Using Participatory System Dynamics Modeling of Agricultural-Environmental Systems in a Rural Development Context

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Innovations in Collaborative Modeling
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Overview

- Project objectives
- Major trends in Zambia
- Participatory system dynamics modeling
- Results: models of deforestation
  - National- and provincial-level baseline
  - Drivers of deforestation
  - Scenarios
    - Maize yield increase
    - Policy scenarios

Acknowledgements: Philip Grabowski, Naomi Sakana, & Kurt Waldman

Global Context for Project

- World population to reach 9 billion by 2050
- Global need to increase food production 50-70%
- Yet, agriculture is
  - largest emitter of greenhouse gases (~30-35% of total)
  - largest consumer of freshwater resources
  - largest user of land resources (~38% of total)
  - greatest contributor to biodiversity losses

Foley et al., 2011

Global Context for Project (*continued*)

- Agricultural intensification
  - Increase food production
  - Without increasing deforestation
  - Limiting impacts to biodiversity
  - Adapting/mitigating the impacts of climate change
- Sustainable intensification
- What are the impacts and linkages on the landscape?

Project Objectives

- Project: Impact of Sustainable Intensification on Landscapes and Livelihoods (SILL)
- Examine the potential for ***sustainable intensification*** of agriculture to contribute to forest conservation in Zambia
- Pilot sites: Eastern and Lusaka Provinces, Zambia
- Participatory system dynamics modeling activities in 2014-15

Acknowledgements: Philip Grabowski, Naomi Sakana, & Kurt Waldman

Major Trends in Zambia

- Relatively low population density
- Population growth
  - Projected to triple by 2050 to 43 million, increase 10x by 2100
- High rates of urbanization
  - Increasing demand for food and energy
- High rates of deforestation
  - 150,000-300,000 ha/year
  - Leading cause of greenhouse gas emissions

Implications

- Food security – demand for food
- Demand for cropland
  - Conventional wisdom: practice of cultivating maize monoculture depletes soils
  - Farmers migrate to land abundant areas
  - Deforestation is driven by clearing land for agriculture
- Degraded soils
- Low non-farm rural employment

Agricultural Practices and Deforestation

- **Dominant narrative**: deforestation is mostly driven by smallholder farmers facing weak yields in degraded soils who abandon their fields and clear new land
- **Hypothesis**: sustainable intensification (SI) practices that increase yields or produce fuelwood will reduce deforestation pressures
  - *Conservation agriculture*: increased yields will reduce need for land conversion
  - *Agroforestry*: on-farm fuelwood production will reduce demand for forest resources


ZAMBIA
0 km 55 110 165 km
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National Capital (1,577,000 in 99)
over 200,000
over 100,000
over 50,000
other main city
other city
Chief town of province
D. R. OF THE CONGO
Kamina
Likasi
Lubumbashi
Congo
Lufira
Lake Tanganyika
Lake Mweru
Lake Mweru Wantipa
Kaputa
Bulaya
Kasaba Bay
Mpulungu
Mbala
Sunzu Mountain
Chiengi
Nchelenge
Mporokoso
Mbereshi
Kawambwa
Kapatu
Nakonde
Mbeya
LUAPULA
NORTHERN
Kasama
Nseluka
Isoka
Liwingu
Kashiba
Mambilima Falls
Mununga
Chinsali
Kasaba
Nsombo
Lake Bangweulu
Chambeshi
Mansa
Chilubi
Mofu
Mbati
Samfya
Chama
Twingi
Mpika
Chembe
Mukulu
Memorial Livingstone
Kapalala
Lundazi
Muchinga Mountains
Ikelenge
Mwinilunga
Solwezi
Mutanda
NORTH-WESTERN
Chililabombwe
Chingola
Mufulira
Kalulushi
Kitwe
Ndola
Luanshya
COPPERBELT
Mpongwe
Chavuma
Chizela
Kawana
Kasempa
Zambezi
Kabompo
Serenje
Kanona
Mfuwe
EASTERN
MALAWI
Chipata
Mkushi
Kapiri Mposhi
CENTRAL
Lukanga Swamp
Kabwe
Katete
Petauke
Lilongwe
Nyimba
Lukulu
Kaoma
Kalabo
Sikongo
Limulunga
Mongu
Mumbwa
WESTERN
LUSAKA
MOZAMBIQUE
Lake Cahora Bassa
Luangwa
Zambezi
Kafue
Chirundu
Namwala
Ngoma
Mazabuka
Kataba
Senanga
Sitoti
Shangombo
Monze
Siavonga
Tete
SOUTHERN
Pemba
Mulobezi
Choma
Chipepo
Lake Kariba
Ngonye Falls
Kalomo
Maamba
Sinazongwe
ZIMBABWE
Ngambwe Falls
Sesheke
Katima Mulilo
Mambova
Livingstone
Harare
BOTSWANA
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Participatory Systems Modeling

- Participatory system dynamics modeling was used to elicit stakeholder views of the system and how it operates, and to use that information to inform the construction of the model.
- It can be a useful tool for identifying the primary drivers of change in complex agro-ecological systems.
- The approach also allows for examining hypothetical or alternative scenarios.

Participatory Modeling Process

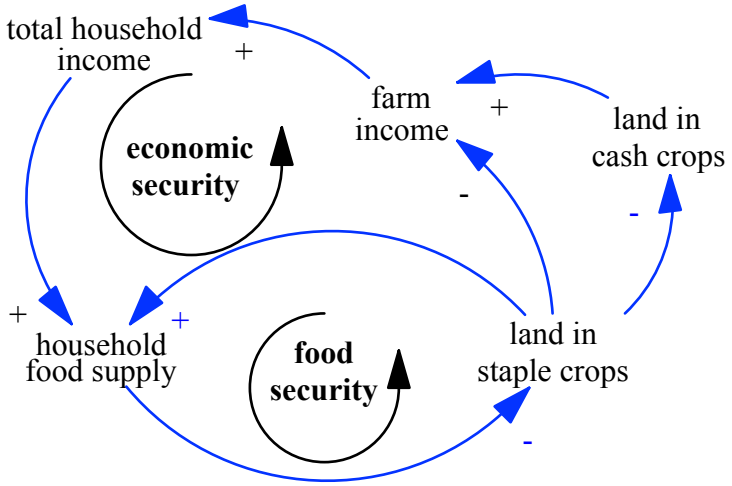
- Identify partners and stakeholders
- Introductory workshop (generate causal loop diagrams)
- Review literature and data sets
- Build national-level model of deforestation in Vensim®
- Participatory modeling workshop (refine parameters)
- Build provincial-level model (Eastern and Lusaka Prov.)
- Final workshop and report

- Total timeline: ~ 15 months (May 2014 – August 2015)

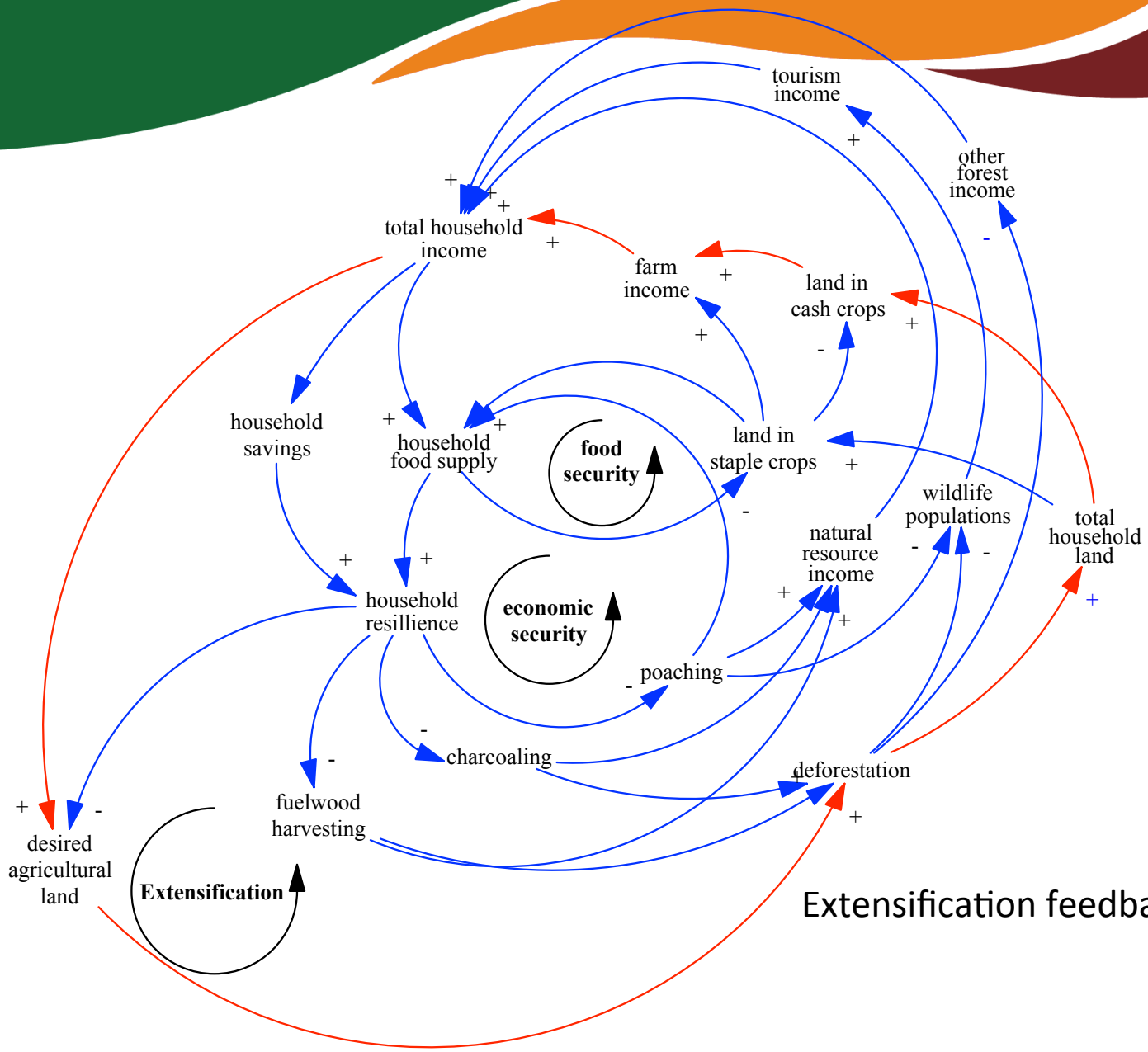
Participants

- Indaba Agricultural Policy Research Institute (IAPRI)
- BioCarbon Partners
- COMACO
- CIFOR
- CIMMYT
- ICRAF
- ICRISAT
- IITA
- Michigan State University
- South Luangwa Conservation Society
- The Nature Conservancy
- TGCC/TetraTech
- Total LandCare
- USAID
- University of Zambia
- WWF
- Zambia Agriculture Research Institute
- Zambia Carnivore Research
- Zambia Forestry Department

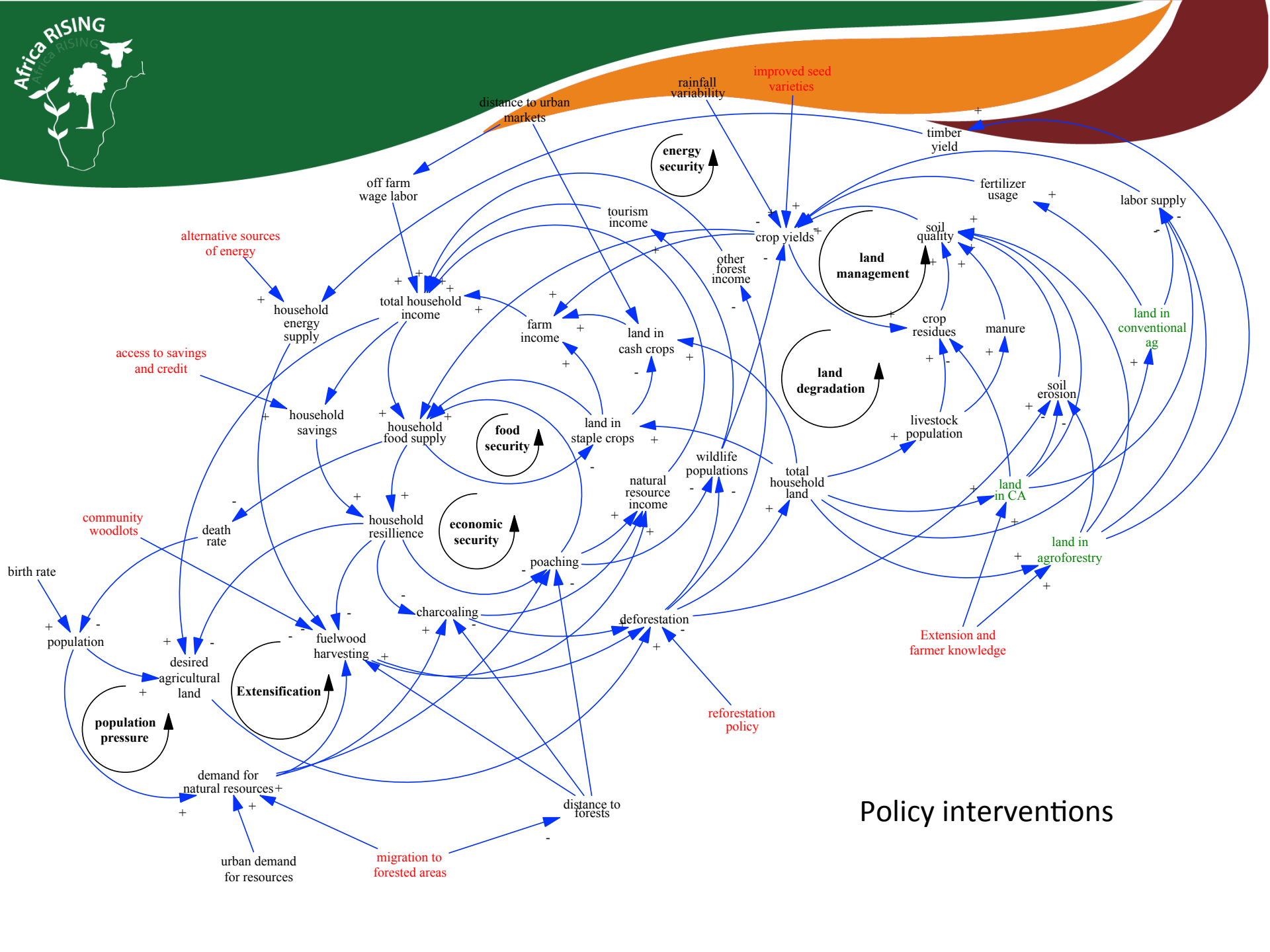
Causal Loop Diagrams



Economic security feedback loop



Extensification feedback loop


Africa RISING
distance to urban markets
rainfall variability
improved seed varieties
timber yield
energy security
off farm wage labor
fertilizer usage
labor supply
tourism income
crop yields
soil quality
alternative sources of energy
other forest income
land management
household energy supply
total household income
farm income
land in cash crops
crop residues
manure
land in conventional ag
access to savings and credit
land degradation
soil erosion
household savings
household food supply
food security
land in staple crops
livestock population
wildlife populations
total household land
natural resource income
land in CA
community woodlots
death rate
household resillience
economic security
poaching
land in agroforestry
birth rate
charcoaling
deforestation
population
fuelwood harvesting
Extension and farmer knowledge
desired agricultural land
Extensification
population pressure
reforestation policy
demand for natural resources
distance to forests
urban demand for resources
migration to forested areas
Policy interventions

Forests in Zambia

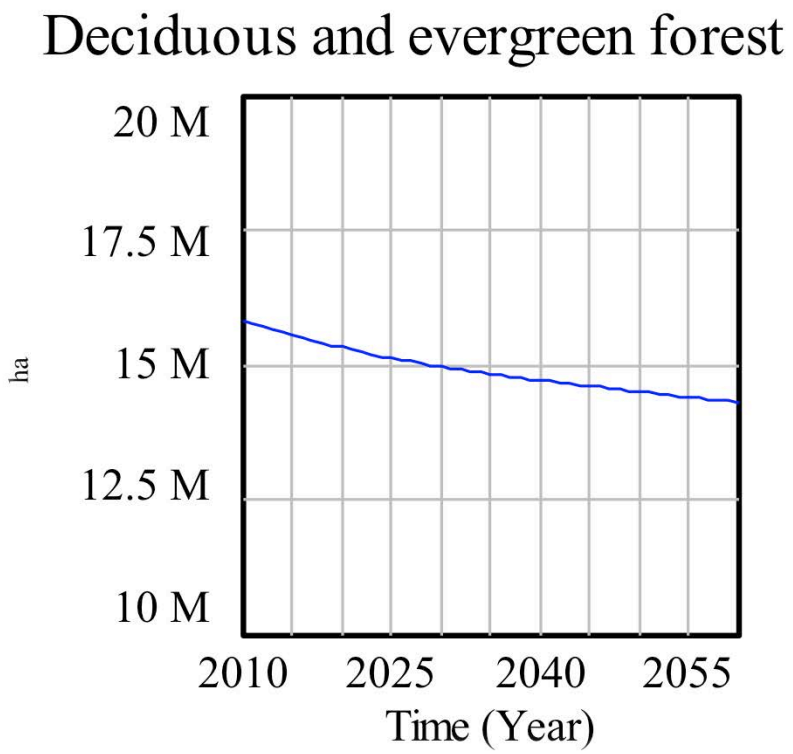
- Modeled drivers of deforestation
  - Integrated Land Use Assessment (FAO, 2008)
- Two types of forests represented in model:
  - Deciduous and evergreen forests
  - Miombo woodlands
- Forests resources used widely for multiple purposes
  - Urban households depend on charcoal for affordable cooking fuel
  - Rural households depend on fire wood for cooking fuel
  - Rural households may produce and sell charcoal as a coping strategy during periods of weak crop yields

Deforestation in Zambia

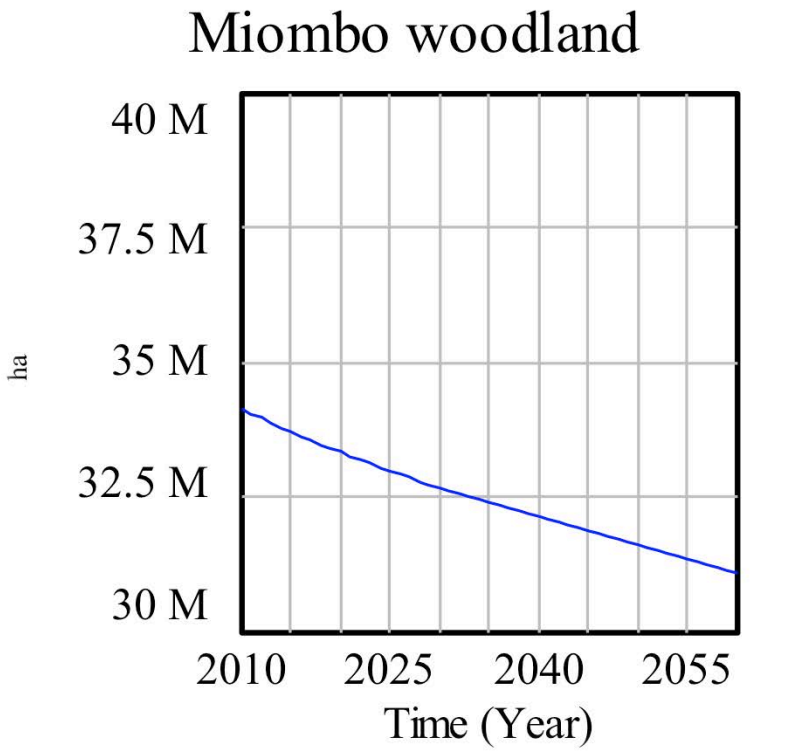
- Sources of deforestation represented in model:
  - Clearing land for agriculture
  - Charcoal production
  - Fuelwood collection
  - Home construction
  - Commercial timber

National-level Baseline Model

Forest Cover

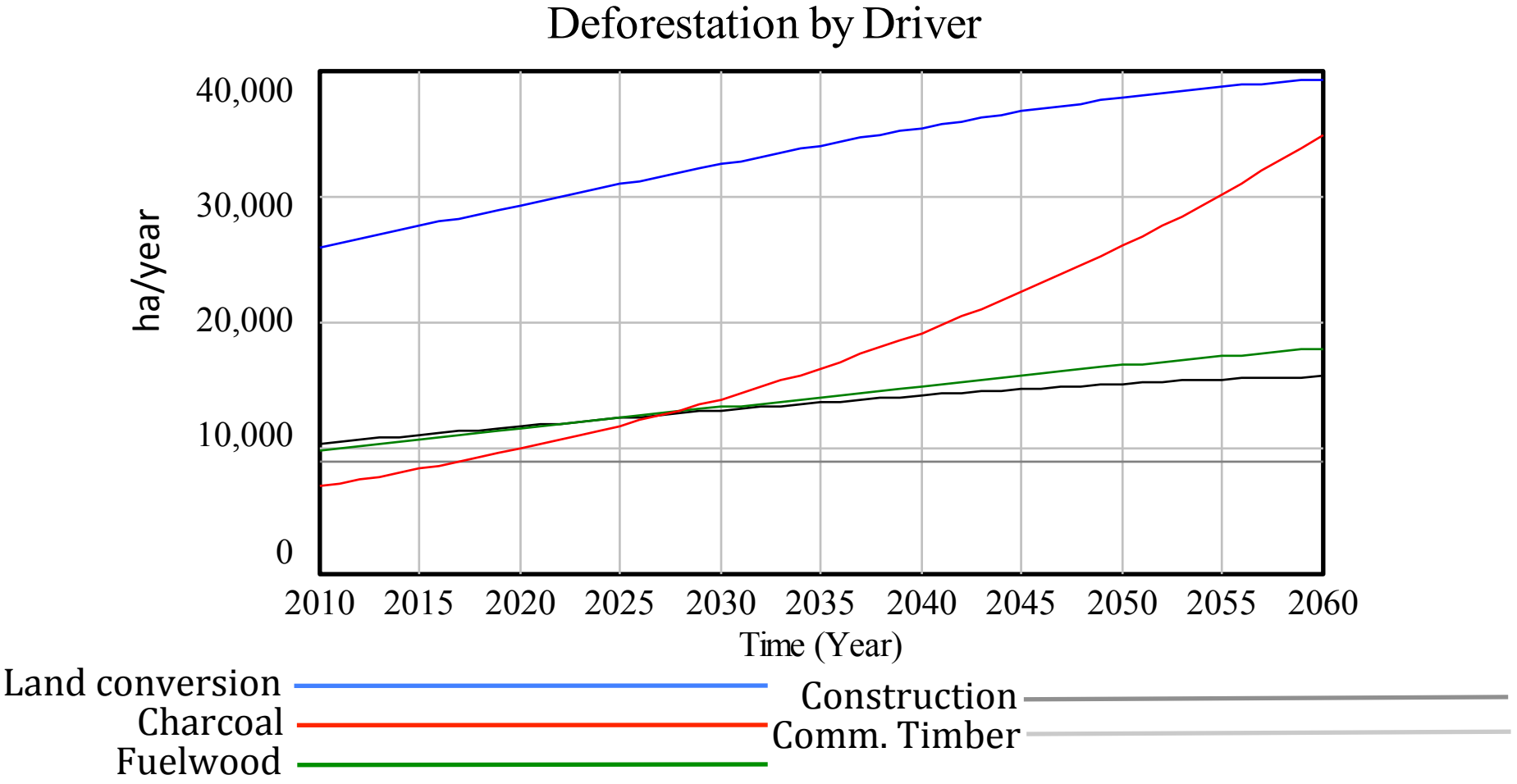


18% loss

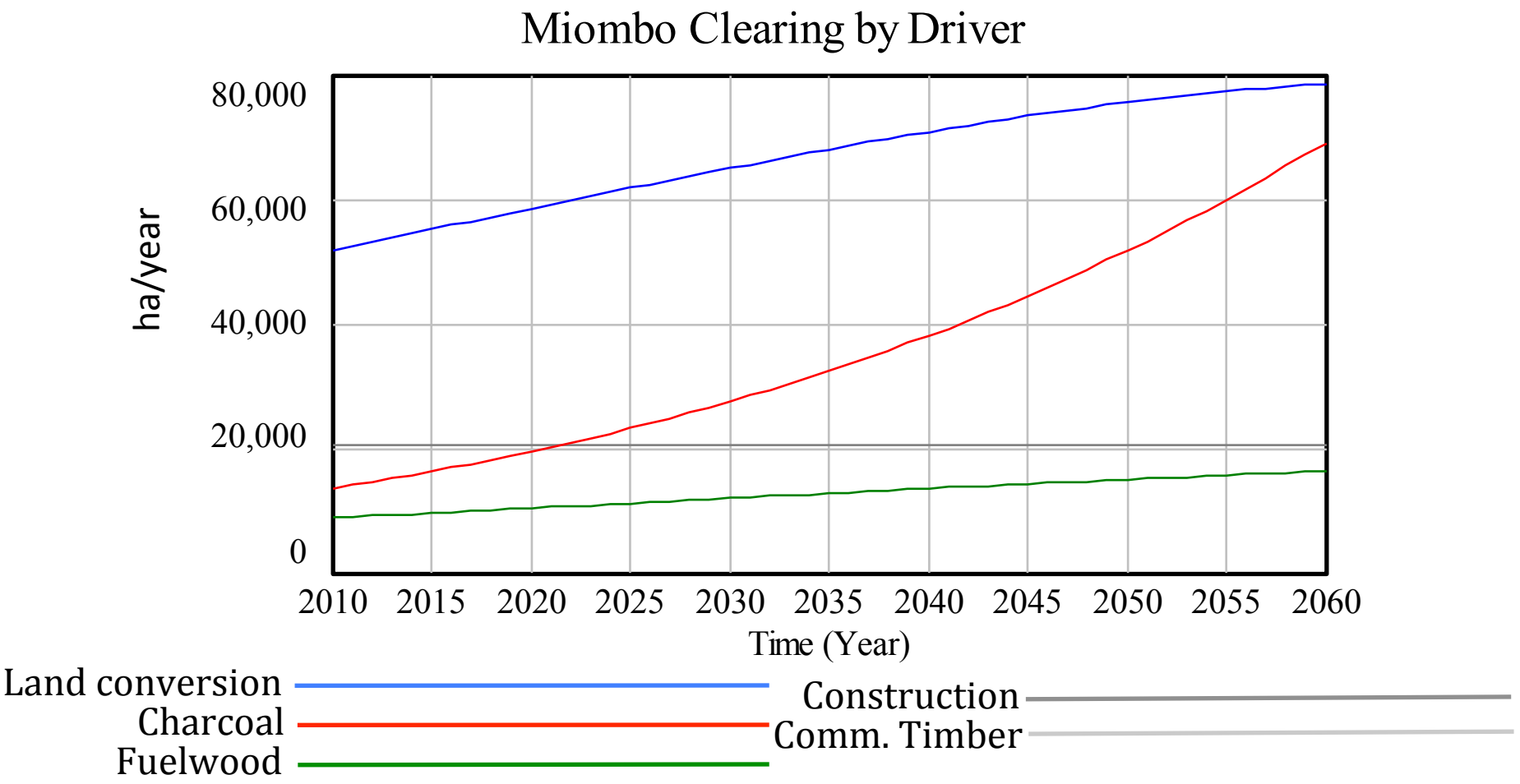


14% loss

National Model

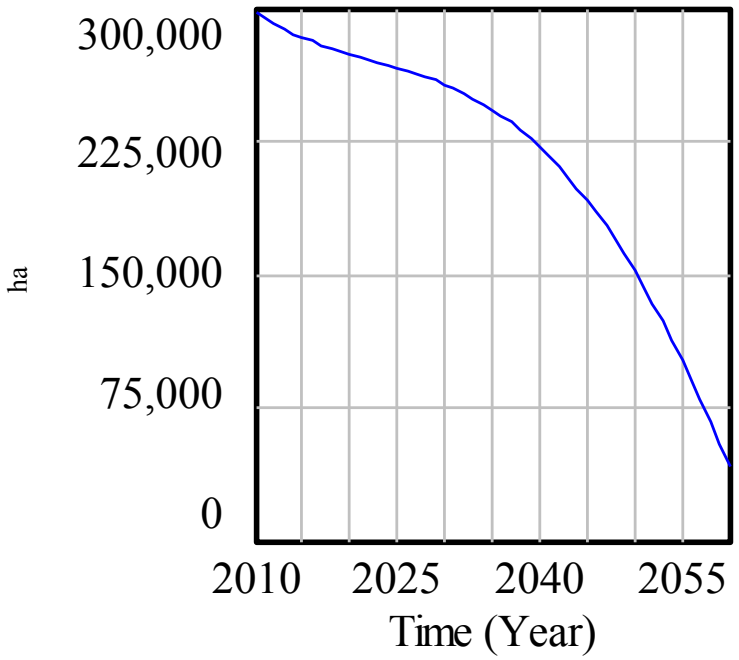


National Model



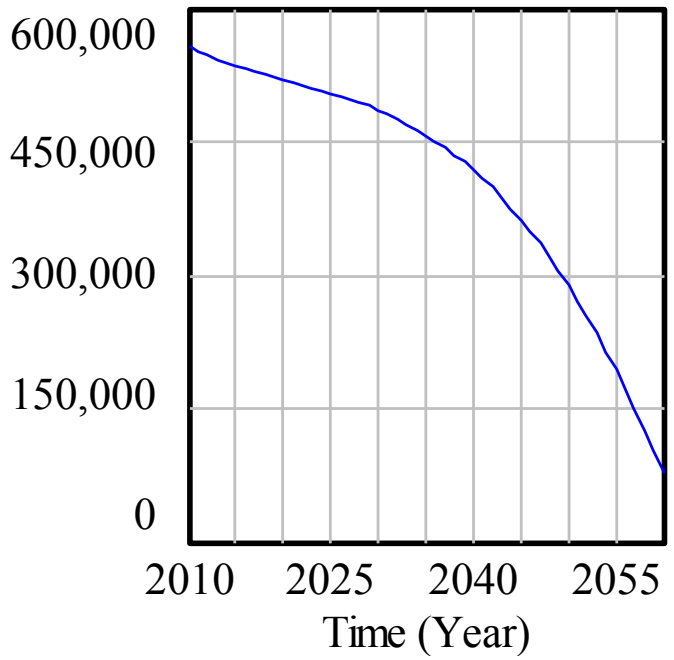
Lusaka Province Baseline

Deciduous and evergreen forest



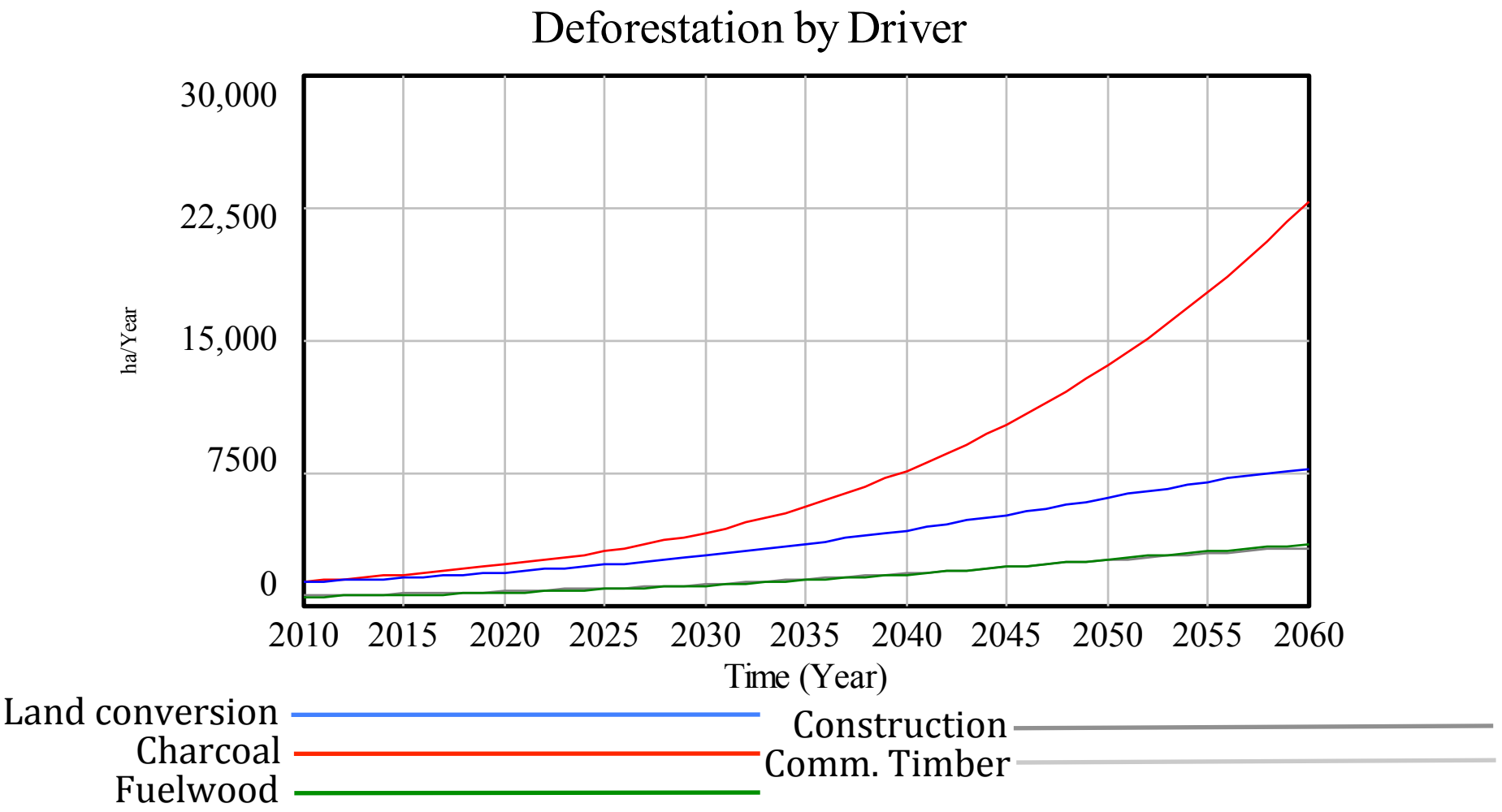
1.23% loss rate in 2010

Miombo woodland

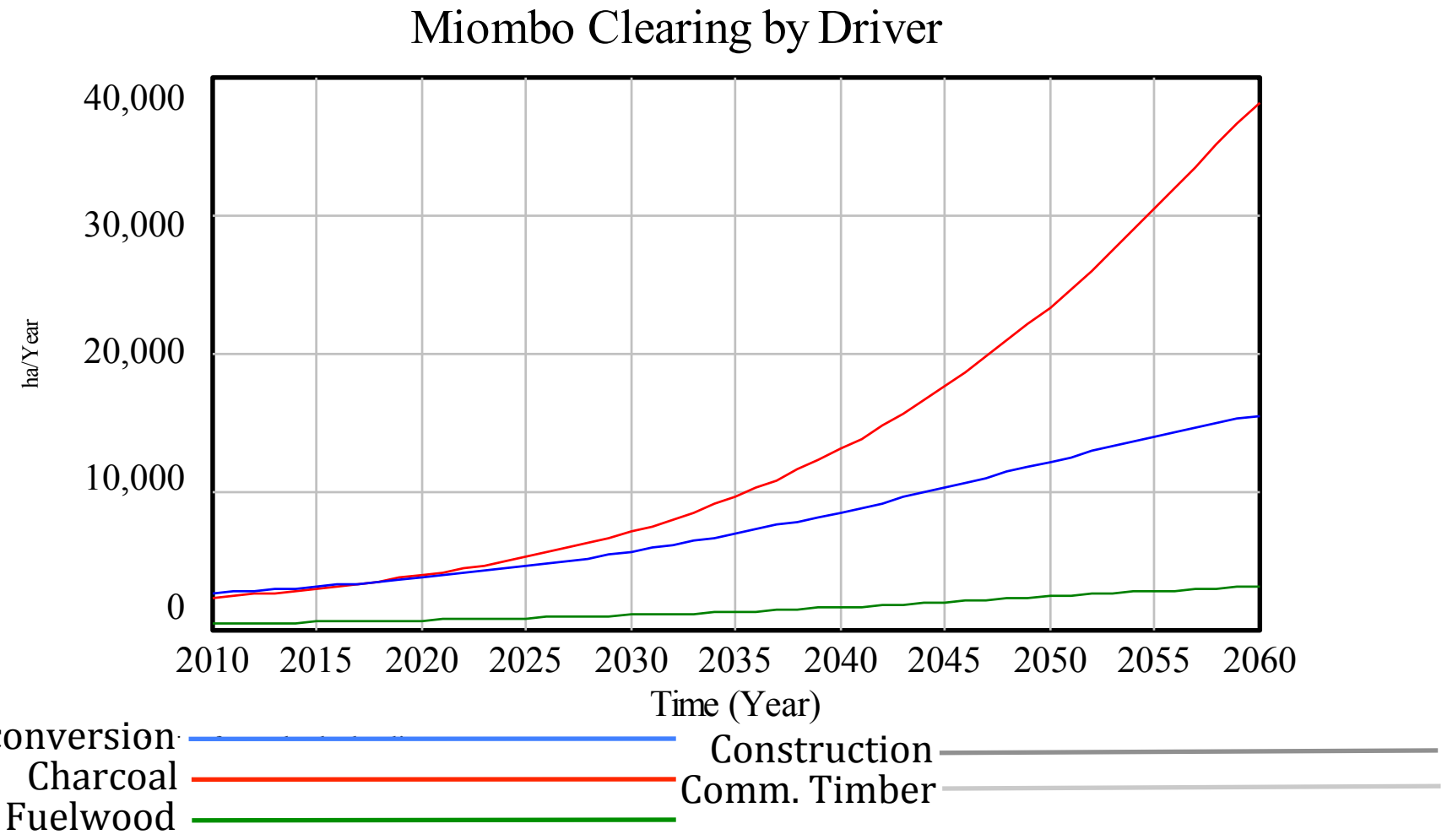


0.93% loss rate in 2010

Lusaka Province Model

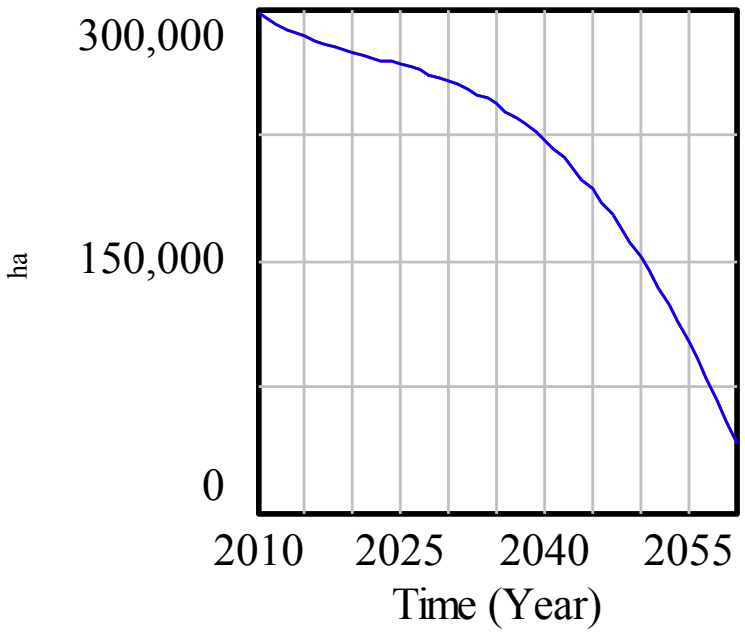


Lusaka Province Model

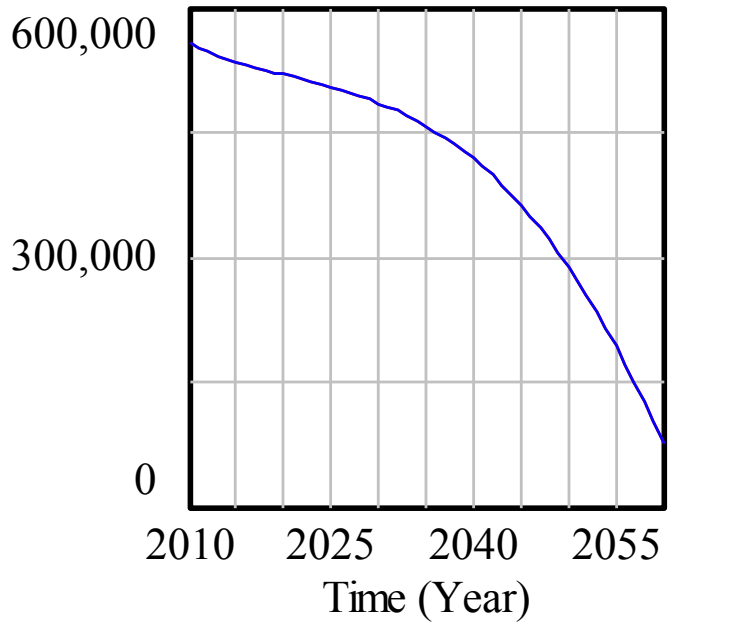


Effects of Maize Yield Increase

Deciduous and evergreen forest



Miombo woodland

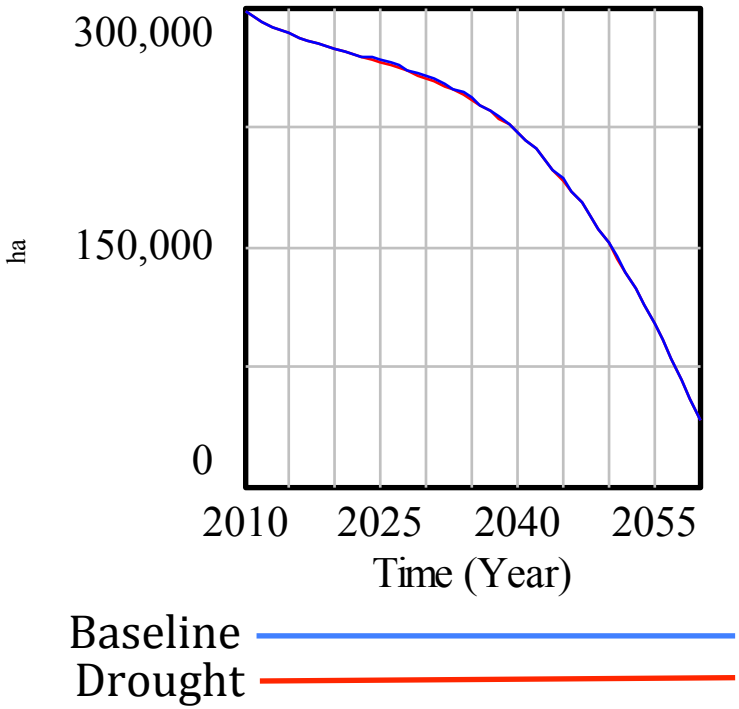


Maize yields increase at 3x their current rate - ***no effect on deforestation***.

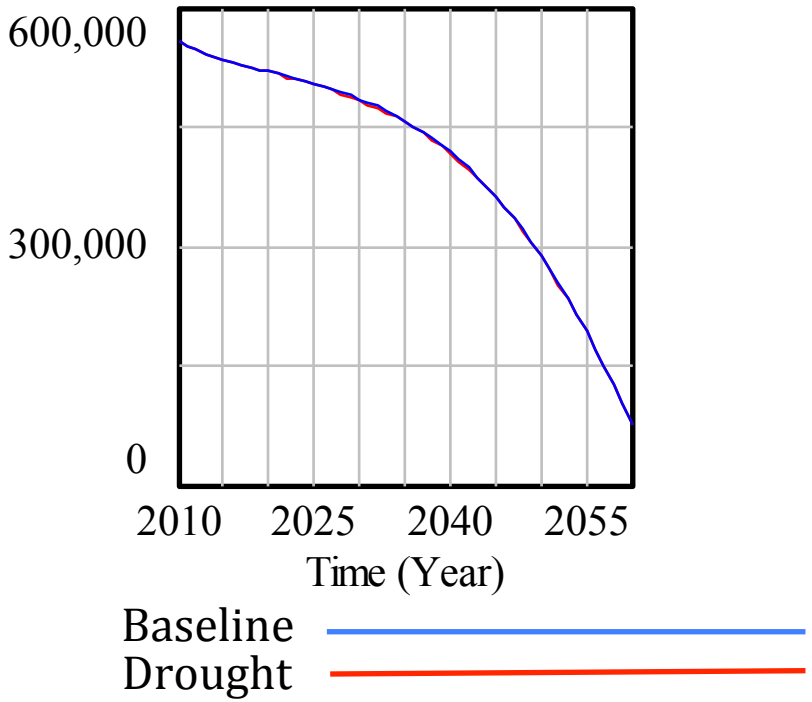
LUSAKA PROVINCE

Effects of Drought

Deciduous and evergreen forest



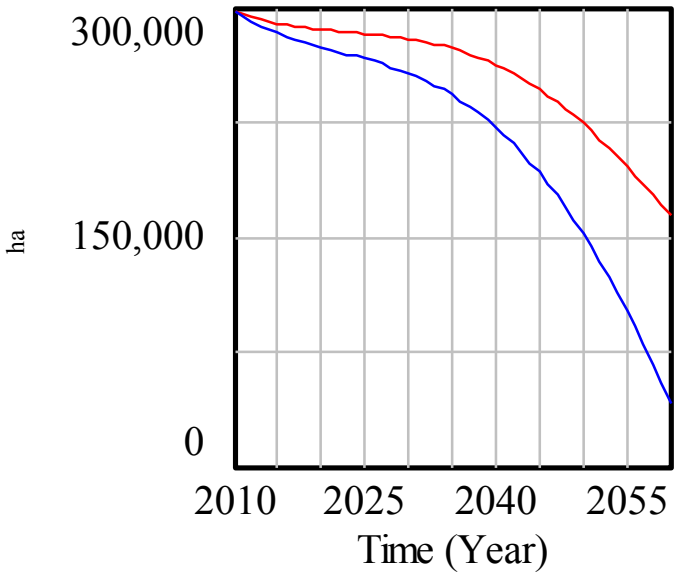
Miombo woodland



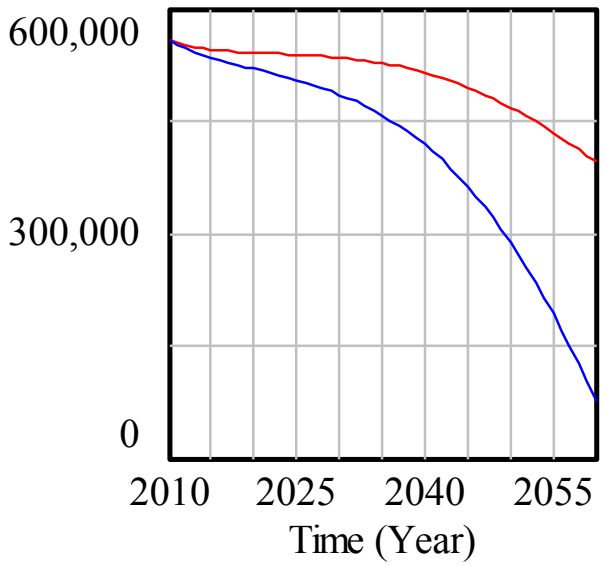
A drought affecting 70% of agricultural area occurs every 40 years, and 40% of area every 8 years. Farmers turn to charcoal production for income in years in which their crops are affected. If farmers engage in CA, they are not affected. ***No effect on deforestation***.

Effect of Full Electrification

Deciduous and evergreen forest



Miombo woodland

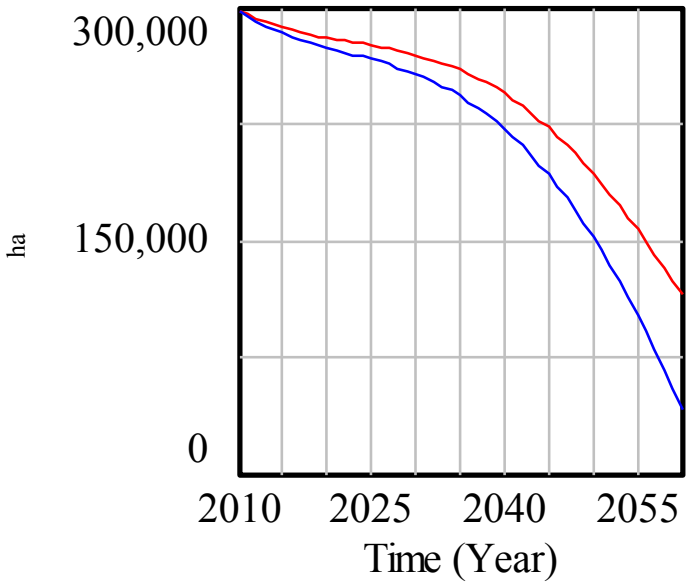


Baseline
Electrification

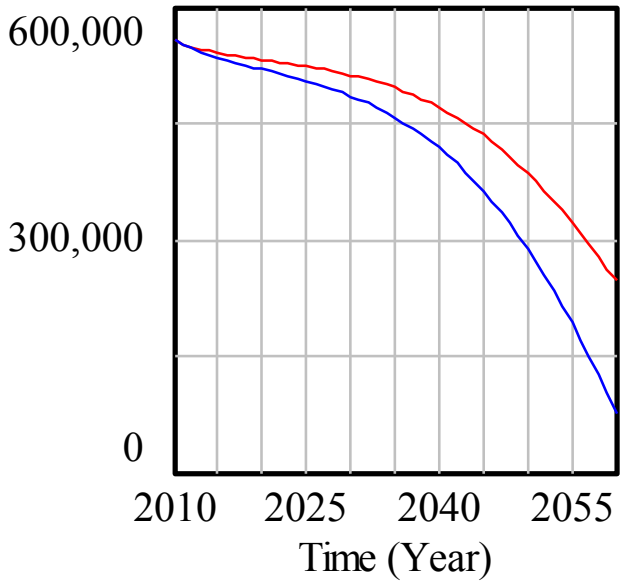
Baseline
Electrification

Effect of Fuel-Efficient Stoves

Deciduous and evergreen forest



Miombo woodland

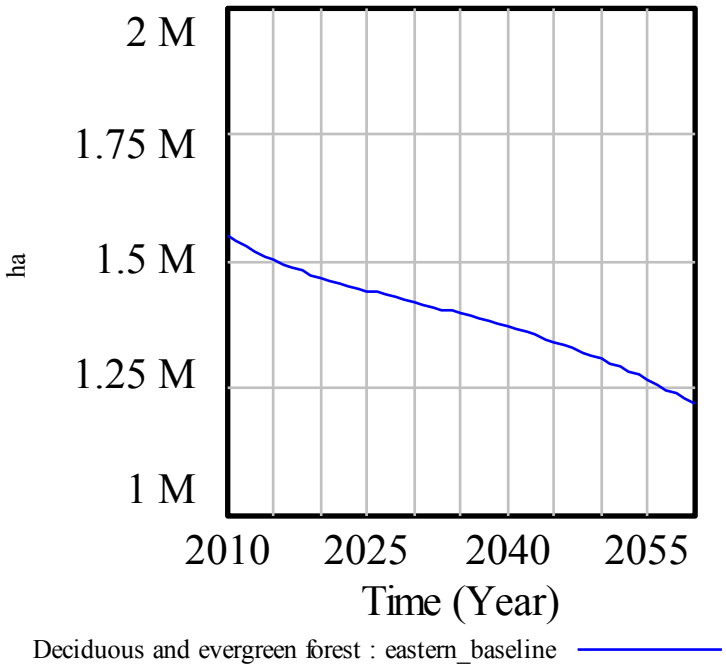


Baseline
Efficient stoves

Baseline
Efficient stoves

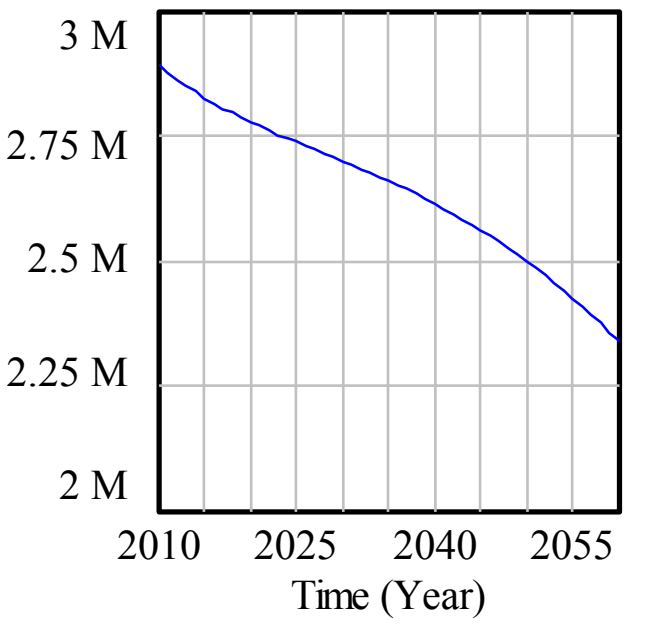
Eastern Province Baseline

Deciduous and evergreen forest



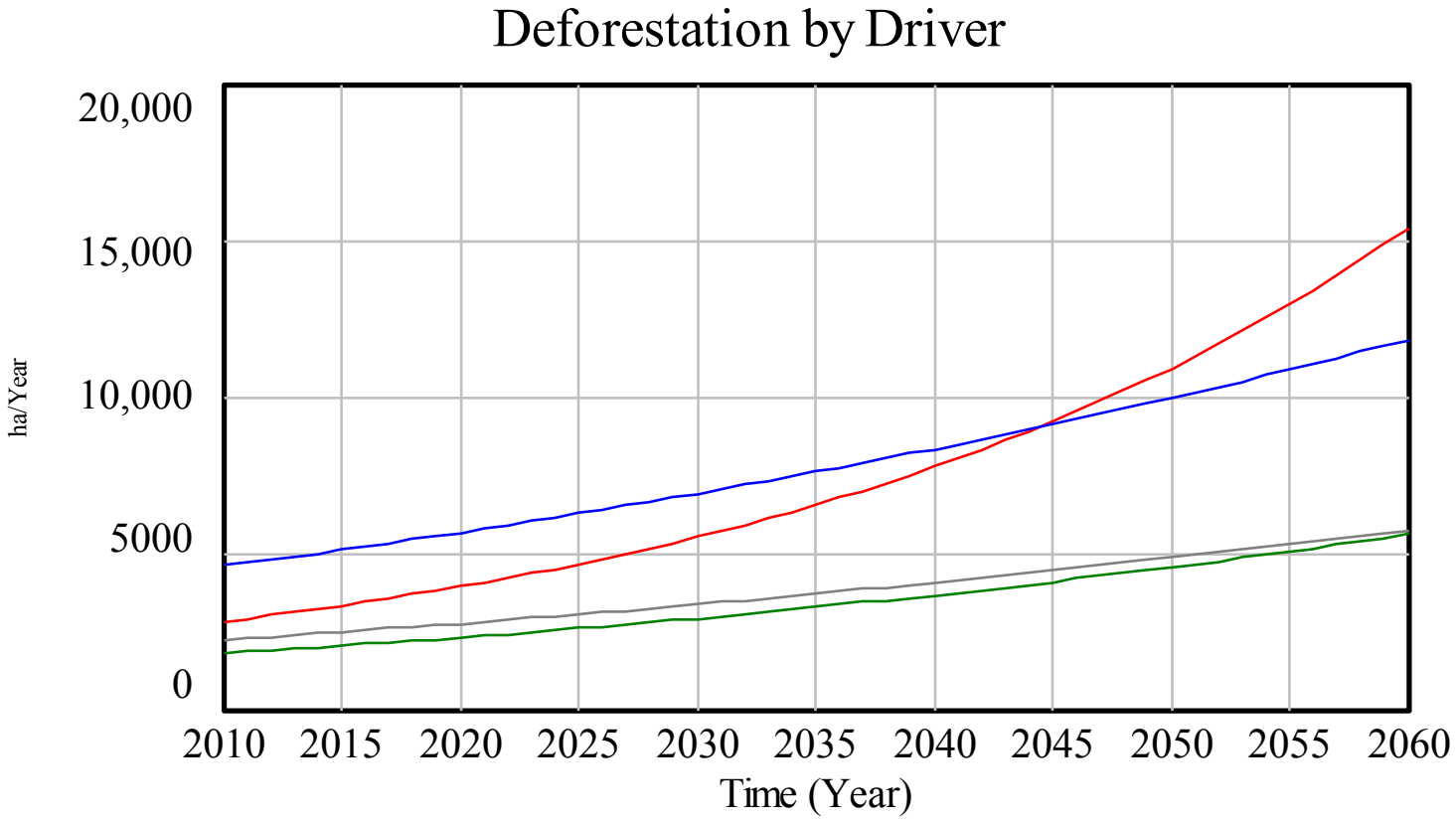
0.74% loss rate in 2010

Miombo woodland

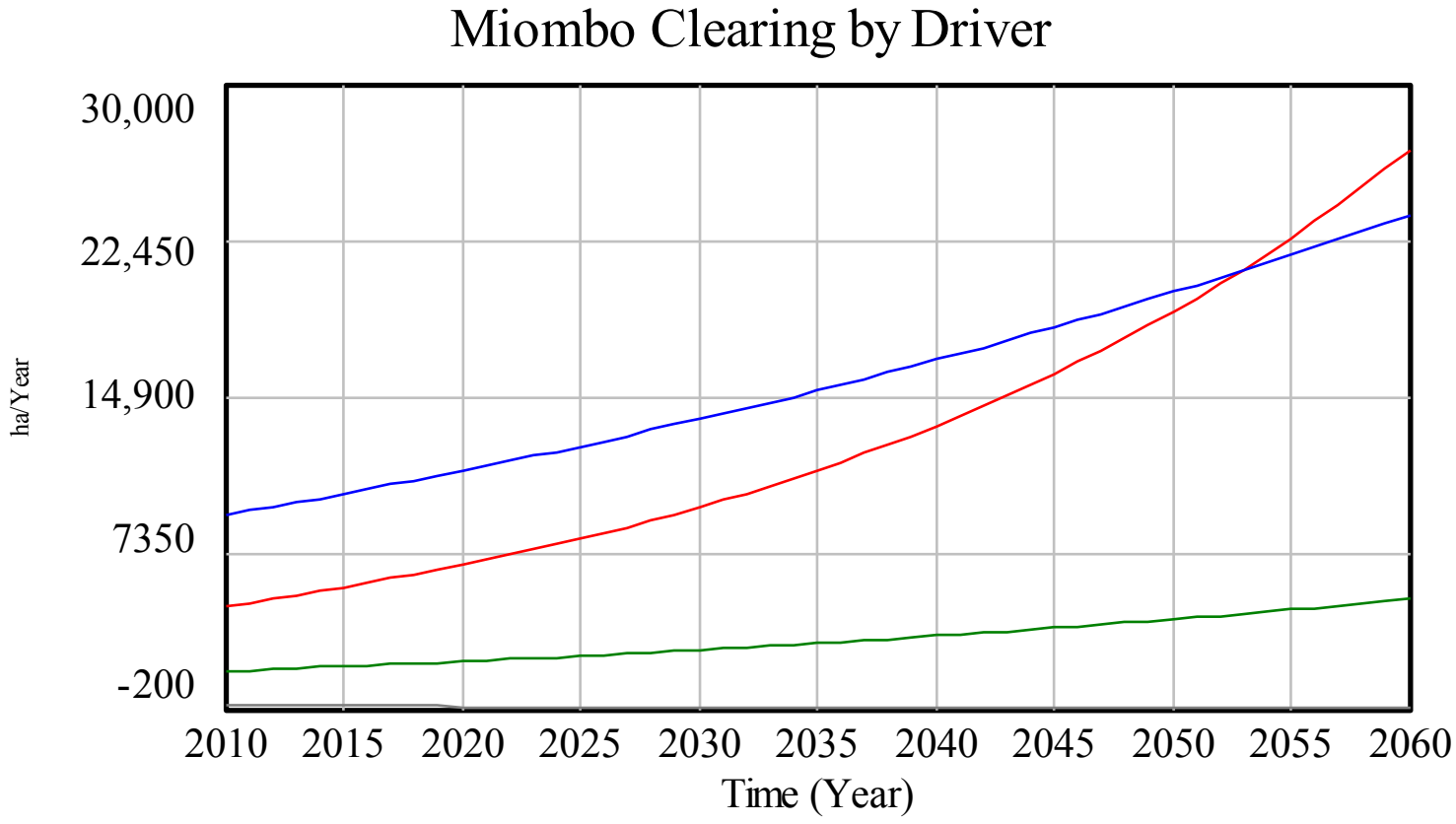


0.54% loss rate in 2010

Eastern Province Model

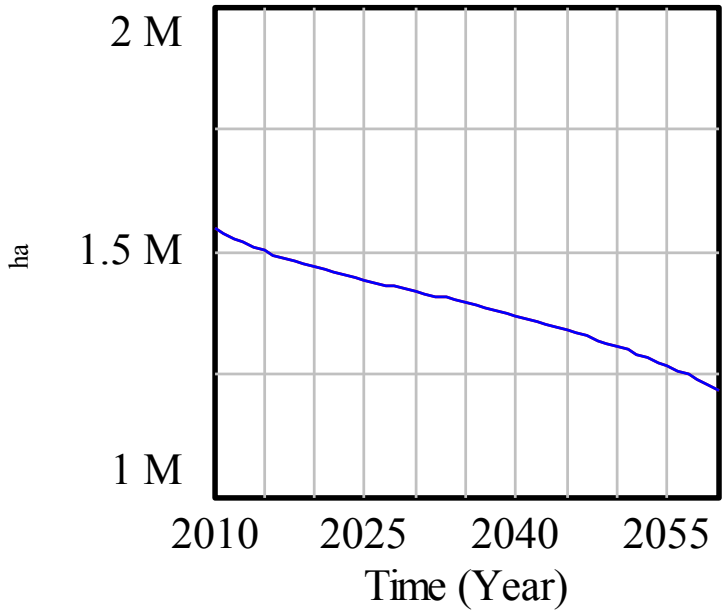


Eastern Province Model

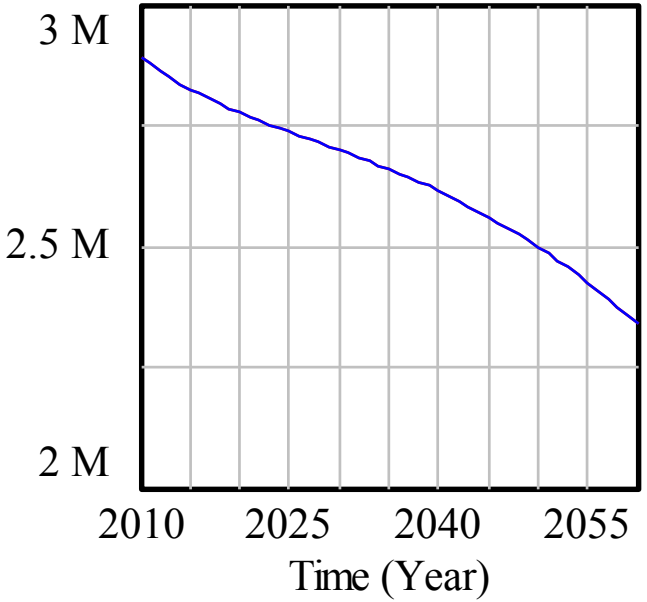


Effects of Maize Yield Increase

Deciduous and evergreen forest



Miombo woodland



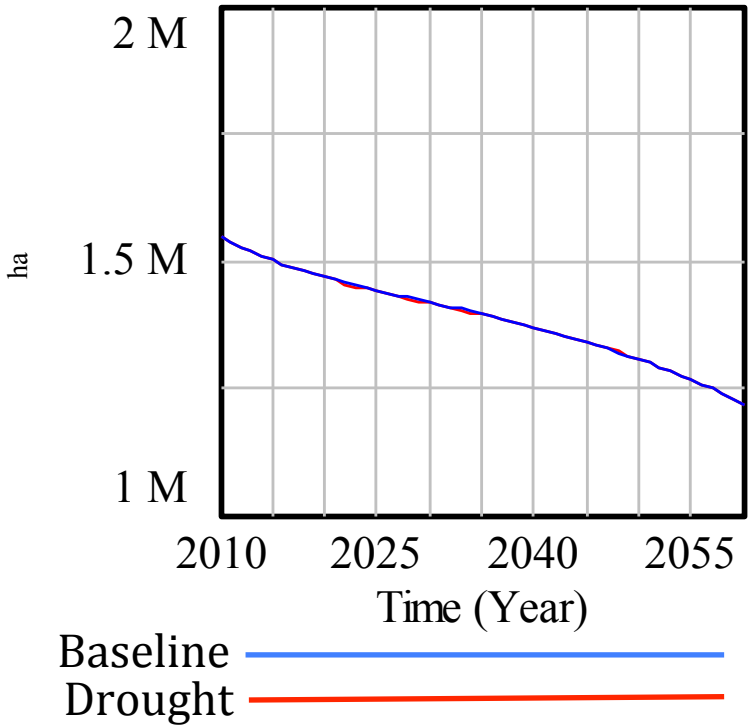
Baseline
Yield increase

Baseline
Yield increase

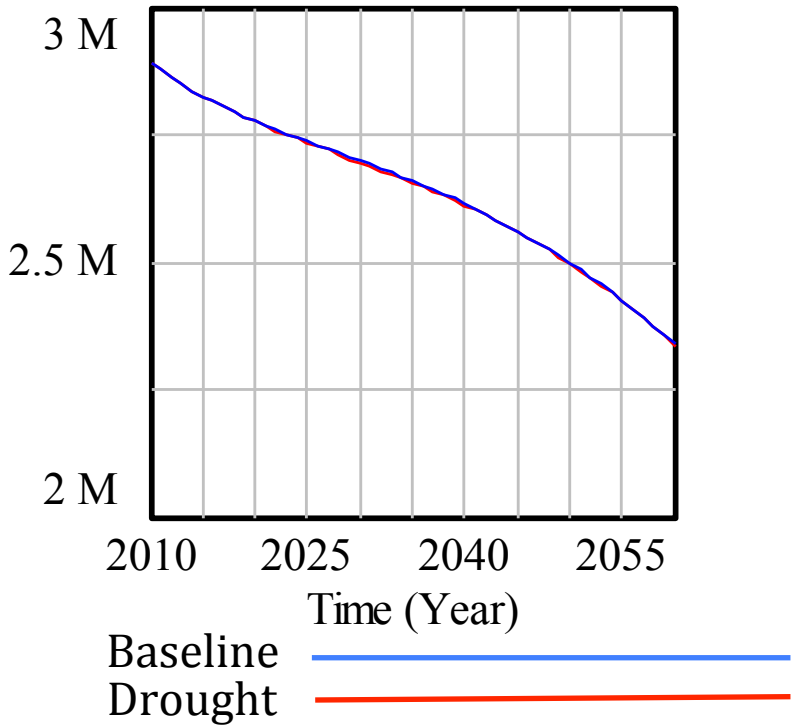
Maize yields increase at 3x their current rate - ***no effect on deforestation***.

Effects of Drought

Deciduous and evergreen forest



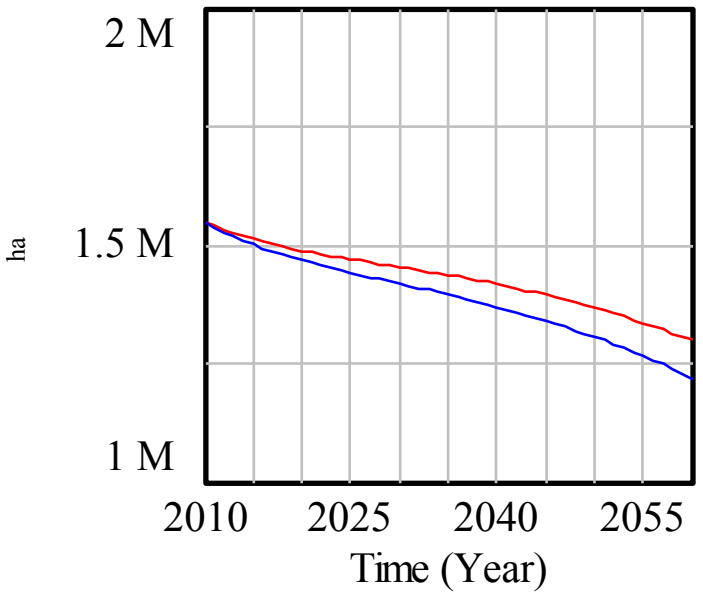
Miombo woodland



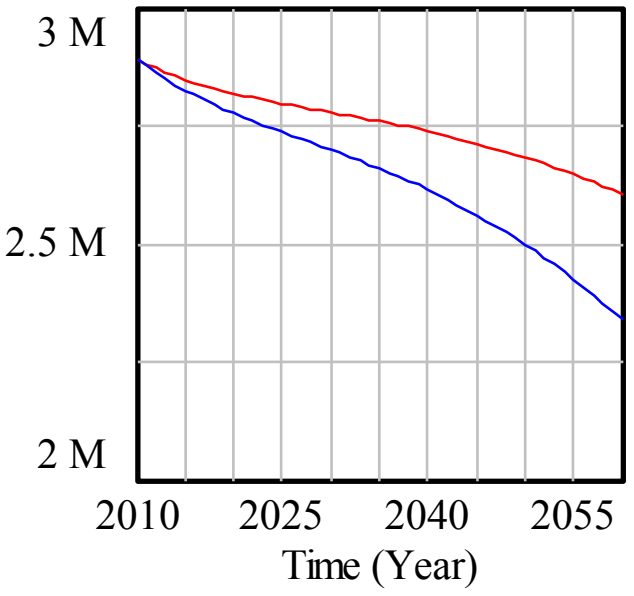
A drought affecting 70% of agricultural area occurs every 40 years, and 40% of agricultural area every 8 years. Farmers turn to charcoal production for income in years in which their crops are affected. If farmers engage in CA, they are not affected.

Effect of Full Electrification

Deciduous and evergreen forest



Miombo woodland

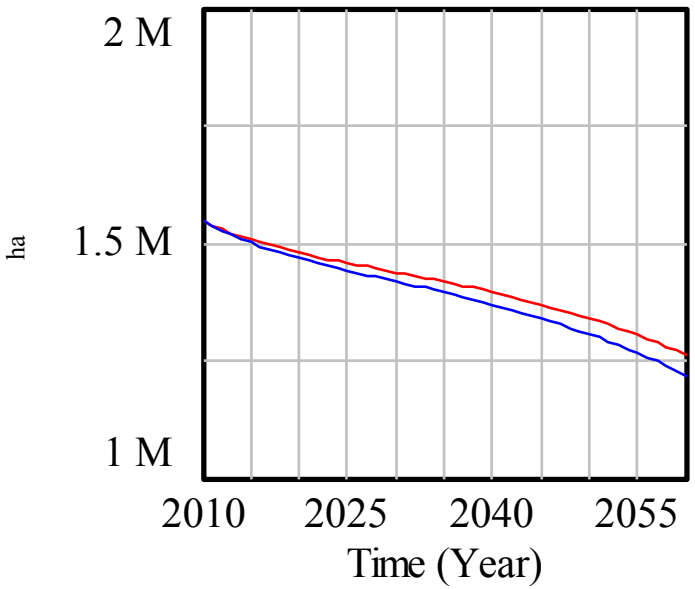


Baseline
Electrification

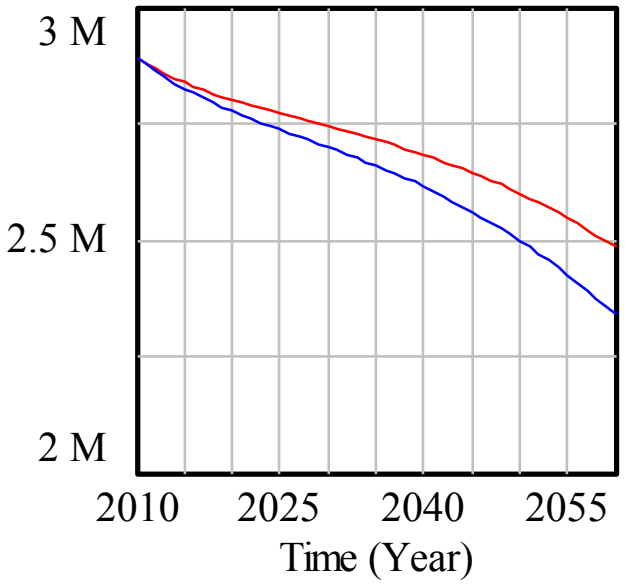
Baseline
Electrification

Effect of Fuel-Efficient Stoves

Deciduous and evergreen forest



Miombo woodland



Baseline
Efficient stoves

Baseline
Efficient stoves

Conclusions

- Charcoal production and clearing for agriculture are both important drivers of deforestation
  - Charcoal currently dominates in Lusaka
  - Clearing for agriculture currently dominates in Eastern
  - Charcoal expected to dominate in both provinces in the future
- Clearing land for agriculture is driven by ***rural population growth***, not low yields or land abandonment
- Charcoal production is driven by ***urban population growth*** and ***energy demand***
- Participatory system dynamics modeling can be a useful tool for identifying the ***primary drivers of change*** in complex agro-ecological systems

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