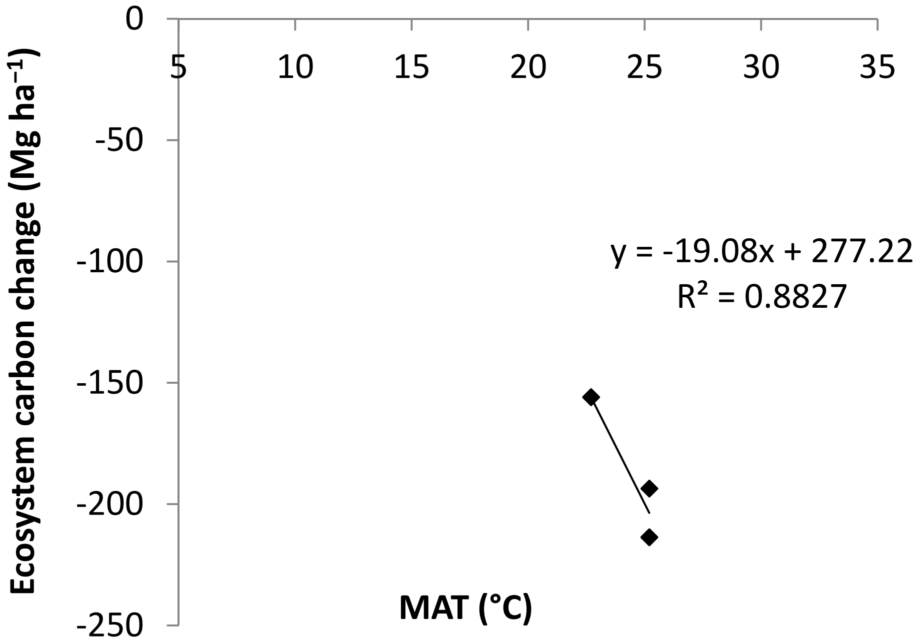
## Primary forest-Pasture

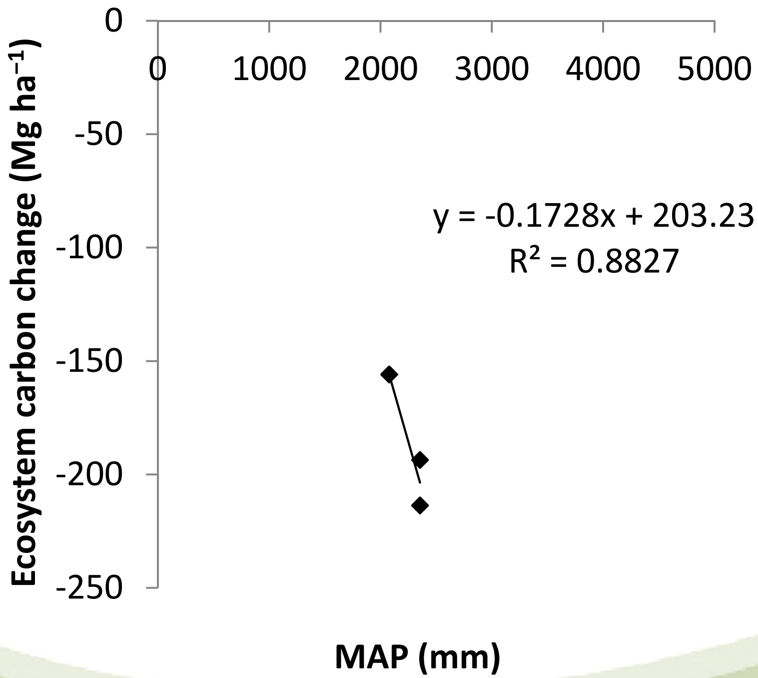


# Carbon stock change

Primary forest-secondary forest



# Multi-regression analysis

| | | Coefficient | n | $R^2$ |
|---|---|---|---|---|
| | | ***Primary forest*** | | |
| Aboveground biomass-C | Constant | 82.45 | 12 | 0.18 |
| | MAT | 1.51 | | |
| | MAP | 0.02 | | |
| SOC | Constant | 199.15 | 12 | 0.06 |
| | MAP | -2.76 | | |
| | MAP | 0.01 | | |
| Ecosystem-C | Constant | 316.42 | 12 | 0.11 |
| | MAT | -1.11 | | |
| | MAP | 0.03 | | |
| | | ***Pasture*** | | |
| Aboveground biomass-C | Constant | 10.31 | 6 | 0.55 |
| | MAT | 1.751 | | |
| | MAP | -0.01 | | |
| SOC | Constant | 65.87 | 6 | 0.89 |
| | MAT | -3.61 | | |
| | MAP | 0.04 | | |
| Ecosystem-C | Constant | 75.38 | 6 | 0.88 |
| | MAT | -1.33 | | |
| | MAP | 0.03 | | |

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# the point is…

- Very limited data available with estimating the whole carbon stock
- no clear relations between carbon stocks and the temperature or rainfall for the limited data analyzed
- Loss of carbon stock (by deforestation) is higher under higher temperature and rainfall

# Estimating carbon stock changes- deriving relations using PALM

## PALM model

- Simulate patches on a landscape
  - DSSAT –based crop models
  - Tree model-Forest growth
  - Ritchie's water balance model
  - CENTURY and DAYCENT-based soil organic carbon and nitrogen models

***Papers***

- *Matthews, R.B., 2002. Chapter 15 in Crop-Soil Simulation Models: Applications in Developing Countries (R.B. Matthews & W. Stephens, Editors), CAB International, Wallingford, UK, pp. 209-230.*
- *Matthews, R.B. & Pilbeam, C.J., 2005. Paper presented at MODSIM05 conference, Dec 9-12, 2005, Melbourne, Australia.*
- *Matthews, R.B. & Pilbeam, C.J., 2005. Agriculture, Ecosystems & Environment 111(1-4):119-139.*
- *Matthews, R.B. et al., 2005. Paper presented at MODSIM05 conference, Dec 9-12, 2005, Melbourne, Australia.*
- *Matthews, R.B., 2006. Ecol. Modelling 194(4):329-343.*

# Sites/Villages considered

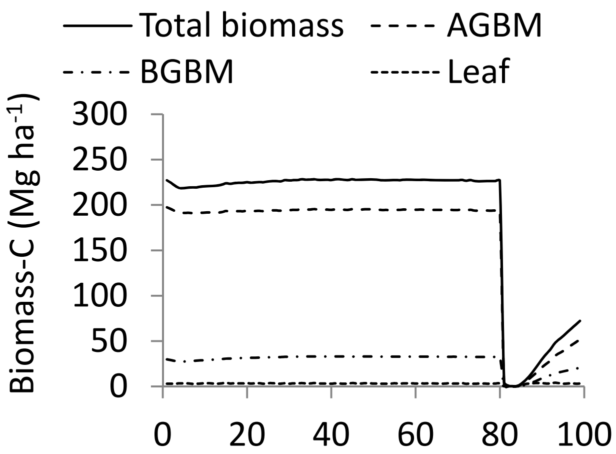
| *Site | Soil type† | Clay (%) | BD (kg $m^{-3}$) | SOC (g $kg^{-1}$) | MAT‡ (°C) | MAP (mm) | MAS (MJ $m^{-2}d^{-1}$) |
|---|---|---|---|---|---|---|---|
| ***Cameroon*** | | | | | | | |
| Alangana | Orthic Ferralsol | 26 (35) | 1410 (1350) | 10.6 (3.5) | 23.4 | 1561 | 17.2 |
| Aloum | Orthic Ferralsol | 22 (28) | 1380 (1350) | 37.1 (6.1) | 23.2 | 2011 | 14.0 |
| BibaYezoum | Orthic Ferralsols | 26 (35) | 1410 (1350) | 10.6 (3.5) | 23.8 | 1630 | 17.5 |
| Keeke | Orthic Ferralsols | 26 (35) | 1410 (1350) | 10.6 (3.5) | 24.4 | 1742 | 15.6 |
| Nyabessan | Orthic Ferralsols | 26 (35) | 1410 (1350) | 10.6 (3.5) | 23.2 | 2159 | 13.7 |
| Ongolzok | Orthic Ferralsols | 26 (35) | 1410 (1350) | 10.6 (3.5) | 24.0 | 1517 | 17.6 |
| ***Peru*** | | | | | | | |
| Ucayali | Eutric Gleysols | 51 (51) | 1210 (1210) | 14.2 (4.3) | 26.2 | 1606 | 19.4 |
| Loreto | Eutric Gleysols | 51 (51) | 1210 (1210) | 14.2 (4.3) | 26.5 | 2913 | 19.0 |
| SanMartin | Dystric Cambisols | 37 (59) | 1270 (1200) | 19.1 (8.6) | 21.6 | 1521 | 18.9 |
| Madrede Dios | Plinthic Acrisols | 25 (38) | 1390 (1310) | 16.2 (6.5) | 25.3 | 2236 | 18.4 |
| ***Vietnam*** | | | | | | | |
| Bac Kan | Orthic Acrisols | 24 (36) | 1220 (1230) | 12.5 (4.5) | 17.7 | 1615 | 12.1 |
| Dak Lak | Ferric Acrisols | 10 (23) | 1580 (1430) | 6.1 (3.0) | 24.4 | 1753 | 18.1 |
| Lam Dong | Orthic Ferralsols | 52 (58) | 1240 (1220) | 16.5 (6.8) | 21.1 | 2565 | 14.9 |
| Son La | Luvisols | 24 (34) | 1400 (1320) | 10 (4.2) | 19.7 | 1453 | 15.2 |

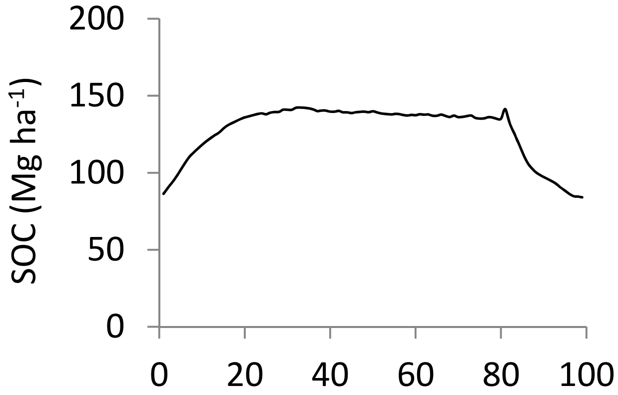
MAT: Mean annual temperature; MAP: Mean annual precipitation; MAS: Mean annual daily solar radiation
* Values in parenthesis correspond to that in 30-70 cm depth
†Soil data source: HWSD (Harmonised World Soil Database)
‡ Weather data generated from MARKSIM (Jones and Thornton, 1993)

# Simulation

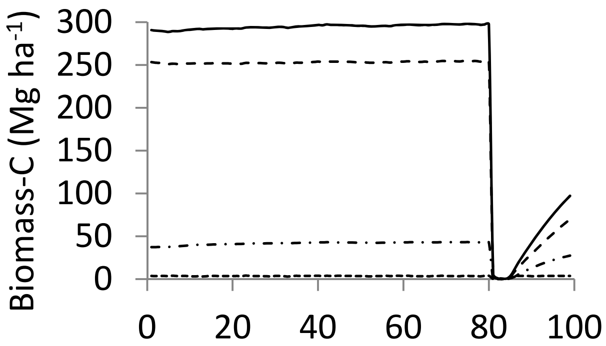
- The PALM was run for LU transition of primary forest (PF)-agriculture (C)- secondary forest (SF) for about 100 years
- The model was run for 80 years under forest to bring biomass and SOC content into an equilibrium
- Following deforestation, the land was subjected cropping for about 4-years
- Crop represents maize (MZ) in all the three countries
- Land is abandoned for a secondary forest for next 16 years.

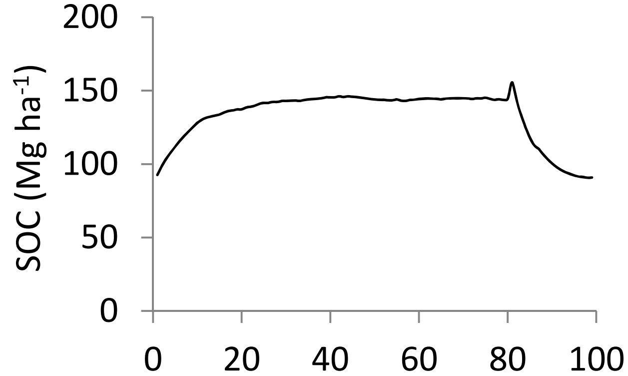
# Alangana, Cameroon



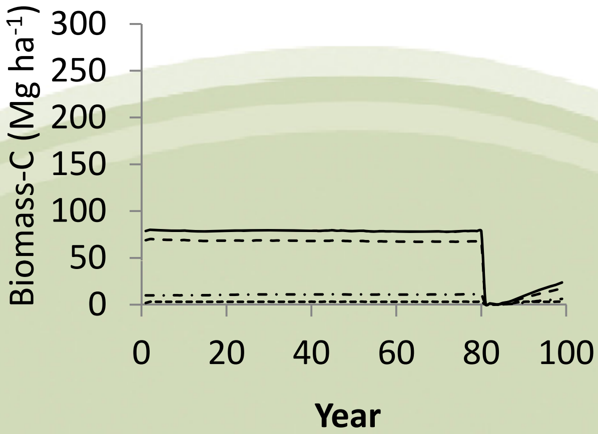



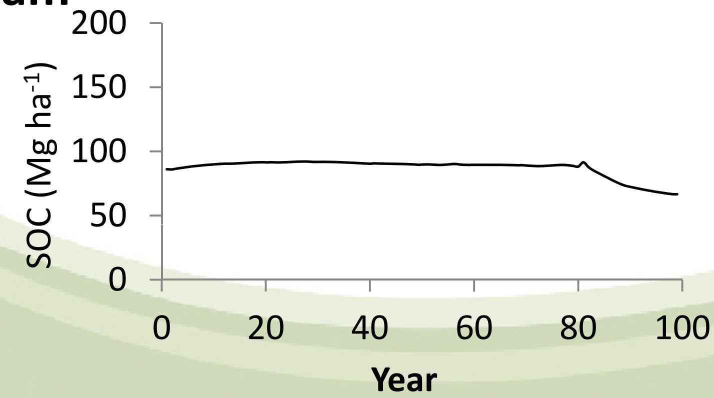

# Loreto, Peru




# Bac Kan, Vietnam

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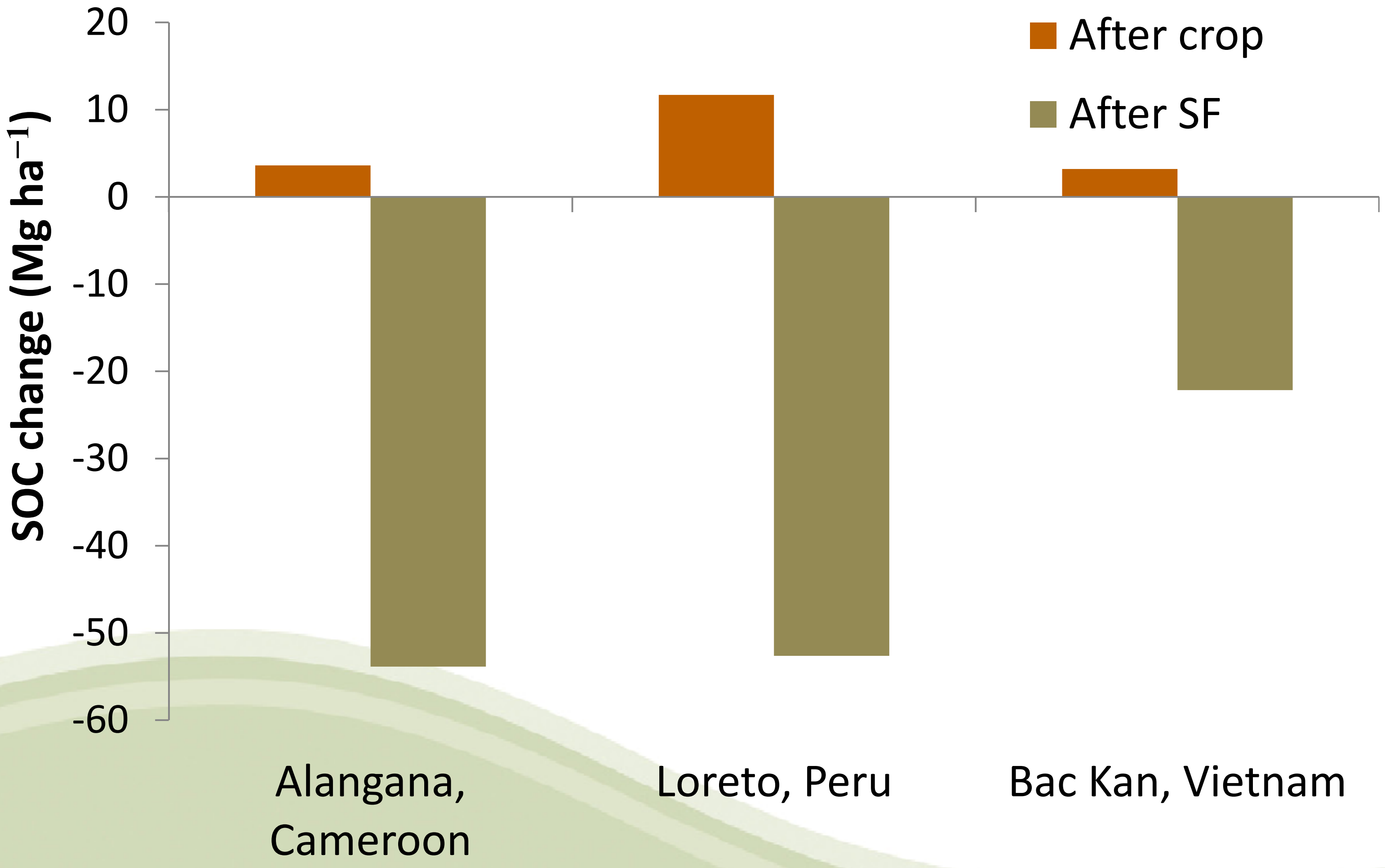
# SOC change following deforestation



# To develop simple relations

- the model was run for a range of temperature (±4 °C), rainfall (±20 %), clay content (±20 % from the given value) and initial SOM content (±20 % from the given value) and in their combinations

# Multi-regression model

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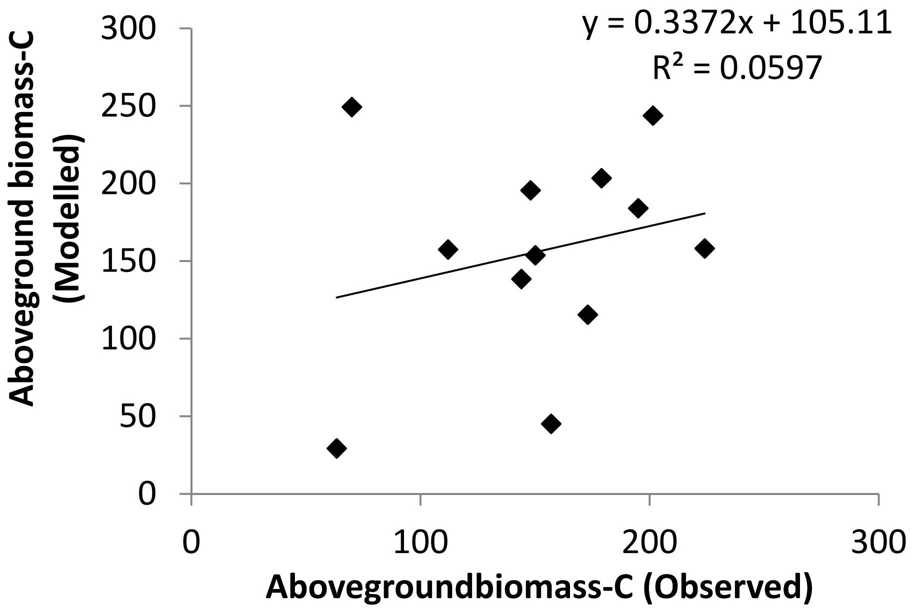
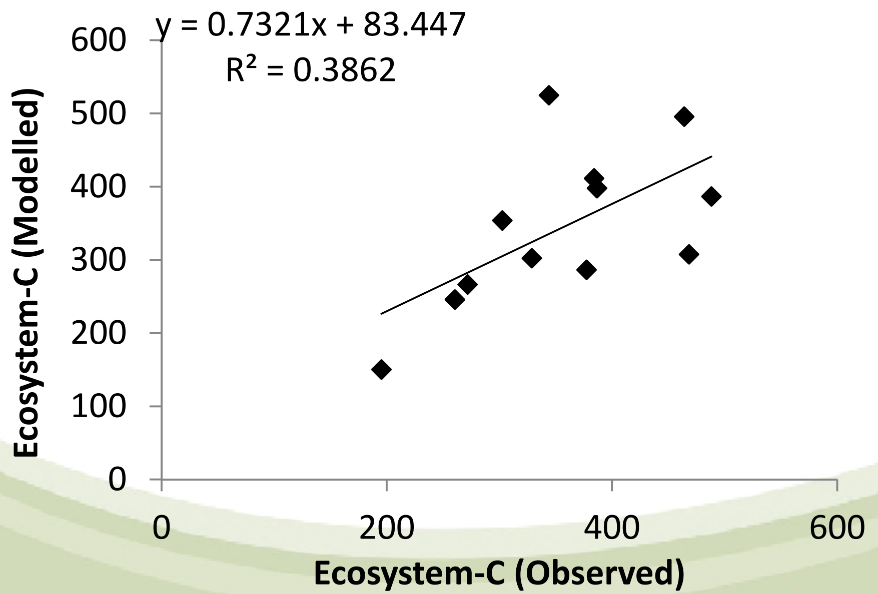
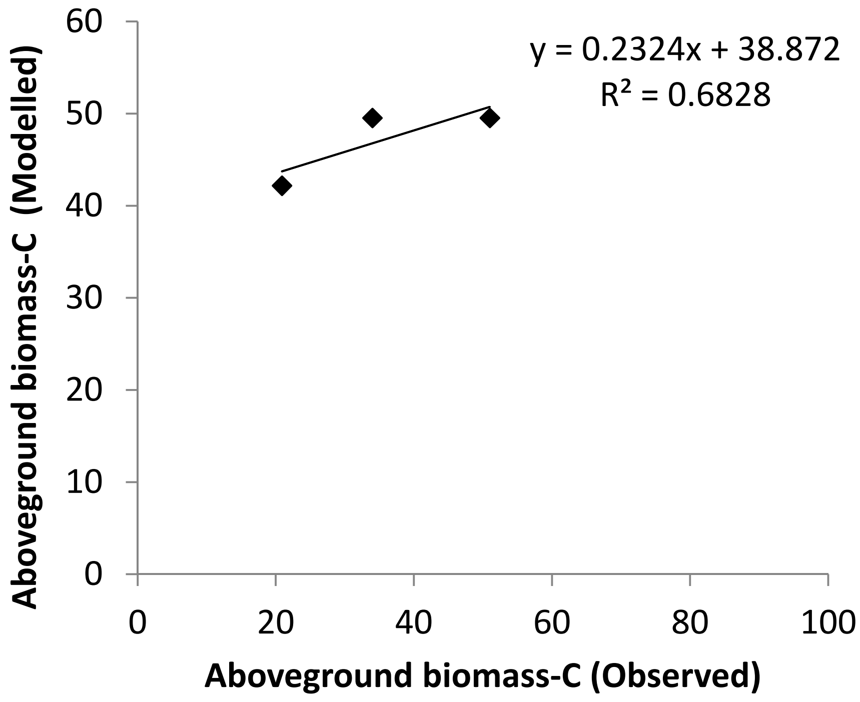
| | $R^2$ | $\Delta R^2$ | Coef. |
|---|---|---|---|
| **PF-Ecosystem-C** | | | |
| Constant | | | -344 |
| MAT | 0.34 | 0.34 | 17.3 |
| SOCI | 0.65 | 0.31 | 0.64 |
| MAS | 0.72 | 0.07 | 11.3 |
| MAP | 0.73 | 0.01 | 0.02 |
| **Crop-Ecosystem-C** | | | |
| Constant | | | 0.21 |
| SOCI | 0.72 | 0.72 | |
| MAT | 0.75 | 0.03 | 2.8 |
| MAP | 0.75 | 0.00 | 0.59 |
| Clay | 0.75 | 0.004 | -0.35 |
| **SF-Ecosystem-C** | | | |
| Constant | | | -98 |
| SOCI | 0.61 | 0.61 | 0.56 |
| MAT | 0.75 | 0.13 | 5.73 |
| MAS | 0.76 | 0.01 | 2.81 |
| MAP | 0.77 | 0.01 | 0.01 |

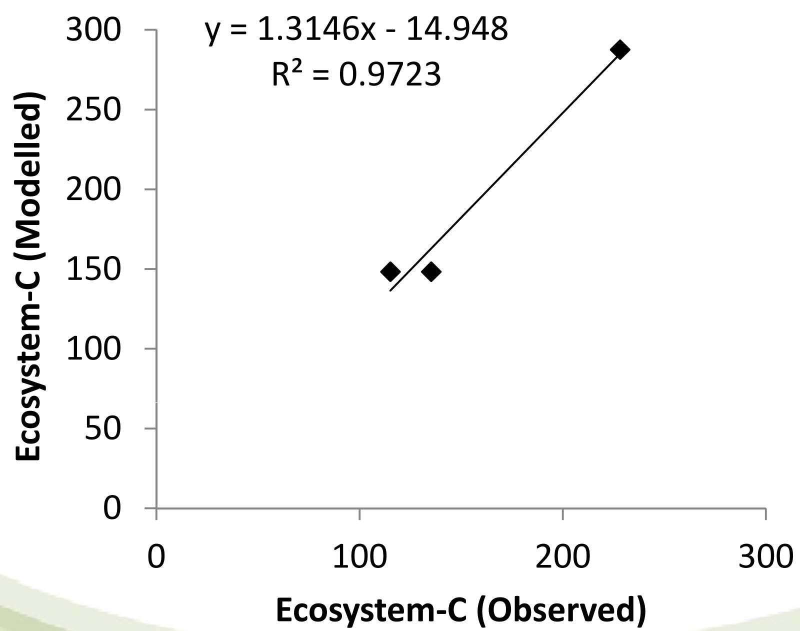
# Simple model results-Primary forest



# Simple model results-Secondary forest



# the challenge is…

- Calibration and testing detailed process models due to scarcity of data (time series)
- Simple models  give only a 'snapshot' of the carbon stocks
- Need a more realistic representation of the system by including more of relevant crops