Modeling the short- and long-term effects of wild plants harvest by local people

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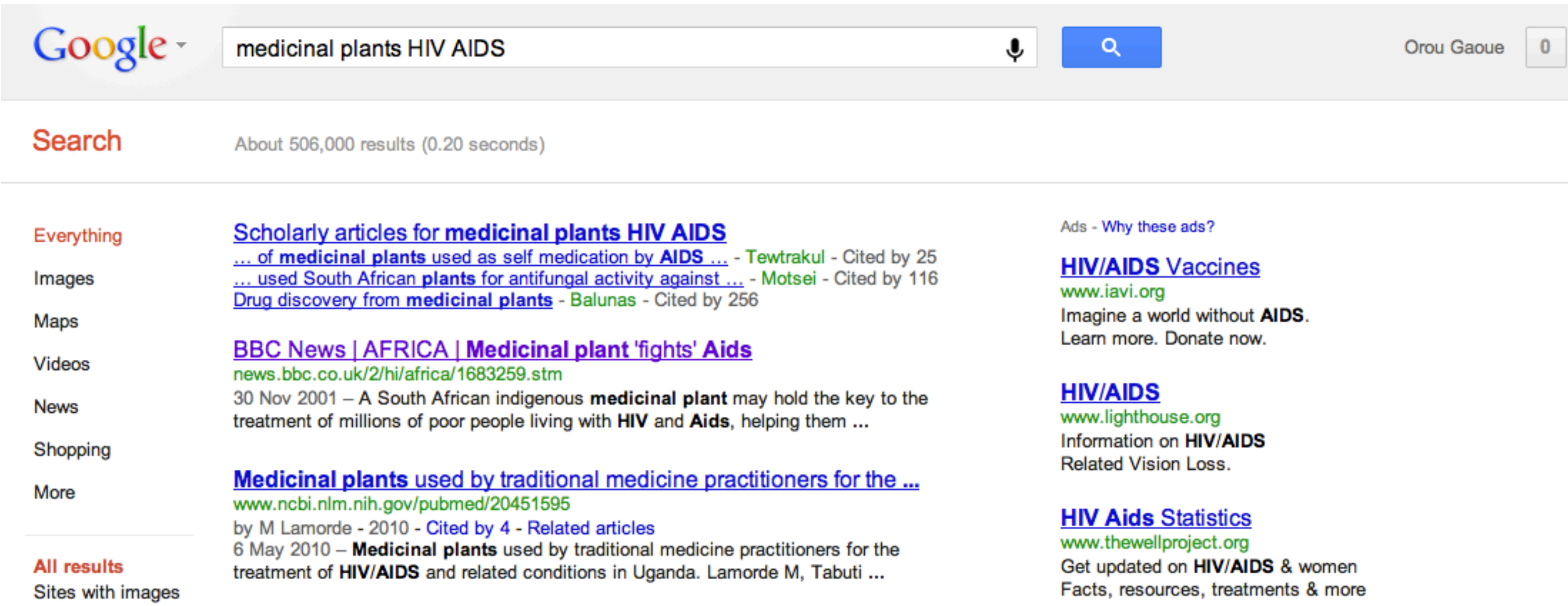
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BBC News | AFRICA | Medicinal plant 'fights' Aids
news.bbc.co.uk/2/hi/africa/1683259.stm
30 Nov 2001 – A South African indigenous medicinal plant may hold the key to the treatment of millions of poor people living with HIV and Aids, helping them ...
Medicinal plants used by traditional medicine practitioners for the ...
www.ncbi.nlm.nih.gov/pubmed/20451595
by M Lamorde - 2010 - Cited by 4 - Related articles
6 May 2010 – Medicinal plants used by traditional medicine practitioners for the treatment of HIV/AIDS and related conditions in Uganda. Lamorde M, Tabuti ...
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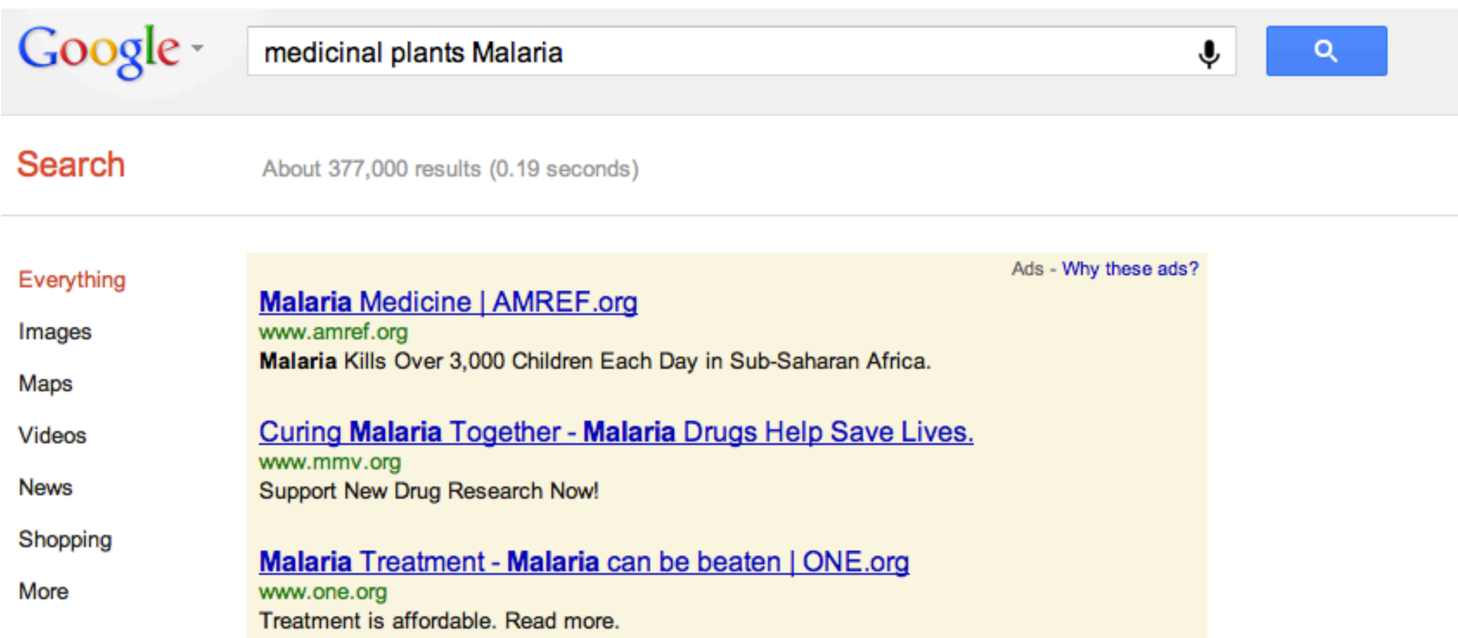
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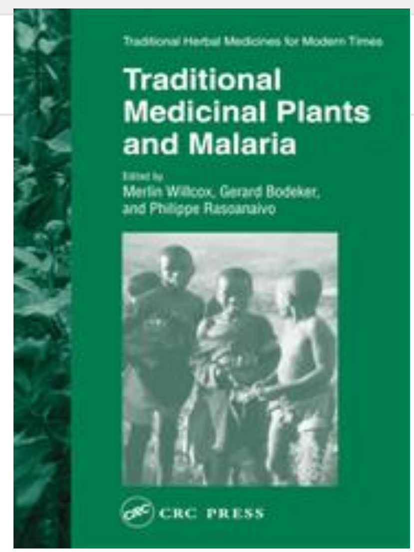

Traditional Herbal Medicines for Modern Times
Traditional Medicinal Plants and Malaria
Merlin Willcox, Gerard Bodeker, and Philippe Rasoanaivo
CRC PRESS

Friday, 30 November, 2001, 08:49 GMT

Medicinal plant 'fights' Aids

Not just a pretty plant

By Carolyn Dempster in Johannesburg

A South African indigenous medicinal plant may hold the key to the treatment of millions of poor people living with HIV and Aids, helping them relieve the symptoms of Aids.

For the first time in South Africa's medical history, the plant, Sutherlandia Frutescens, sub-species Microphylla, is to undergo clinical trials to assess its immune-boosting properties.

The Medical Research Council will conduct the trials early next year and results are expected within three to six months.

> **We are certainly not making the absurd claim that Sutherlandia is a cure-all or a cure for Aids**

WATCH/LISTEN ON THIS STORY

By Carolyn Dempster in Johannesburg
The San call it Insisa - the one that dispels the darkness

AIDS around the world

Regional picture
- Africa devastated
- European hotspots

Background
- What is Aids?
- Race to find a cure
- Aids drugs factfile

Case studies
- Argentina's young victims
- SA plant 'fights' Aids
- Bad blood in China
- Thai Aids fears
- Russia's crisis

CLICKABLE GUIDE
- Aids in Africa
- World at a glance

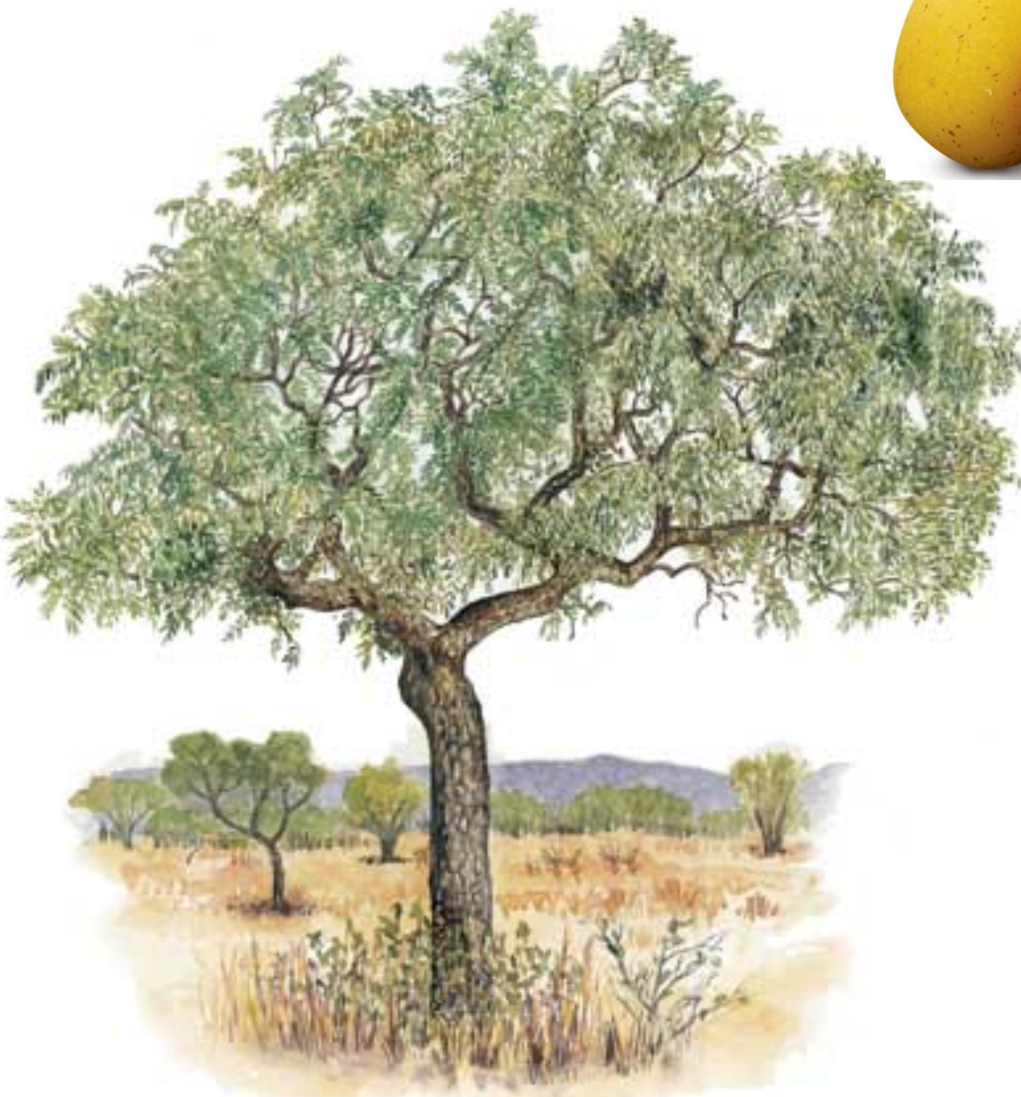
TALKING POINT
- Is enough being done to combat Aids?

See also:
- 27 Nov 01 | Africa
Hand out Aids drug says SA judge

You open, you pay!

Vitellaria paradoxa

Sclerocarya birrea



http://slowvelder.wordpress.com/tag/marula/

Non-Timber Forest Products

The value of wild plant harvest

- Up to 300 million people annually earn part or all of their livelihood and food from forests.

- Nearly US$90 billion in non-timber forest products harvested per year.

- 80% of world population relies upon medicinal plants for their primary healthcare.

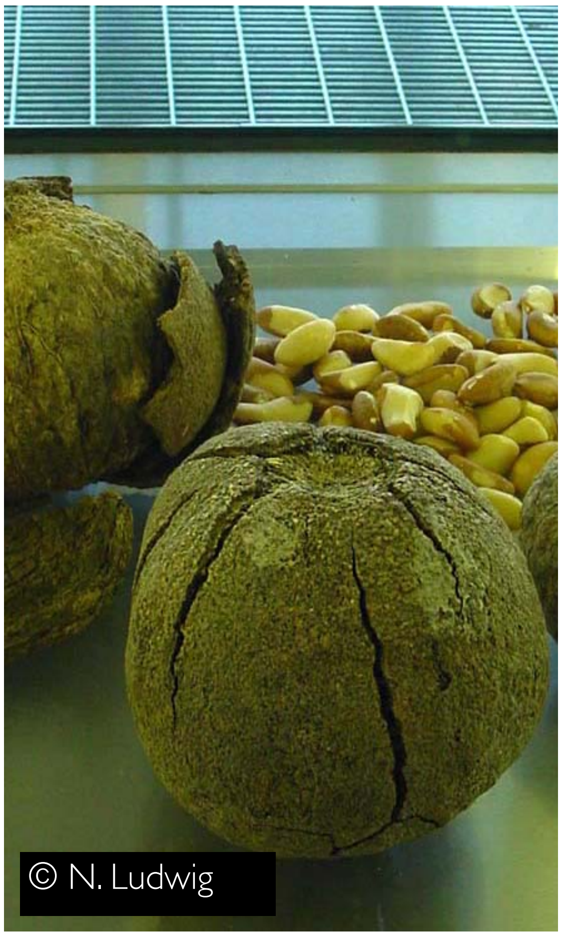
Ecological Society of America

Pimentel et al. 1997, Human Ecology 25: 91-120

How sustainable is our current use of forest resources?

Over-exploitation

Bertholletia excelsa, Brazil nuts



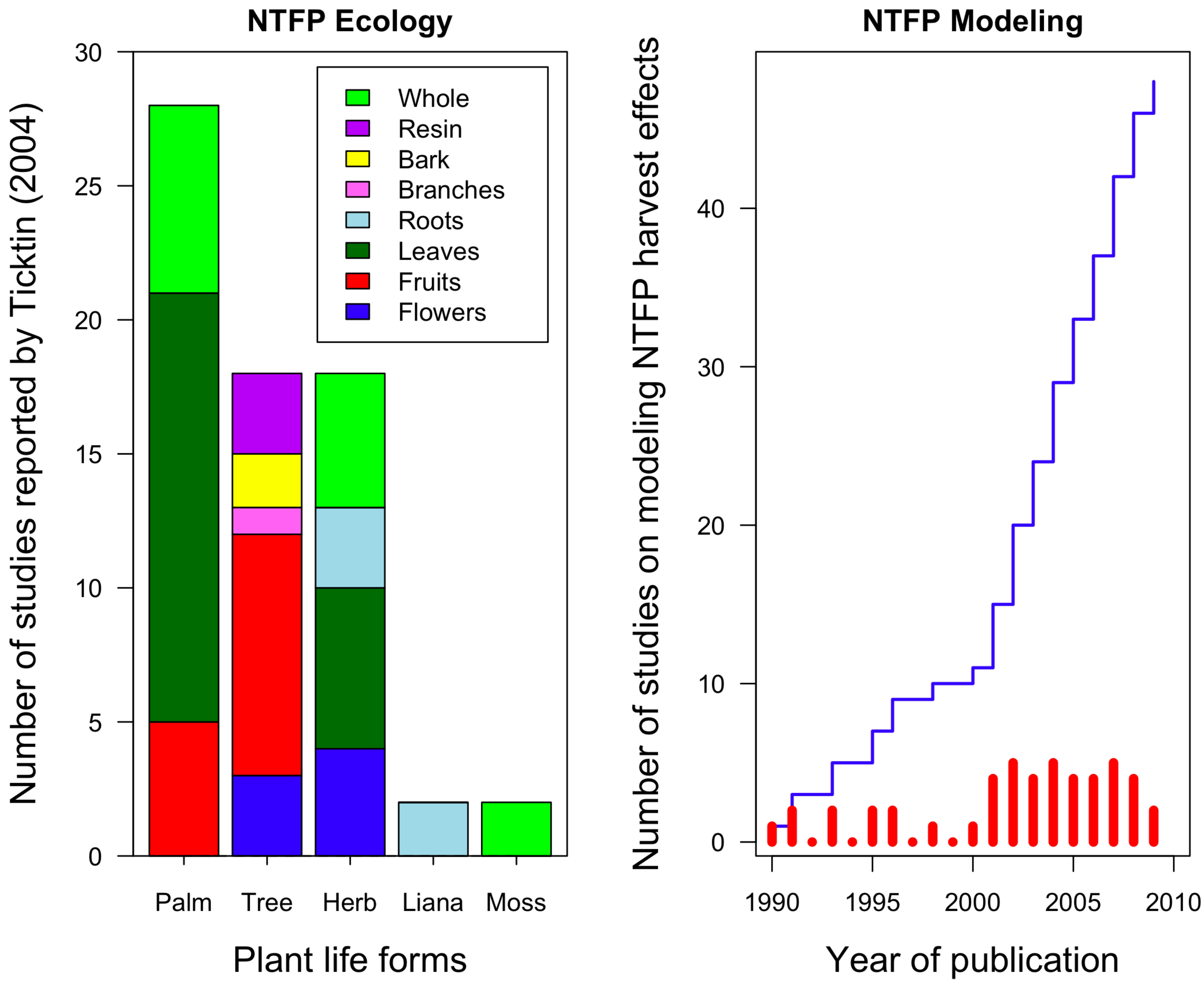
Peres et al. 2003, Science 302: 2112-4

Warburgia salutaris, Bark

Botha 2004, Biodiv & Cons 13: 1675-98

Prunus africana, Bark

Cunningham & Mbenkum. 1993. UNESCO



Ticktin (2004) J. Appl. Ecol. 41: 11-21

- Are species more resilient to harvest in less stressful environments (moist, nutrient rich, etc.)?

- How do you quantify sustainability of use when environmental conditions are changing (testing I.I.D. versus Markovian environments)?

Harvest matrix models

$$\mathbf{n}(t+1) = \mathbf{HAn}(t)$$

where **H**=diag(h_i,…. h_s), and **A** is a s×s matrix

h_i is the proportion of stage *i* surviving harvest

For harvest to be sustainable, the dominant eigenvalue of **HA** must be ≥1

Context and Data

Khaya senegalensis, **Mahogany**

Benin

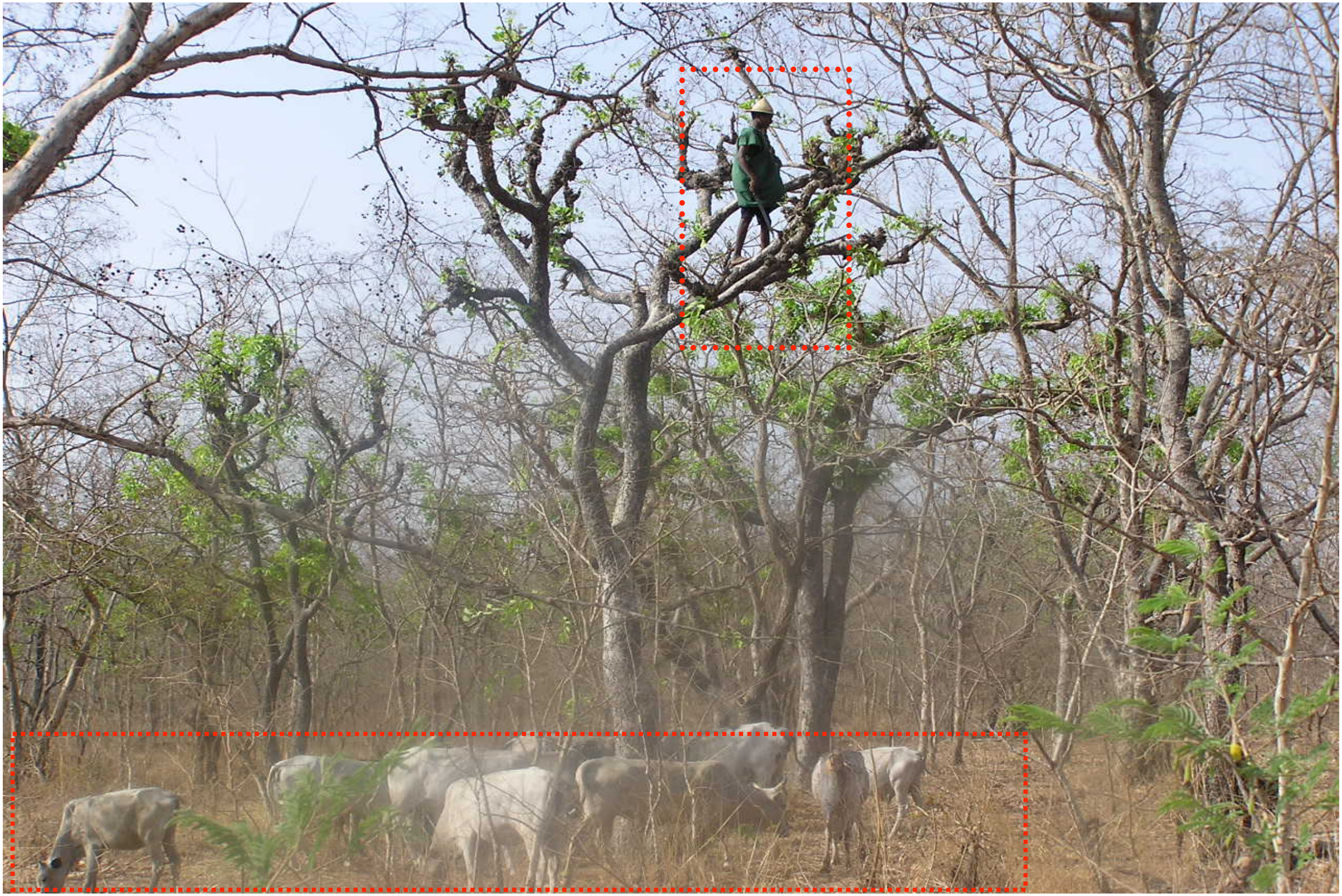
Areas: 114, 763 Km^2
Population (2010): 9.05 million
GDP (2009): $1,500 per capita
Cotton: 40% of GDP
70% of export

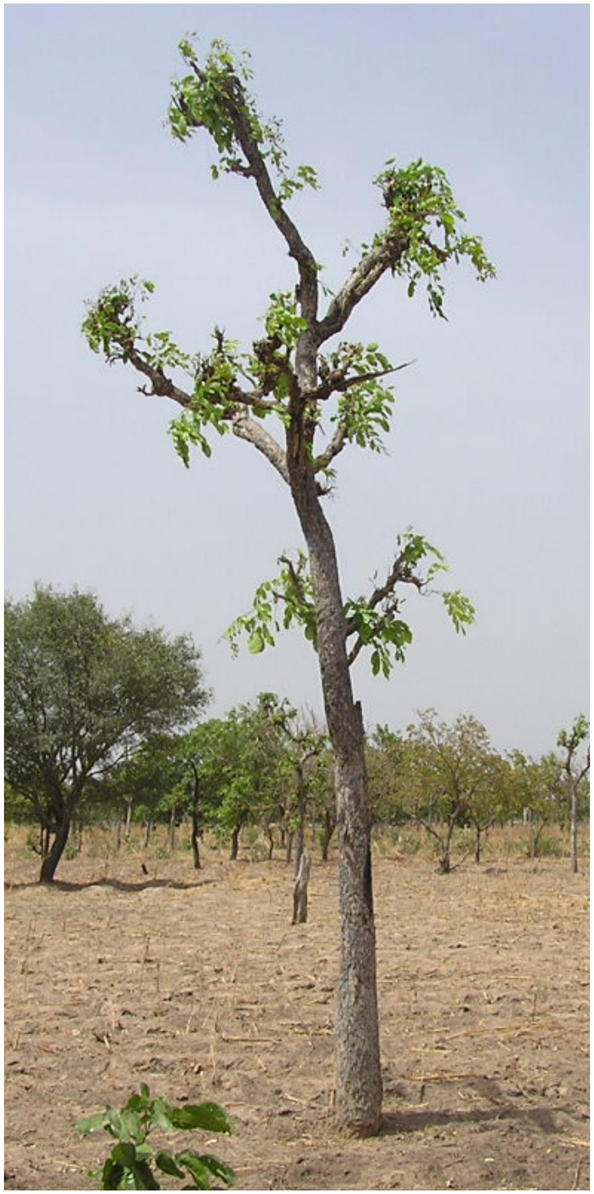
Bierschenk *et al.* (2003) *Dev. Policy Review* 21:161-78; US State Dept. (2010)

mahogany timber

grazing

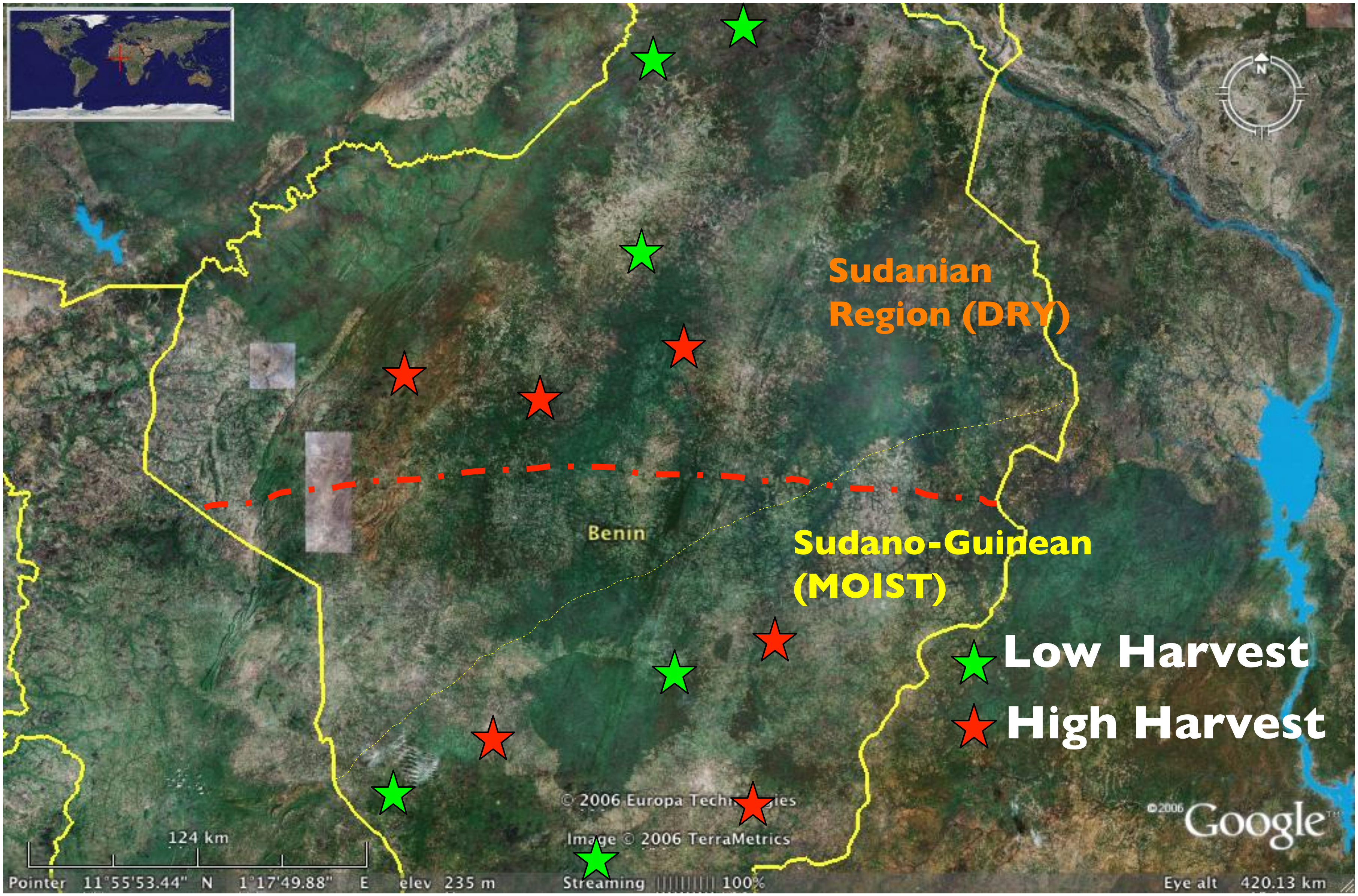
Khaya senegalensis: source of **fodder** for cattle

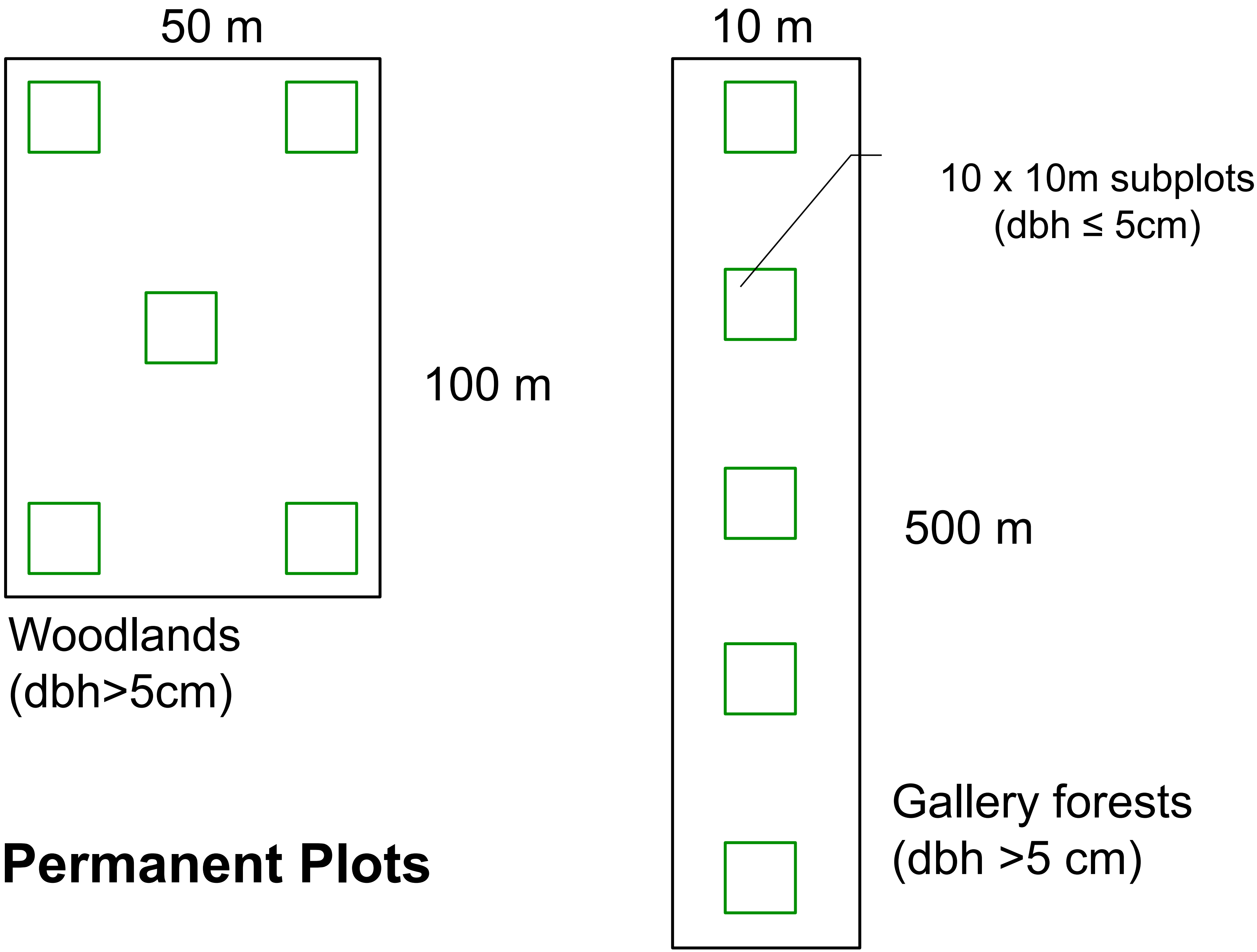




Gaoue & Ticktin 2007.
Biological Conservation

Study design



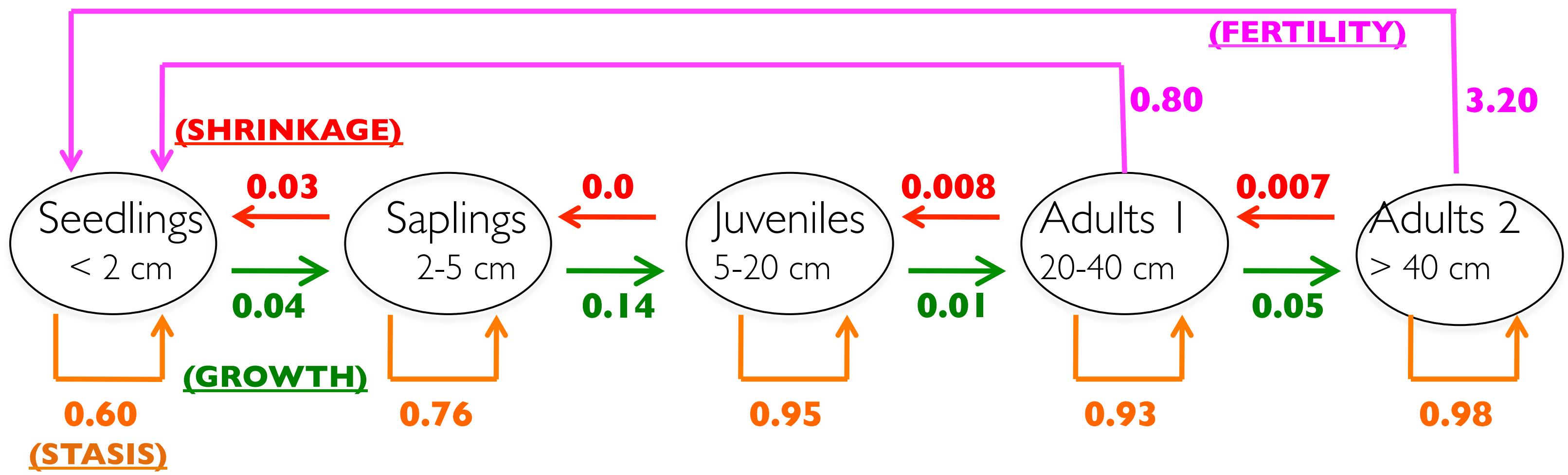


Permanent Plots

Tagging individuals

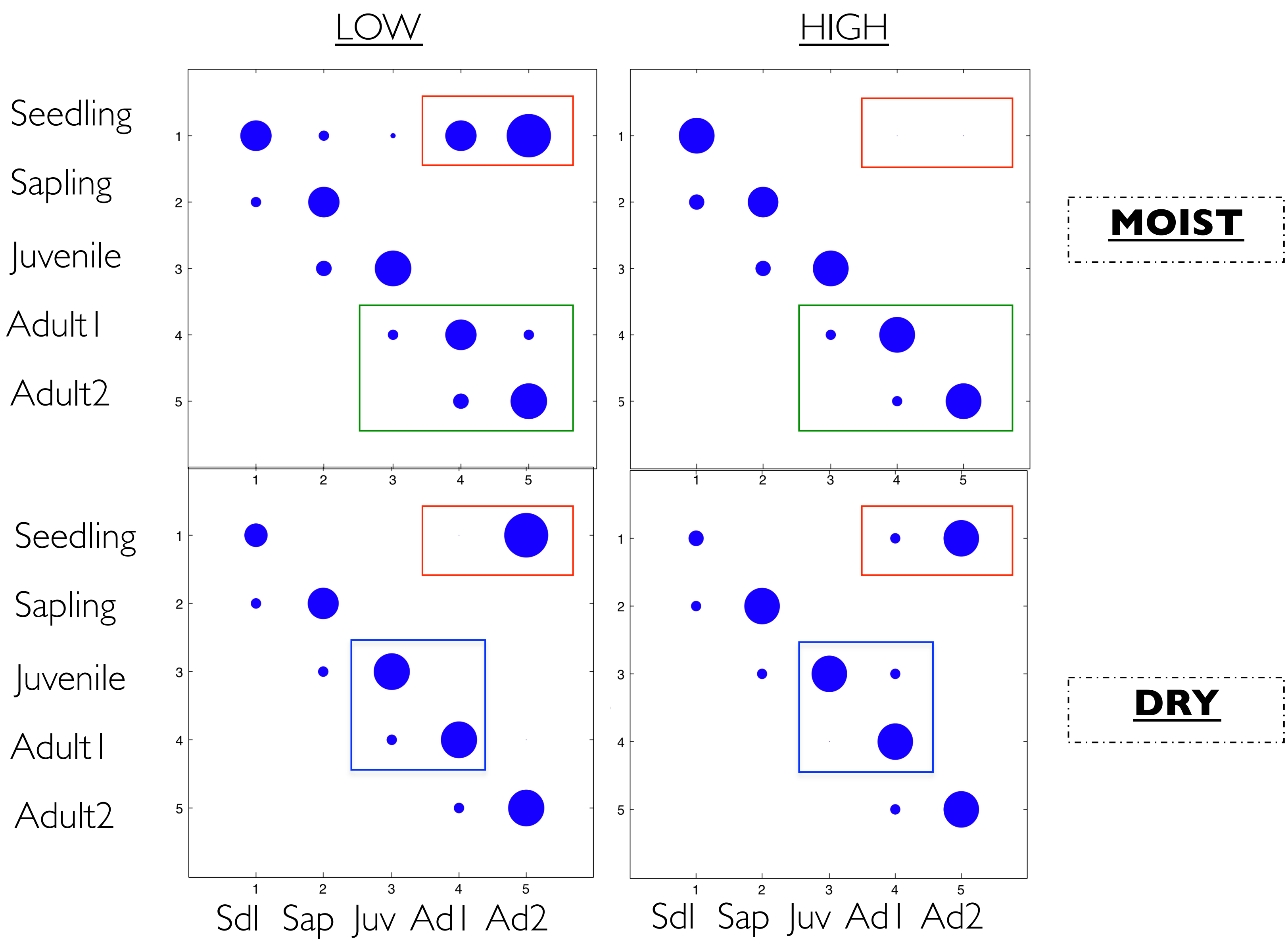
DBH, Height, # of fruits, seeds, seedlings…

Khaya **Population Matrix "A"**



	Seedling	Sapling	Juvenile	Adult 1	Adult 2
Seedling	0.60	0.03	0	0.80	3.20
Sapling	0.04	0.76	0	0	0
Juvenile	0	0.14	0.95	0.008	
Adult 1	0	0	0.01	0.93	0.007
Adult 2	0	0	0	0.05	0.98

Khaya **harvest matrices**



Ecological variation, stochasticity and the sustainability of harvest

Lefkovitch (stage-based) matrix model

$$\mathbf{n}(t+1) = \mathbf{A}\mathbf{n}(t)$$

$$\begin{pmatrix} n_1 \\ n_2 \\ n_3 \\ n_4 \end{pmatrix}(t+1) = \begin{pmatrix} P_1 & R_2 & F_3 & F_4 \\ G_1 & P_2 & 0 & 0 \\ 0 & G_2 & P_3 & 0 \\ 0 & 0 & G_3 & P_4 \end{pmatrix}\begin{pmatrix} n_1 \\ n_2 \\ n_3 \\ n_4 \end{pmatrix}(t)$$

λ: population growth rate

Harvesting: deterministic model

$$n(t+1) = \mathbf{A}n(t)$$

LLLLLLLLLLLLLLLLLLLLLLLLLLLLL

MMMMMMMMMMMMMMMMMMM

HHHHHHHHHHHHHHHHHHHHH

Stochastic matrix population models

$$\mathbf{n}(t) = \mathbf{A}(t)\mathbf{n}(t-1)$$

$$\mathbf{n}(t) = \mathbf{A}_{t-1}\mathbf{A}_{t-2}\ldots\mathbf{A}_0\mathbf{n}_0$$

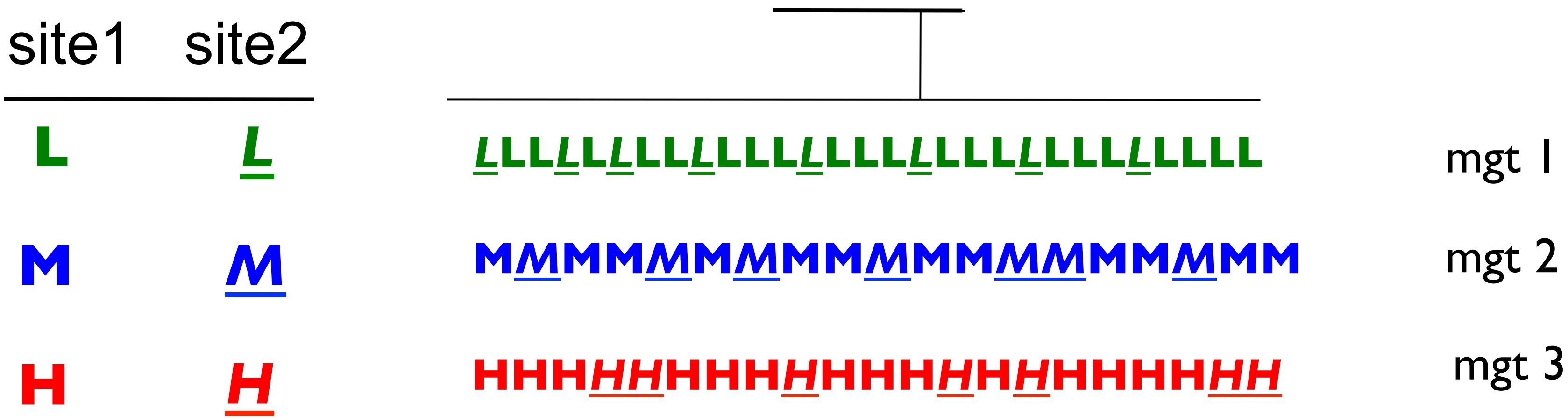
$$\begin{pmatrix} n_1(t) \\ n_2(t) \\ n_3(t) \\ n_4(t) \end{pmatrix} = \begin{pmatrix} P_1(t) & 0 & F_3(t) & F_4(t) \\ G_1(t) & P_2(t) & 0 & 0 \\ 0 & G_2(t) & P_3(t) & 0 \\ 0 & 0 & G_3(t) & P_4(t) \end{pmatrix} \begin{pmatrix} n_1(t-1) \\ n_2(t-1) \\ n_3(t-1) \\ n_4(t-1) \end{pmatrix}$$

$$\log \lambda_S = \lim_{t\to\infty} \frac{1}{t} \log \left\| \mathbf{A}_{t-1}\mathbf{A}_{t-2}\ldots\mathbf{A}_0\mathbf{n}_0 \right\|$$

Logλ_s is the stochastic population growth rate.

Harvesting: stochastic I.I.D. model

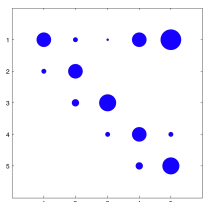
$$n(t) = \underline{\mathbf{A}(t)}\, n(t-1)$$



Harvesting as Markov Process

Harvest states

L



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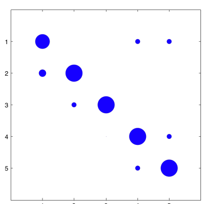

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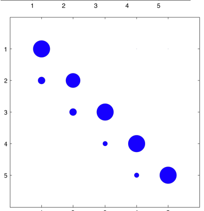


$$\mathbf{n}(t) = \underline{\mathbf{A}(t)}\mathbf{n}(t-1)$$

HHHHHHLLLLLMMMMMHHHLLLL mgt 1

LLLLLLMMMMMMMHLLLLLHLMML mgt 2

. .

. .

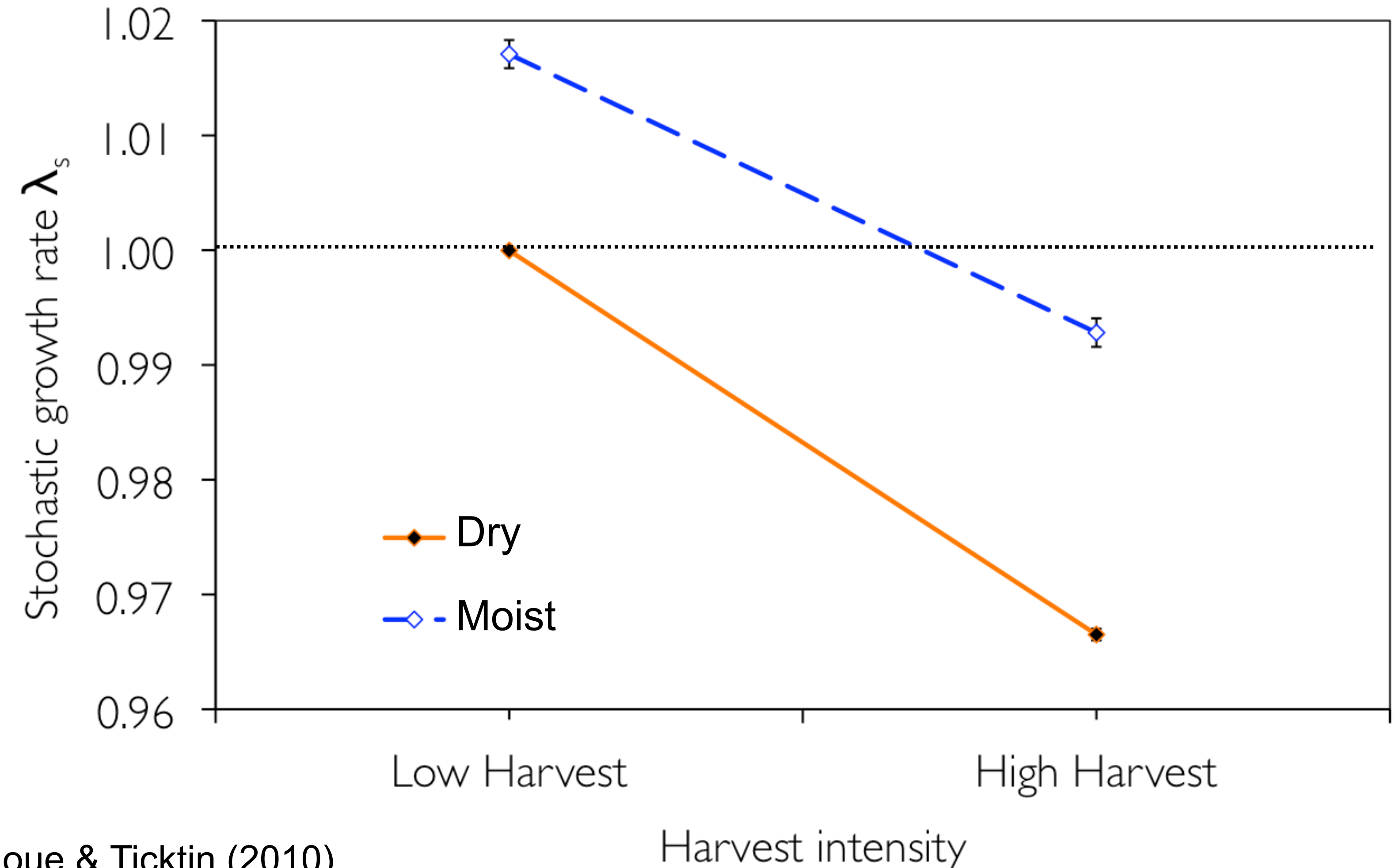
HHMHMHMLLHLMLMLMLHHHLMH mgt 36

$$\log \lambda_S = \lim_{t\to\infty} \frac{1}{t} \log \left\| \mathbf{A}_{t-1}\mathbf{A}_{t-2}\ldots\mathbf{A}_0\mathbf{n}_0 \right\|$$

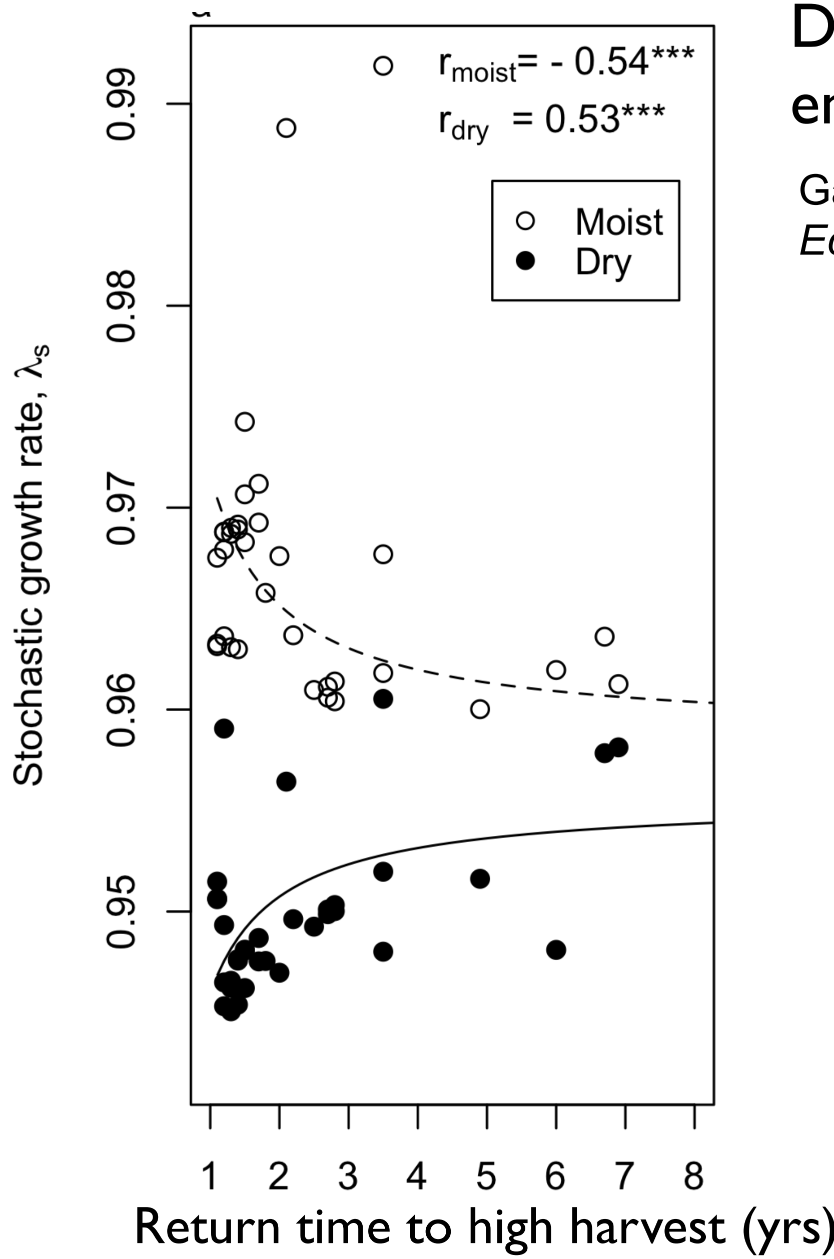
Caswell 2001

Stochastic (i.i.d.) population dynamics

(for a given harvest level and climate, at each time step, matrices were drawn at random with equal probability)



Gaoue & Ticktin (2010)
Conservation Biology



Dynamics in Markovian environments

Gaoue, Horvitz & Ticktin (2011)
Ecological Applications

Asymptotic growth rates underestimate the transient response to harvest

ECOLOGY LETTERS
Ecology Letters, (2011) doi: 10.1111/j.1461-0248.2011.01659.x

REVIEW AND SYNTHESIS

A framework for studying transient dynamics of population projection matrix models

Iain Stott,[1] Stuart Townley[2] and David James Hodgson[1]*

Abstract
Empirical models are central to effective conservation and population management, and should be predictive of real-world dynamics. Available modelling methods are diverse, but analysis usually focuses on long-term

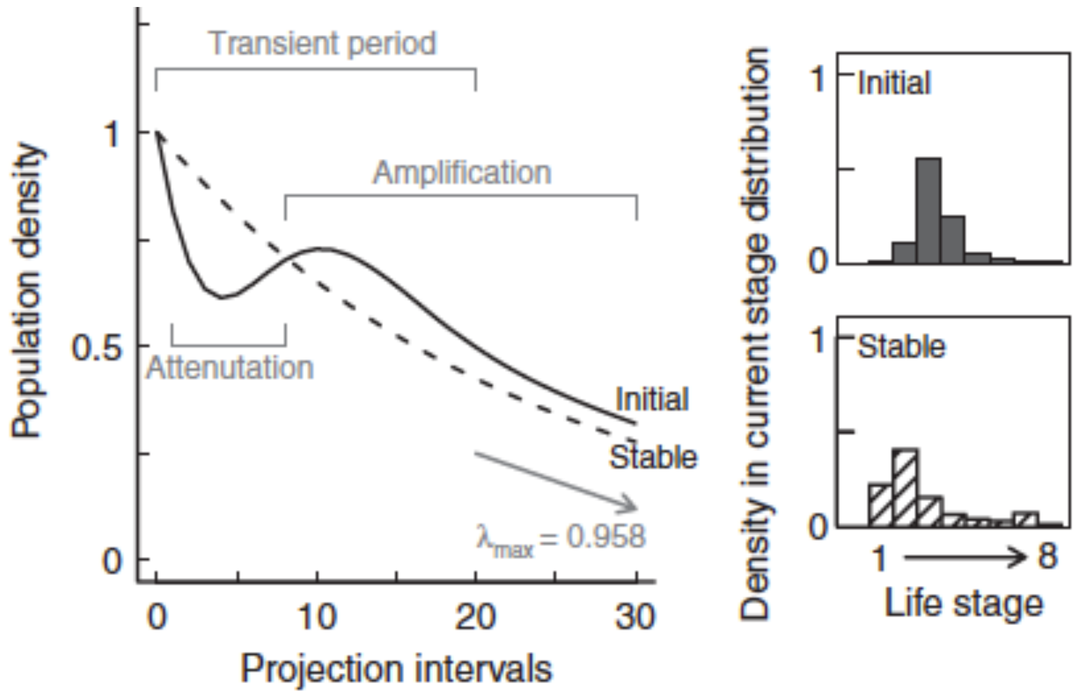


Figure 1 Illustration of transient population dynamics arising from a density-independent, time-invariant PPM model. A population with stable demographic distribution (dashed line; hatched bar plot) declines at a rate equal to λ_{max} each time interval. However, real-world populations have initial demographic distributions that differ from the stable demographic distribution (solid line; grey bar plot) and exhibit transient dynamics.

Ecology Letters, (2007) **10**: 1143–1153 doi: 10.1111/j.1461-0248.2007.01108.x

LETTER

Time, transients and elasticity

C. V. Haridas* and Shripad Tuljapurkar

Abstract
How does life history affects the short-term elasticities of population growth rate? We decompose short-term elasticity as a sum of (i) the effect of the perturbation in rates on

Ecology Letters, (2007) **10**: 1–15 doi: 10.1111/j.1461-0248.2006.01001.x

IDEA AND PERSPECTIVE

Sensitivity analysis of transient population dynamics

Hal Caswell*

Abstract
Short-term, transient population dynamics can differ in important ways from long-term

Journal of Applied Ecology
British Ecological Society
Journal of Applied Ecology doi: 10.1111/j.1365-2664.2010.01801.x

REVIEW

Matrix models for a changeable world: the importance of transient dynamics in population management

Thomas H. G. Ezard[1]*, James M. Bullock[2], Harmony J. Dalgleish[3], Alexandre Millon[4], Fanie Pelletier[5,6], Arpat Ozgul[1] and David N. Koons[3]

Journal of Ecology
British Ecological Society
Journal of Ecology doi: 10.1111/j.1365-2745.2011.01845.x

Distance to stable stage distribution in plant populations and implications for near-term population projections

Jennifer L. Williams[1,2]*, Martha M. Ellis[3], Mary C. Bricker[2]†, Jedediah F. Brodie[3] and Elliott W. Parsons[3]

Ecology, 90(7), 2009, pp. 1878–1890

Model complexity affects transient population dynamics following a dispersal event: a case study with pea aphids

Brigitte Tenhumberg,[1,4] Andrew J. Tyre,[2] and Richard Rebarber[3]

vol. 156, no. 3 the american naturalist september 2000

Population Numbers Count: Tools for Near-Term Demographic Analysis

Gordon A. Fox[1,*] and Jessica Gurevitch[2,†]

Journal of Applied Ecology 2007
44, 1243–1251

Predicting transient amplification in perturbed ecological systems

STUART TOWNLEY*, DAVID CARSLAKE†, OWEN KELLIE-SMITH*, DOMINIC MCCARTHY* and DAVID HODGSON†

ELSEVIER
Review *TRENDS in Ecology and Evolution* Vol.19 No.1 January 2004 39

Transients: the key to long-term ecological understanding?

Alan Hastings

ology, 88(11), 2007, pp. 2857–2867

POPULATION INERTIA AND ITS SENSITIVITY TO CHANGES IN VITAL RATES AND POPULATION STRUCTURE

David N. Koons,[1,2,5] Randall R. Holmes,[3] and James B. Grand[4]

Lefkovitch matrix models

$$\mathbf{n}(t+1) = \mathbf{A}\mathbf{n}(t)$$

$$\begin{pmatrix} n_1 \\ n_2 \\ n_3 \\ n_4 \end{pmatrix}(t+1) = \begin{pmatrix} P_1 & R_2 & F_3 & F_4 \\ G_1 & P_2 & 0 & 0 \\ 0 & G_2 & P_3 & 0 \\ 0 & 0 & G_3 & P_4 \end{pmatrix}\begin{pmatrix} n_1 \\ n_2 \\ n_3 \\ n_4 \end{pmatrix}(t)$$

Elasticity of asymptotic dynamics

$$s_{ij} = \frac{\partial \lambda}{\partial a_{ij}} = \frac{v_i w_j}{v^T w} \qquad (1)$$

w = right eigenvector
v = left eigenvector

$$e_{ij} = \frac{\partial(\log \lambda)}{\partial(\log a_{ij})} = \left(\frac{a_{ij}}{\lambda}\right)\left(\frac{\partial \lambda}{\partial a_{ij}}\right) = \left(\frac{a_{ij}}{\lambda}\right) s_{ij} \qquad (2)$$

Transient dynamics: *r*(*t*) and elasticity

(Caswell 2007. Ecology Letters 10:1-15)

$$r(t) = \log N(t+1) - \log N(t) \tag{1}$$

$$\Delta r(t) = r(t)_{Low} - r(t)_{High} \tag{2}$$

$$\frac{\mathrm{d}\, r(t)}{\mathrm{d}\boldsymbol{\theta}^{\mathrm{T}}} = \frac{\mathbf{c}^{\mathrm{T}}}{N(t+1)} \frac{\mathrm{d}\,\mathbf{n}(t+1)}{\mathrm{d}\boldsymbol{\theta}^{\mathrm{T}}} - \frac{\mathbf{c}^{\mathrm{T}}}{N(t)} \frac{\mathrm{d}\,\mathbf{n}(t)}{\mathrm{d}\boldsymbol{\theta}^{\mathrm{T}}} \tag{3}$$

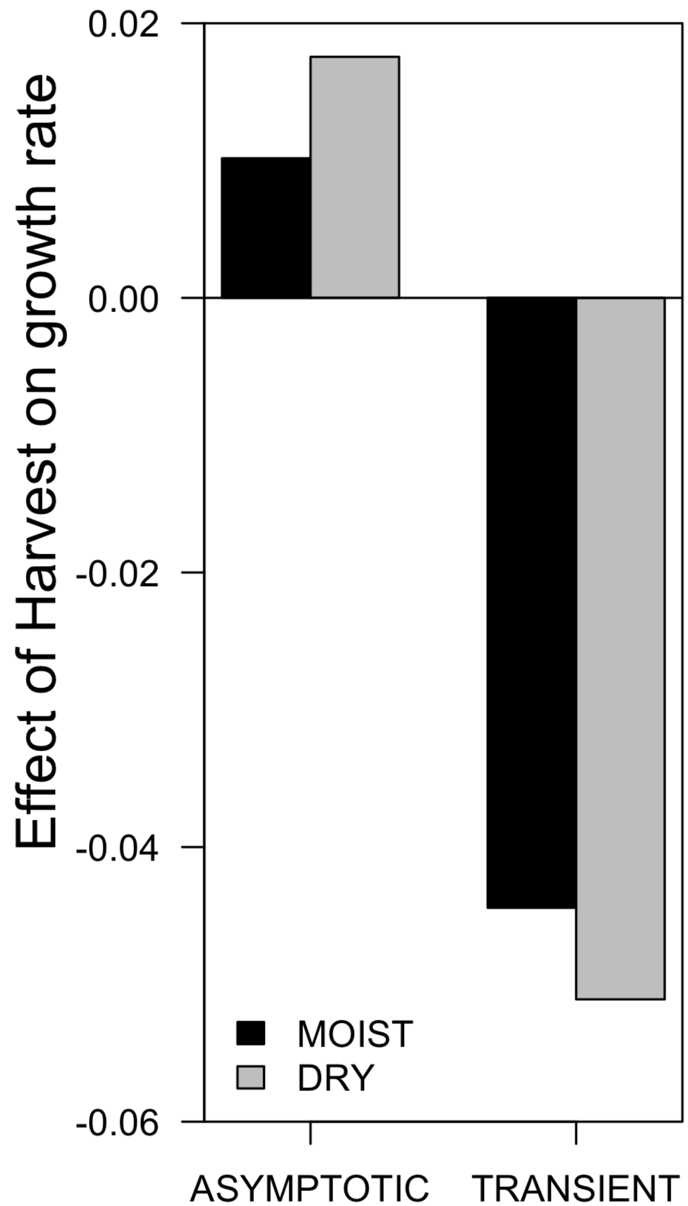
$$e_{r(t)} = \frac{\boldsymbol{\theta}_j}{r(t)} \frac{dr(t)}{d\boldsymbol{\theta}_j} \tag{4}$$

You can derive $\mathrm{d}\,\mathbf{n}(t+1) / \mathrm{d}\boldsymbol{\theta}^{\mathrm{T}}$ from eq. 5

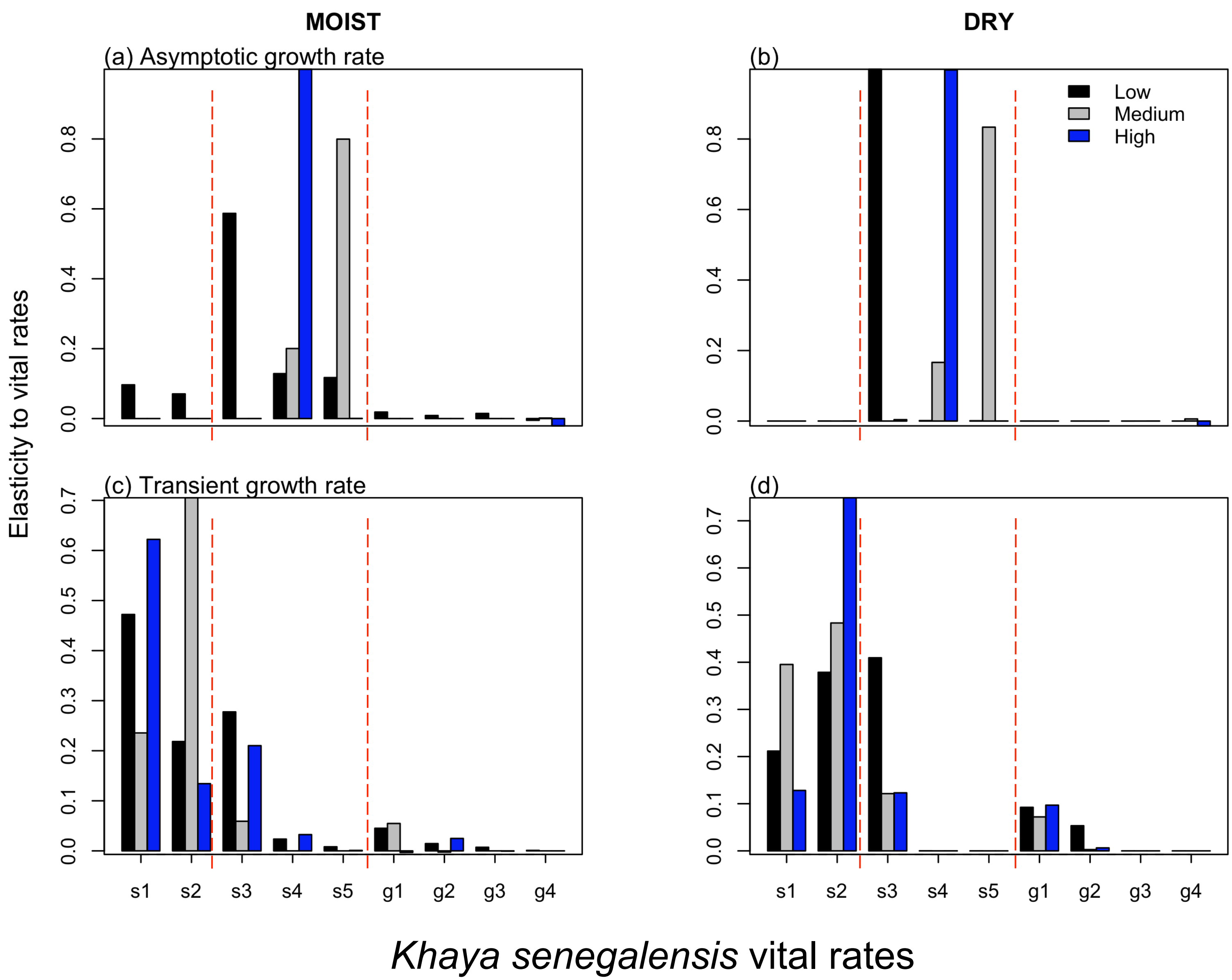
$$\frac{\mathrm{d}\,\mathbf{n}(t+1)}{\mathrm{d}\boldsymbol{\theta}^{\mathrm{T}}} = \mathbf{A}\frac{\mathrm{d}\,\mathbf{n}(t)}{\mathrm{d}\boldsymbol{\theta}^{\mathrm{T}}} + (\mathbf{n}^{\mathrm{T}}(t) \otimes \mathbf{I}_{\mathrm{s}}) \frac{\mathrm{d}\, vec\mathbf{A}}{\mathrm{d}\boldsymbol{\theta}^{\mathrm{T}}} \tag{5}$$

$t = 10$

Effect of harvest on asymptotic vs. transient



Elasticity of short- vs. long term dynamics



Journal of Applied Ecology

Journal of Applied Ecology 2011, **48**, 815–826 doi: 10.1111/j.1365-2664.2011.01999.x

What do matrix population models reveal about the sustainability of non-timber forest product harvest?

Isabel B. Schmidt[1,2]*†, Lisa Mandle[1]†, Tamara Ticktin[1] and Orou G. Gaoue[3]

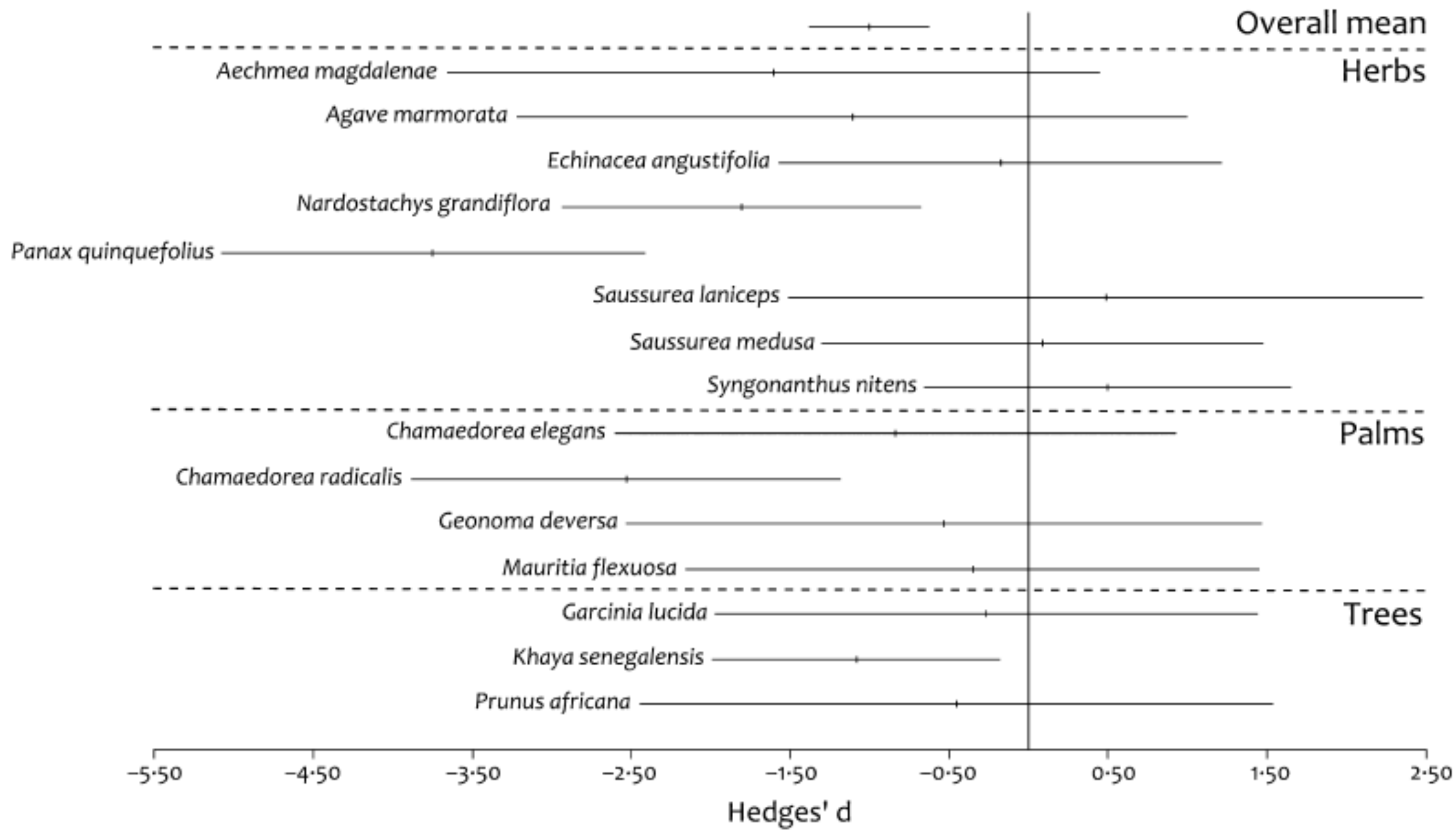


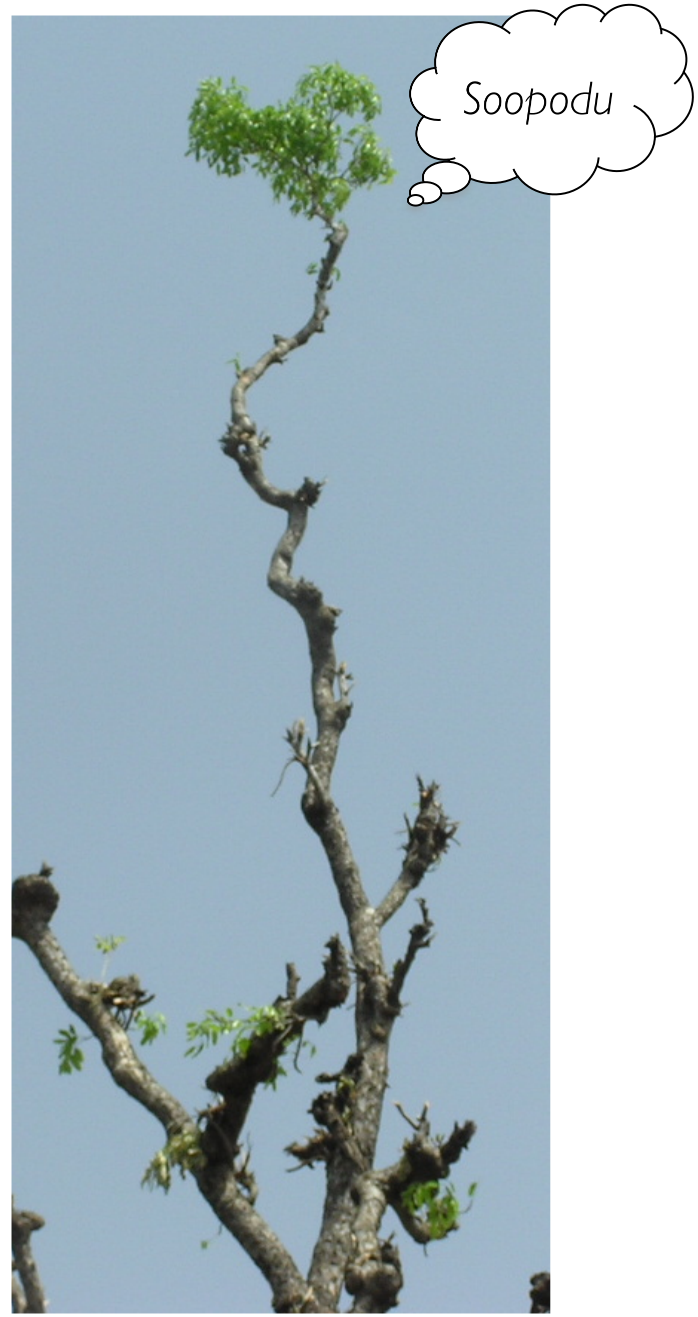
Fig. 1. There is a significant effect of harvest on projected population growth rates [ln(λ)] across 15 non-timber forest product species. When considered individually, only four studies – including two herbs, one palm, and one tree – show a significant decline in projected growth rates in harvested populations.

Summary

1. Harvest of foliage from African mahogany is not sustainable. Effects of harvest is even stronger in populations in stressful environments or when harvesting sequence mimicked reality.

2. Effect of harvest on population dynamics is stronger in short-term than long-term.

3. Strategy to enhance survival at early life stage is the best approach to maintain population in the short term but long term persistence require enhancing survival of adults reproductive.



Gaoue & Ticktin (2009)
Economic Botany 63:256-270

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Acknowledgments

Funding: Vavilov Frankel Fellowship – Bioversity International, International Foundation for Science, British Ecological Society, African Forest Research Network, National Foundation for Science, EECB Program at the University of Hawaii at Manoa.

Field Assistance: Bara Evariste, Yacoubou Boni, Ulysse Korogone, Taiba Madougou, Hugues Akpona, Aziz Guerra, Yarou Salomon, Honore Biaou, Hermann Ereeq, Aboubakar Bani Bio, Marcelin Agbessi, Kader Baba Cheick, Samba Tobou, Rachidi Saliou.

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