Allometric equations for biomass estimations of *Ensete ventricosum* grown in indigenous agroforestry systems, southern-eastern Ethiopia

implication for climate change mitigation on agricultural landscapes

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Outlines

- Introduction
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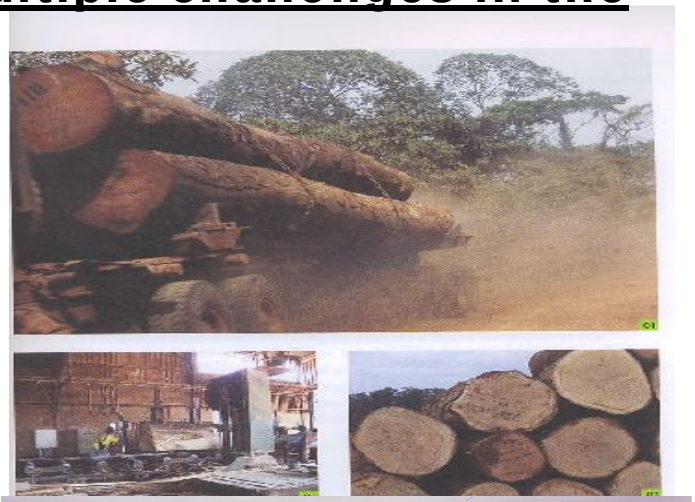
Introduction

Forest resources are major climate adaptation and mitigation measures, however, have faced **multiple challenges in the tropics**



Introduction cont'd

- **complementary land uses** such as **agroforestry that support livelihoods while sequestering carbon**

- More focus on **woody species** (e.g. Kaonga and Bayliss-Smith, 2010)

- Less attention to **perennial non-woody components such as enset (*Ensete ventricosum*)**

Introduction cont'd

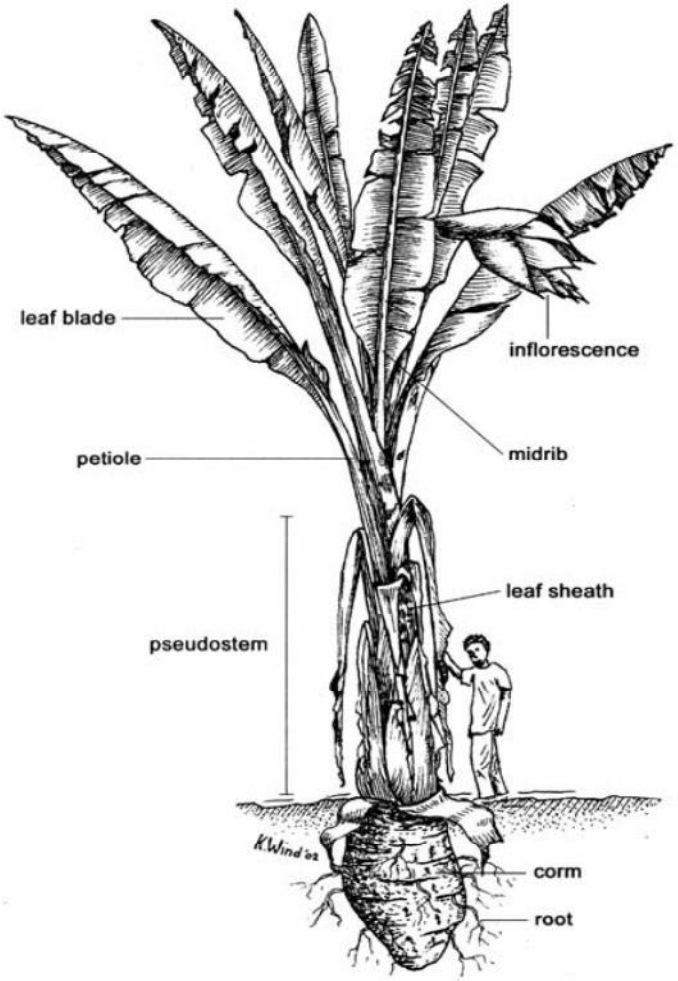
- Enset serves the same **ecological roles as forest** (Tesgaye 2002)

- Much is known about **productivity and management of *E. ventricosum*** for food

- **However, little attention** has been given to the plants overall **biomass production and carbon sequestration**.

- This necessitates developing **a means** to measure the biomass and carbon contents of the plant.

Introduction cont'd



Enset (*Ensete vetricosum*, family Musaceae)

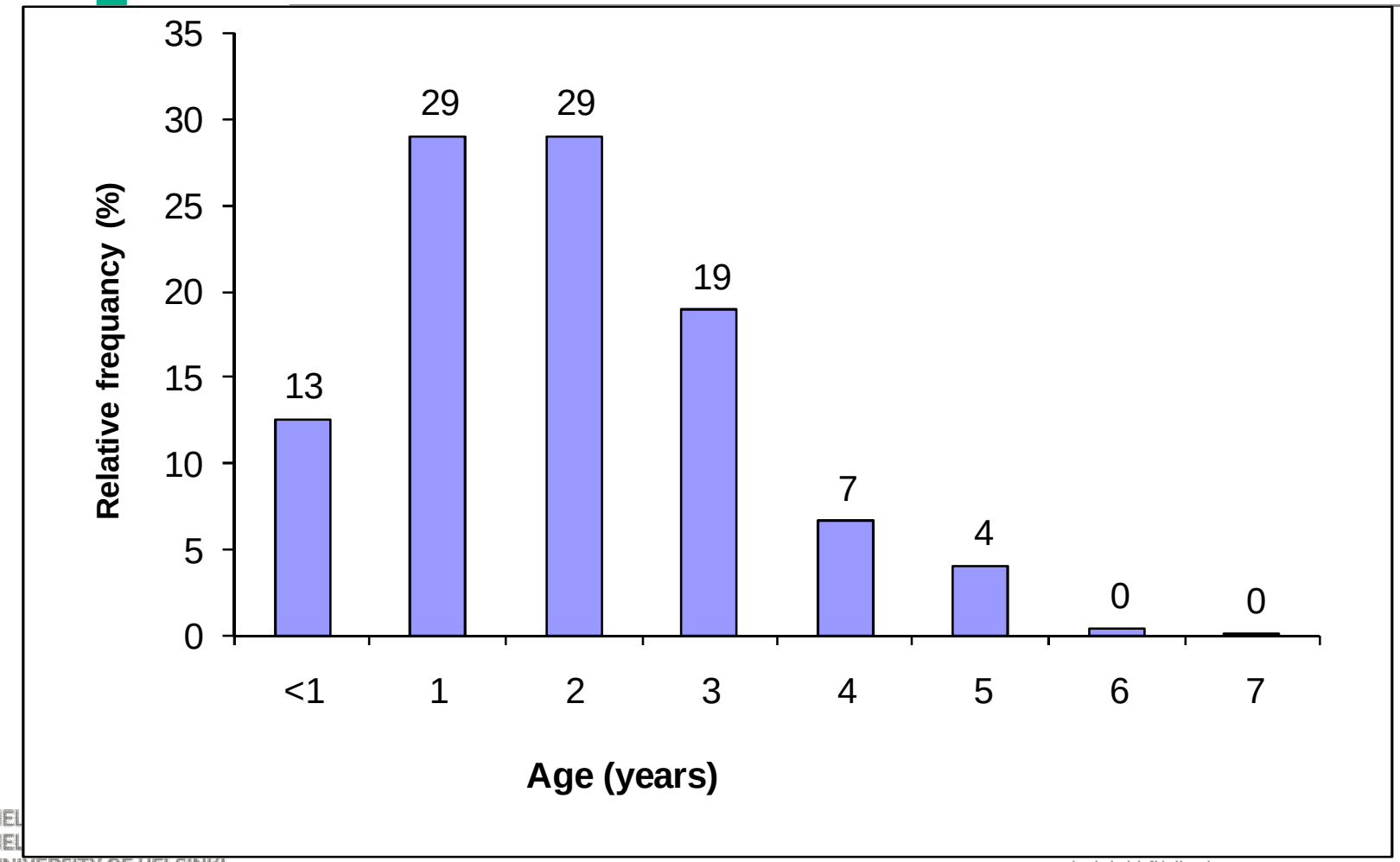
- **sub-Sahara Africa**, **Madagascar and parts of Asia**
- up to **13m height**
- up to **2m in psuedostem** diameter
- Rotation period **3 to 15 years**

Why enset?

- **Highest productivity (**i.e. **49t/ha** vs **cereals** (0.7-2.5 t/ha) and **root crops** (8.1-13.7t/ha/annum) (FAO 1986).
- serves as a **food plant** in Ethiopia (plus >22 uses)
  - **300,000 hectares** yielding **4.4 million metric** tons per annum
- supporting the livelihood of **10-15 million people**
- **Resilient** for climate change (i.e. drought tolerant)
- **least studied** domesticated crop in Ethiopia and Africa

Shank and Chernet (1996), Brandt et al. (1997), Blench (2003)

Population structure of enset



Research objectives

Overall objective of this study

- to develop and evaluate **allmoteric models for estimating the above-and-belowground biomass of *E. ventricosum*** grown in indigenous agroforestry systems in Rift Valley escarpment of south-eastern, Ethiopia.

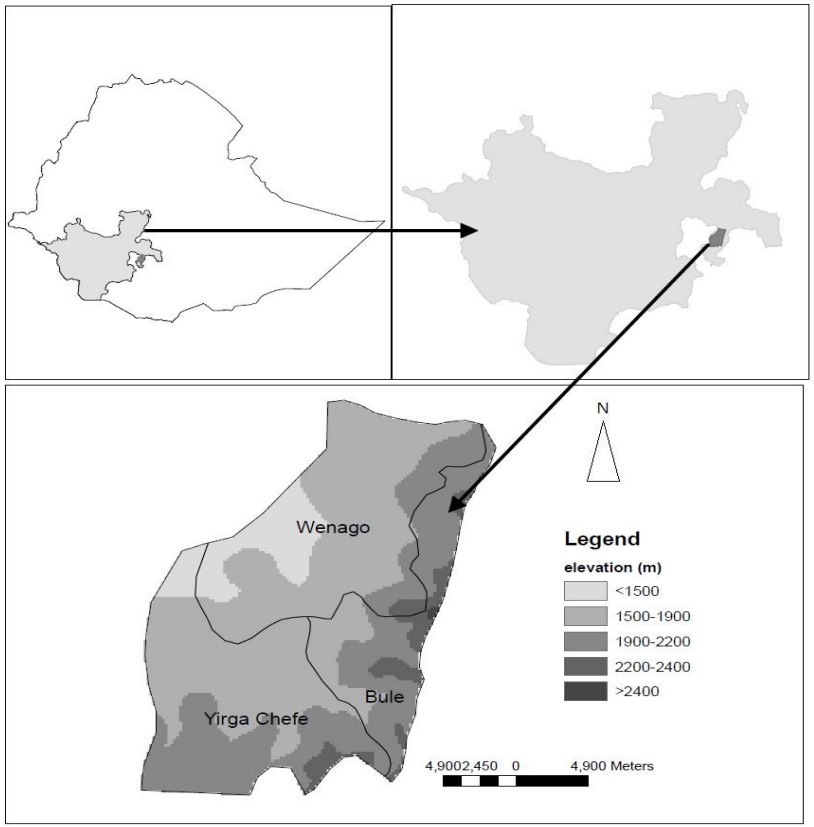
Specific objectives were to:

1) determine the **dry weight and organic matter content** of above-and-belowground biomass components (foliage, psuedostems and corm),
2) determine which **plant size parameters** were best **correlated to biomass**; and
3) derive and evaluate **various allometric models** to predict biomass

Methods

Study site

Map of the study sites with respect to Ethiopia and SNNPRs



- Elevation **1900 to 2400 m.a.s.l**
- Annual rainfall 800 - 200 mm
- mean annual temperature from 13 - 28^{0}C
- Soil type
  - humic-rich Eutric Nitosol (*ca.* 48%),
  - Eutric Fluvisols (20%), and
  - Dystric Nitosol (20%).
- Population density **1300 persons / km^2**

Methods

3467 ±947 plants ha^{-1}
(~2200-2400m)

1550±482 plants ha^{-1}
(~1900–2200m)

(~ 1500-1900m)

Altitude (m asl)

Enset-AF

Enset-coffee-AF

Fruit-coffee-AF

Methods cont'd

Enset biomass harvest

- **20 farms** were selected randomly
- **3 and 5** years age categories
- **40 enset** plants were harvested

parameters measured

- Diameters at **10, 30, 130, 200cm** height
- total height
- crown height
- pseudosetm height

Methods con't

Summary statistics of the harvested *E. vetricosum* (n=40)

Parameters	Mean	Minimum	Maximum	SD
d_{10},cm	**36.5**	20.0	**53.0**	8.3
d_{30},cm	33.2	18.0	47.0	7.8
d_{130},cm	21.9	13.0	37.5	5.5
d_{200},cm	**18.9**	12.5	32.0	4.4
Pseudosetm height, m	2.0	1.1	2.9	0.4
Crown height, m	2.9	0.8	12.2	1.8
Total height, m	**4.9**	2.4	**14.7**	2.0

Methods cont'd

Biomass sampling

uprooted Enset plant

foliage

Pseudostem

corm plus adventitious roots

Photos by M Negash.

Methods cont'd

Determination of carbon content

foliage

pseudostem

corm plus adventitious roots

Chopping

Sun-drying

LOI

Photos by M Negash.

Methods

Biomass model development

- Except for the corm component (= below-ground biomass), where we **tested 23 equations, 22 equations** for each biomass component and combination.

- Model performance was assessed using various goodness-of-fit statistics (**R^2 , D, B, SEE, MAB, PRESS**)

Results

Determination of organic matter content

Biomass component	Dry wt,kg	organic matter,%
Foliage	1.1 (0.08)	88.7(0.82)
Pseudostem	6.0(0.58)	94.6(0.83)
Pseudostem + foliage	7.1(0.63)	93.6(0.64)
Corm+adventitious roots	2.2(0.29)	93.9(0.51)
Total	9.3(0.84)	93.6(0.62)

- Pseudostem 64%, corm for 24%,foliage for 12%
- Aboveground biomass 76% of total biomass

Results cont'd

Enset biomass predictor variables

Biomass component	d_{10}	d_{30}	d_{130}	d_{200}	H_p	H_c	H
Foliage	**0.775****	0.698**	0.701**	0.673**	0.359*	0.320*	0.344*
Pseudostem	0.944**	0.890**	0.685**	0.645**	0.596**	0.453**	**0.501****
AGB	0.963**	0.904**	0.738**	0.699**	0.585**	**0.440****	0.493**
BGB	0.742**	0.634**	0.553**	0.527**	**0.267**^{ns}**	**0.259**^{ns}**	**0.226**^{ns}**
Total	**0.980****	0.901**	0.748**	0.697**	0.545**	**0.422****	0.454**

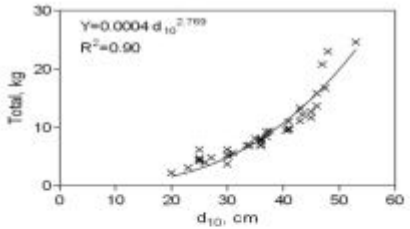
- Biomass for **total and AGB** were strongly correlated to **diameter and height** while **BGB** was correlated to **diameter measurements**

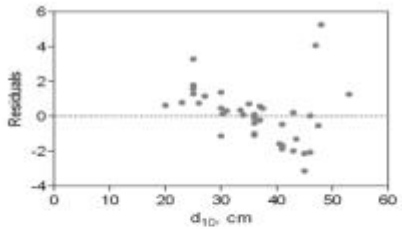
Results cont'd

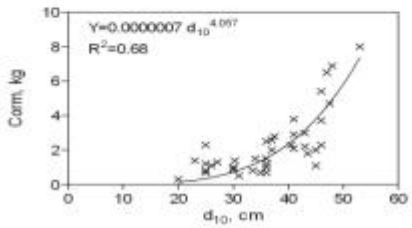
Biomass models

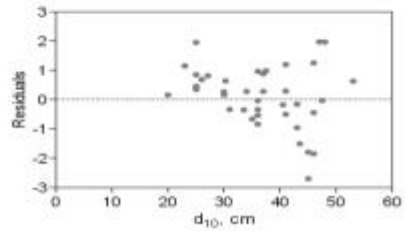
The best selected models	R^2	Bias
1. $B_t = 7x10^{-4}\, d_{10}^{\,2.571}\, H^{0.101}$	91%	-0.1063
2. $B_t = 4x10^{-4}\, (d_{10}^{\,3.004}\, d_{30}^{\,-0.351}\, d_{130}^{\,0.105})$	90 %	-0.1369
3. $B_t = 4x10^{-4}\, (d_{10}^{2.762}\, d_{130}^{0.011})$	90 %	0.1410
4. $B_t = 4x10^{-4}\, d_{10}^{\,2.769}$	90 %	-0.1473
5. $B_t = -11.772 + 0.582\, d_{10}$	82%	-0.0059

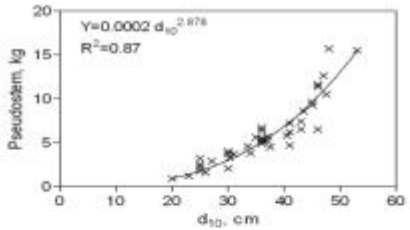
Results cont'd

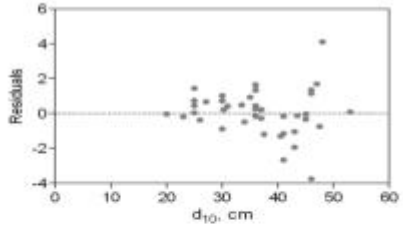


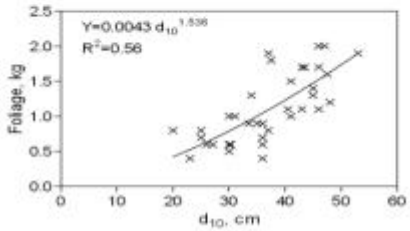


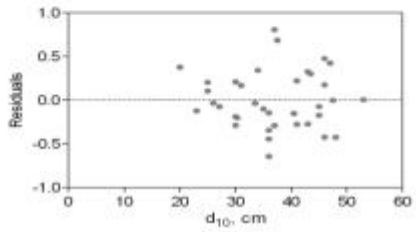












Results cont'd

Enset based AF

Bt=8.2 Mg ha^{-1}, 28% of the total vegetation biomass)

Enset-Coffee- AF

Bt=7.3 Mg ha^{-1}, 13 % of the total vegetation biomass)

Conclusions

- The total biomass of *Ensete vetricosum* plants aged **of 3-5 years** grown in an indigenous agroforestry system averaged **9.4 kg per plant.**

- **The power model** combining basal **diameter (d_{10})** and **total height** was the best model, except the corm.

- However, **the power model using d_{10} alone could explain 90 %** of the variation for total and aboveground biomasses.

- **The biomass models and organic matter contents** presented can be used to predict the **biomass and carbon density** of enset plants in these agroforestry systems

Acknowledgments

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Thank you for your attention!!!