Using miniature plots to assess the effects of soils on the productivity of tropical plantation forests

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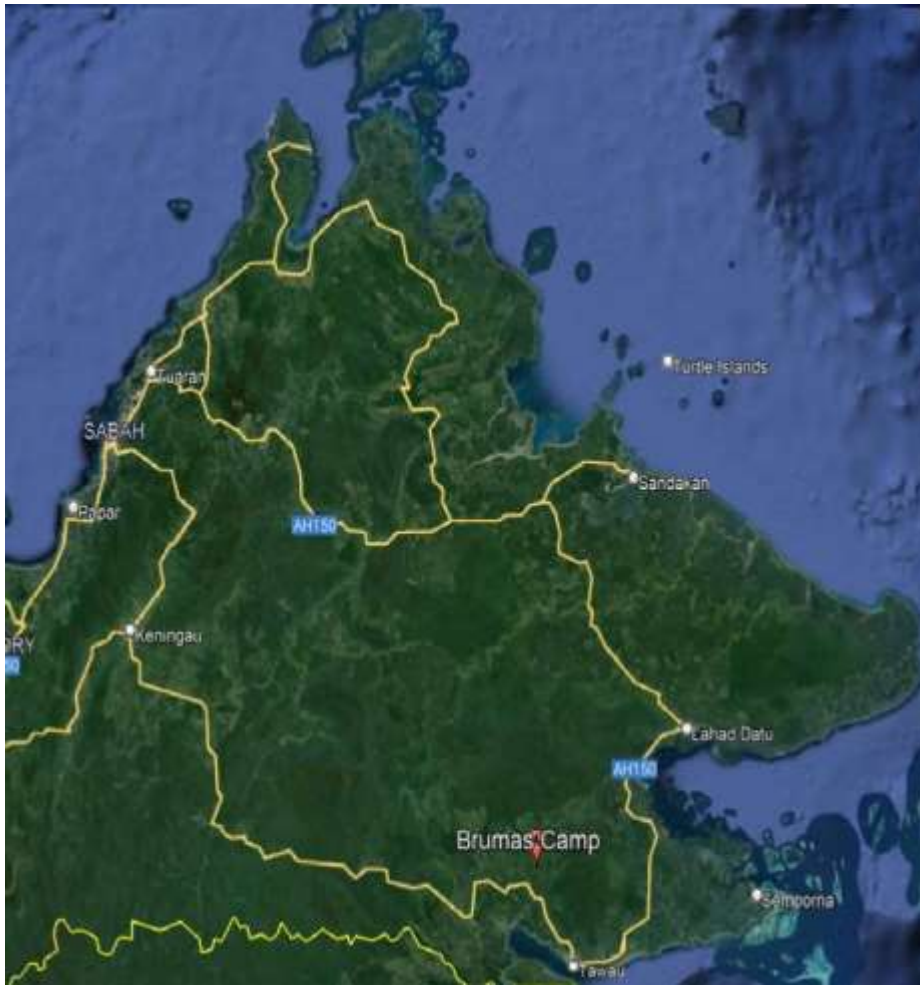
Introduction

- Fast-growth plantation forests relatively new in SE Asia
- Need for monitoring, assessment of plantation forest soils and productivity
- Miniature plots to investigate site productivity for
  - *Falcataria moluccana, Acacia mangium, Euc. pellita*
- Miniature plots are small-scale, short-term experiments
  - Analogous to operational stands over a normal rotation.

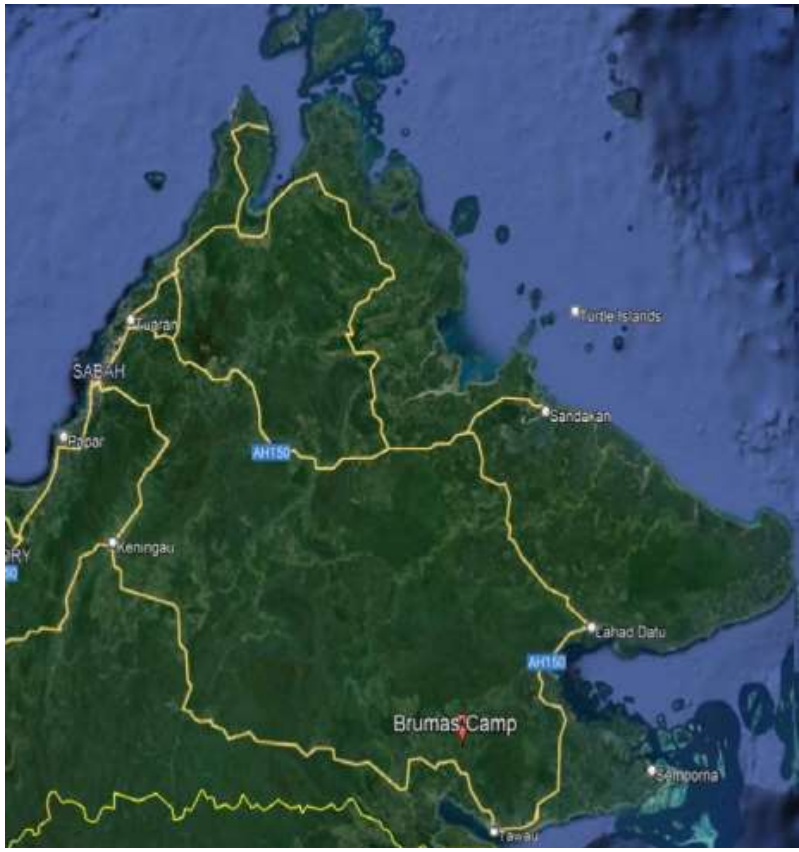
Study Area Location and Climate

- SSB plantations near Brumas Camp, near Tawau, SE Sabah
- Climate is Tropical rainy
- Rainfall
  - MAR 2300 mm
  - Twin peaks during year
  - Varies considerably with dry spells of several weeks
- Mean annual temperatures 25°C - 27°C



Soils in study area

- Soils are Orthic Acrisols
  - Kumansi, Tanjung Lipat and Kapilit families
- Formed on sedimentary rocks
- Generally deep, well-drained
  - Imperfect drainage for some sites, particularly in toeslope locations.

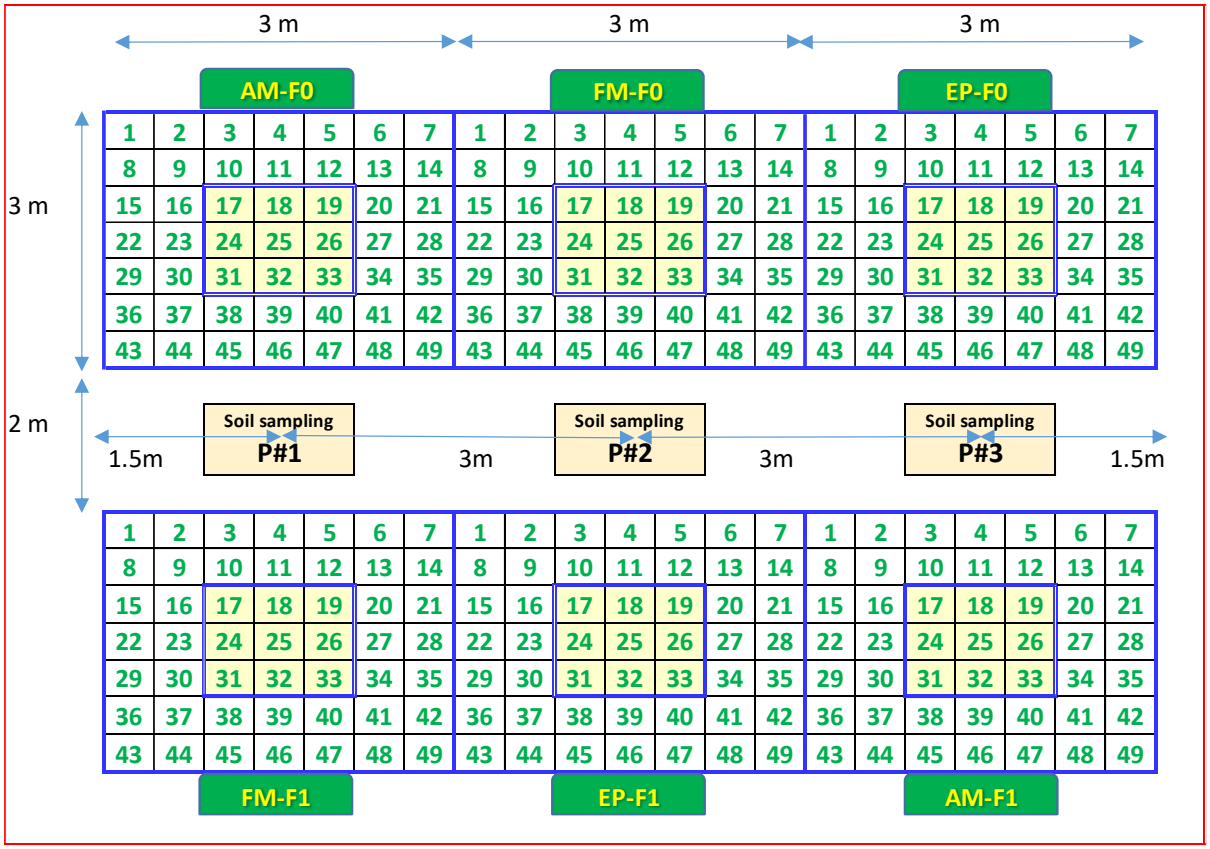


Experimental Sites

Cpt	Previous species	Latitude	Longitude	Rotation	Harvest method	Altitude (m AMSL)
048H	A. mangium	4°33’49.08”	117°42’53.36”	4	Cable	335.3
105A	A. mangium	4°38’27.71”	117°45’28.93”	4	Cable	243.8
085A	A. mangium	4°36’40.62”	117°47’7.49”	3	Cable	243.8

- Three compartments
- Previous crop *A. mangium*
- 3rd and fourth rotation sites
- Cable harvesting
- Plots located on
  - Ridge
  - Midslope
  - Toeslope
- Nine plots

Experimental Layout & Treatments



Nested design with three species treatments randomised within control (F0) or full (F1) fertiliser treatments. Species (FM, EP, AM) and fertiliser (F0, F1) treatments are shown in the green labels

Tree growth response variables

- Seedlings measured monthly over 12-months
- GLD (cm), H (m) used to calculate stem V (m^3)
  - $V=0.25(\pi(GLD/200)^2 H)$
- Convert stem V x 40,000 =V/ha ($m^3\ ha^{-1}$)
- MAI ($m^3\ ha^{-1}\ year^{-1}$) =V/ha÷age (years)
- MAI increased until 9 months then stabilised
  - plots were fully occupied (full canopy closure)
- Response variable for growth=MAI (9mo)

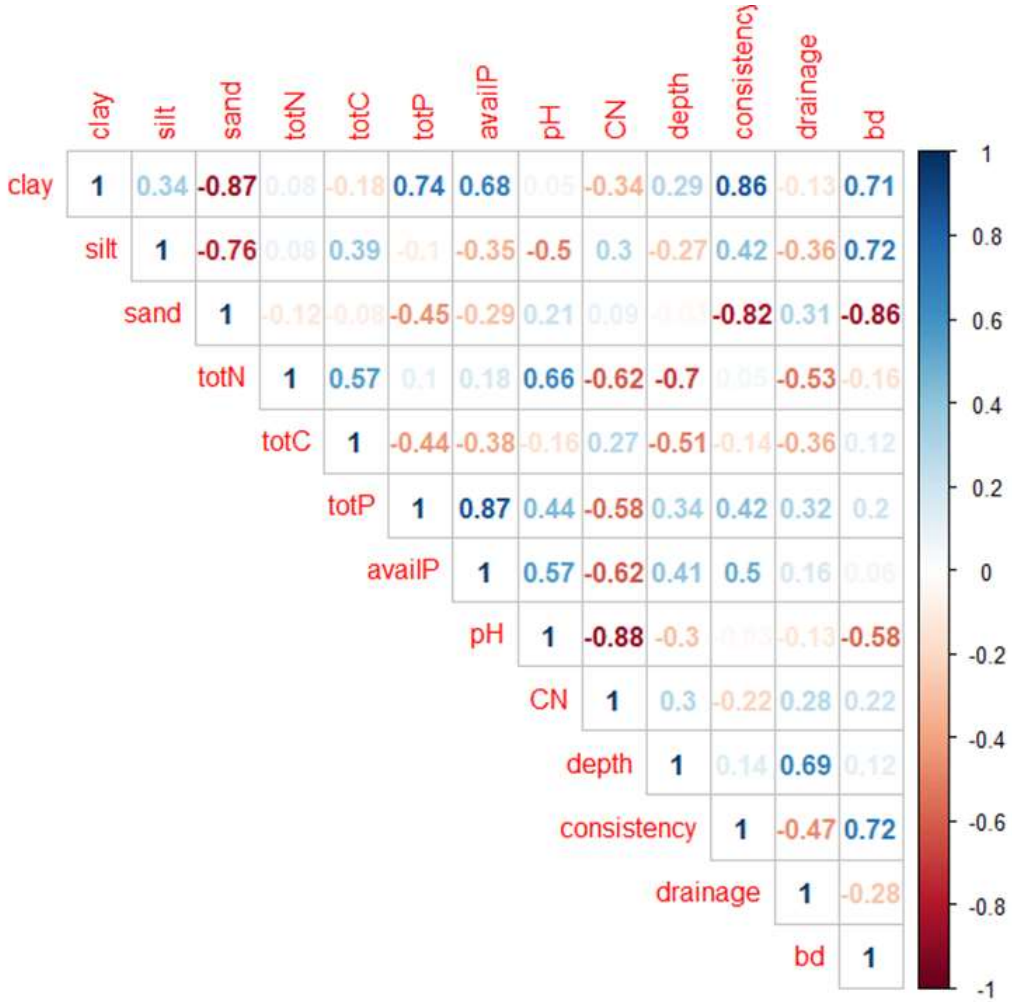
Physical soil variables measured

Soil property	Qualitative Assessment or measurement
Drainage/Permeability classes	Assessed on a 0-4 scale, very poorly drained (0) to well-drained (4), based on depth and % of soil mottles, and/or depth of soil gleying
Soil consistency (moist)	Assessed on a 0-5 scale, loose (0) to extremely firm (5)
Soil depth (cm)	Numerical measurement down to a maximum of 90 cm or to impeding layer or parent material if shallower.
Potential root depth (cm)	Depth to a limiting layer preventing tree root penetration e.g. very abundant coarse fragments, hard, waterlogged layer, hard or compact bedrock.
Soil rock (% by volume)	% by volume, of gravels, cobbles, stones or boulders below the soil surface

Soil nutrient variables measured (0-10 cm)

cpt	slope	totN (%)	totC (%)	totP (mg/kg)	availP (mg/kg)	pH	CN
48H	mid	0.19	2.14	200	1.26	4.00	11.3
48H	rdg	0.17	1.86	228	2.54	4.16	10.7
48H	toe	0.20	1.81	172	1.52	4.48	9.1
85A	mid	0.25	2.13	305	3.30	4.98	8.5
85A	rdg	0.19	1.78	150	1.81	4.87	9.6
85A	toe	0.21	1.75	239	2.20	4.69	8.2
105A	mid	0.15	1.41	300	3.45	4.39	10.1
105A	rdg	0.22	1.69	450	28.3	5.18	7.6
105A	toe	0.18	1.54	502	18.3	4.67	8.4

Soil variable correlations



Model Variables	Abbreviation
Response variables	
Mean annual increment	MAI
Fertiliser response	FR (MAI(F1)/MAI(F0))
Explanatory variables	
Compartment	cpt
Species	AM, FM, EP
Slope position	Slope, rdg, mid
Fertiliser treatment	F0, F1 (complete luxury)
Soil Variables	
Total C	totC
Total N	totN
Total P	totP
Available P	availP
C:N ratio	CN
Fertiliser × C:N ratio	(fert × CN)
% Clay	clay
Soil depth	depth
Soil drainage	drainage

Growth responses by species

Response variable (Std Dev'n in brackets)	*A. mangium*		*F. moluccana*		*E.pellita*	
MAI (m^3/ha/yr) F1	57.2	(20.2)	57.4	(18.4)	56.8	(23.9)
MAI (m^3/ha/yr) F0	44.6	(19.1)	26.1	(10.0)	31.9	(12.0)
FR	1.44	(0.65)	2.20	(0.91)	1.61	(0.69)

"Best fit" models

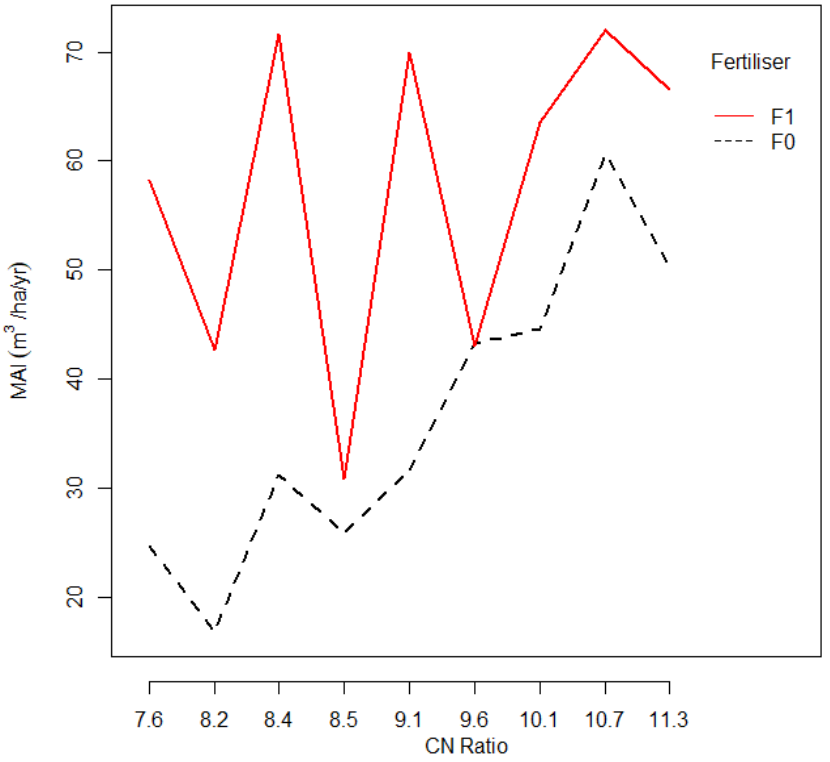
$$\log(MAI) = -5.96 + 0.22 * \log(availP) + 4.131 * \log(CN) + 5.10402 * I_{\{fert=F1\}} - 2.08 * I_{\{fert=F1\}} * \log(CN)$$

$$\log(FR) = 5.89 - 2.41 * \log(CN) - 0.61 * I_{\{cpt=085A\}} - 0.17 * I_{\{cpt=105A\}} + 0.11 * I_{\{species=EP\}} + 0.44 * I_{\{species=FM\}},$$

where $I_{\{\cdot\}} = 1$ when the condition within the braces is fulfilled and 0 otherwise.

Response to CN ratio

- C:N ratio superior to soil N as predictor of N fertility
- C:N ratio
  - No influence on MAI for F1
  - But MAI increased positively with C:N for F0
- Unusual result
  - higher C:N ~lower soil N supply
- Possible reasons
  - previous crop N-fixing species
  - potentially depleted soil C



Other growth responses

- *F. moluccana* higher FR than *A. mangium*.
- *E. pellita* somewhat higher FR than *A.mangium*
- Available P
  - Positive effect on MAI
  - But no effect on FR
- Although not in “best” model, in alternative models:
  - FR decreased by 4-5 $m^3ha^{-1}year^{-1}$ for each pH unit increase
  - Soil fertility less limiting to growth in soils with higher pH?

Potential use of miniature plots

- Miniature plots could rapidly assess potential site productivity in tropical fast-growth plantations within 9 months from their establishment
- Rapid establishment and measurement of plots
- Can miniature plots accurately scale with site productivity for an operational stand?
  - MAI values for F1 plots very high compared with normal operational stands.
  - But MAI values for F0 trees were low
  - High F1 productivities result of the fertiliser rate 1400 kg ha^{-1}, much higher than operational rates?

Conclusions

- Limited by the small size of study and coverage
- But results were encouraging
- Miniature plots have potential for monitoring and investigating site productivity in fast-growth tree plantations in Southeast Asia
  - A large network of miniature plots could be valuable in ensuring sustainable management of SE Asian forest plantations
- References:
  - Nguyen, L., Alwi, A., Japarudin, Y., Moltchanova, E., & Bloomberg, M. (2021). Using miniature plots to assess the effects of soils on the productivity of tropical plantation forests: a case study from Sabah, Malaysia. New Forests, 1-17.