Land-use modelling

CEEEZ, UCL

CEEEZ Centre for Energy, Environment and Engineering Zambia Limited

UKaid from the British people

Climate Compatible Growth

University Partnership:

University of Oxford · The Open University · Imperial College London · UCL · Climate Parliament · Centre for Global Equality · Loughborough University · KTH · University of Cambridge

5th Nov 2024

Agenda

- Introduction to participants – 9am
- Introduction to CCG and this project – 9.15am
- Land-use change drivers and dynamics – 9.30am
- Model concept and example questions and results – 9.45am
- Break – 10.30am
- Drivers and assumptions for each process – 11am
    - Discussions on yields, forestry etc
- Next steps for model development, applications, collaborations… – 12.30 – 1pm

Introduction – Climate Compatible Growth programme

- £95M UK FCDO-funded research programme, running 2021-2030
- Aims to help countries take a path of low carbon development, unlocking investment in green infrastructure, opening up new markets and supporting delivery of the Sustainable Development Goals
- The research is *demand-led* and *practically-orientated* to help provide solutions to economic and environmental challenges
- CCG takes a holistic and cross-sectoral approach to addressing climate compatible and inclusive growth.
- CCG research aims to deliver:
  - A robust and effective evidence base that informs decisions
  - Tools and decision-support frameworks
- Working with partners in Zambia, Kenya, Ghana, Vietnam, Laos. Soon Malawi and Nepal.

UK partners:

Introduction – CCG Zambia Land Cover Change project

Collaboration between UCL, CEEEZ, Tec Analytics

Motivation:

- Vital importance of land for livelihoods, environment, resources, economic development
- Historic land cover change: expansion of cropland and grasslands, reduction of forests
- Future plans include multiple elements which will impact and depend on land:
  - agricultural production and productivity, energy crops, cash crops, urban planning, mining, infrastructure, forestry...
- There is a need to understand how these factors could evolve and combine, and how multiple goals can be met, e.g.
  - How to strengthen rural livelihoods and food security, while stemming deforestation
  - How to increase agricultural production and economic value, while achieving NDC emissions targets
- Helpful to explore scenarios and quantify their effects.

Introduction – CCG Zambia Land Cover Change project

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Aims:

- To bring together conversations on sectors affecting and depending on land-use change
- To examine how land-use and land cover might change in the future, and how multiple objectives can be achieved

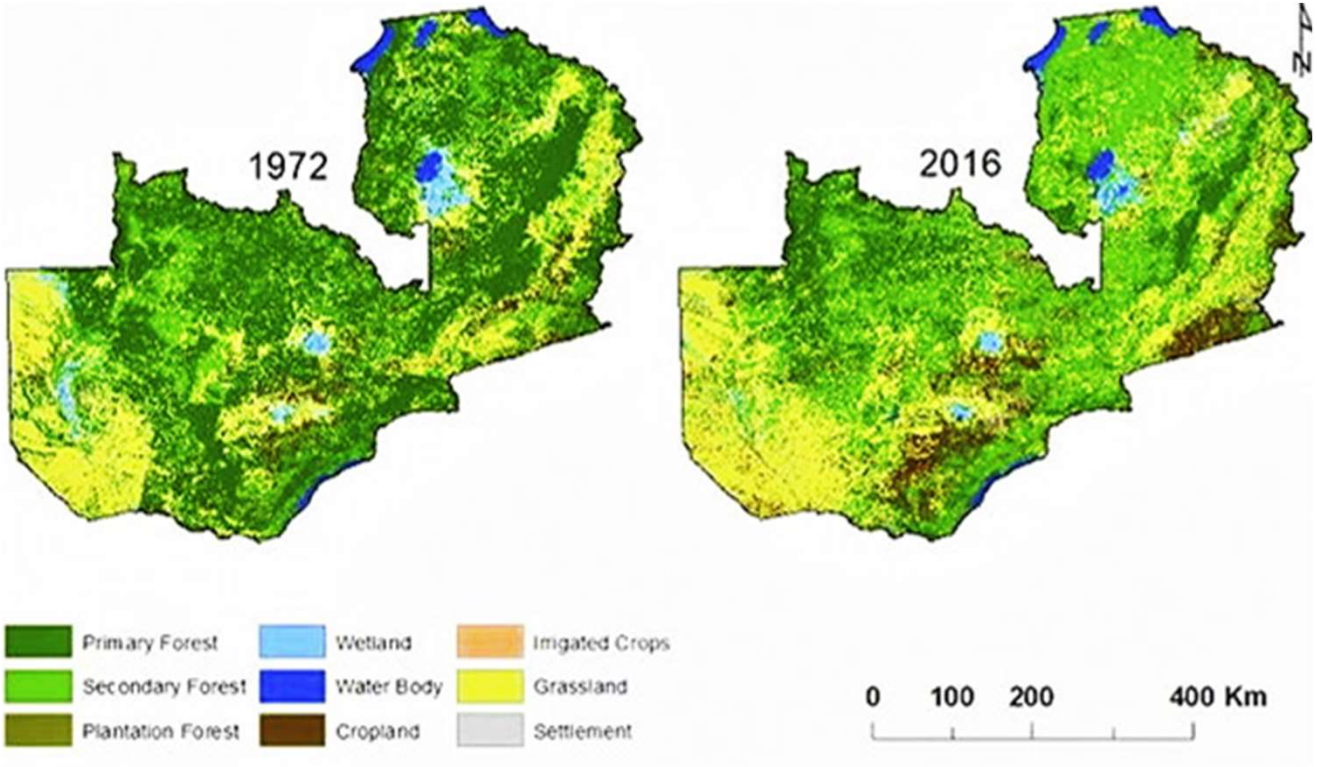
We are developing:

- **Qualitative narrative scenarios** of land-use
- An Excel tool to estimate **future land cover change**, **bioenergy resources** and **GHG emissions**

Principles:

- Co-development with stakeholders
- Transparent assumptions and calculations
- Open-source model and data

Historic Land Cover Change



Main drivers of LCC:

- percentage of area under agriculture
- distance to water bodies
- change in crop yield
- mean temperature
- elevation

Protection status was the most important factor for forest reversion and recovery

Phiri et al (2019) Long-term land cover change in Zambia: An assessment of driving factors

Land cover change drivers

Drivers of land-use change

- Agricultural demands for food, fodder, cash crops, biofuel crops…
- Agricultural techniques
- Soil degradation and regeneration
- Demands for wood
- Forestry practices
- Population growth and urbanisation
- Mining, other industry, infrastructure

External factors

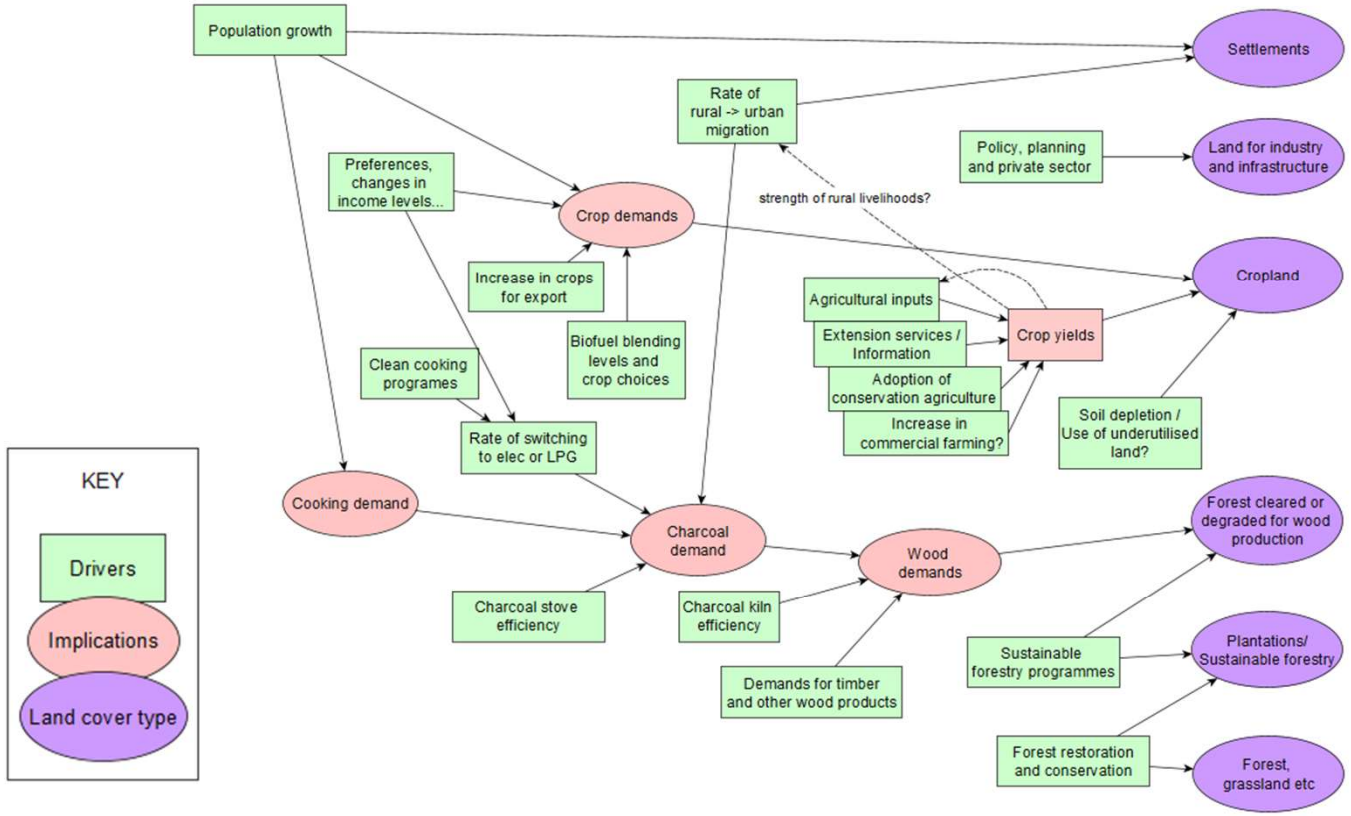
- Climate change impacts
- Trade dynamics and shocks

Zambian priorities that affect and depend on land

- Agricultural production for food security and economic value
- Shift to more large-scale agriculture
- Reducing deforestation
- Increased mining
- Energy security
  - hydro, solar, biofuels, clean cooking
- Sustainable livelihoods

Land cover change system

Initial mapping of drivers and implications leading to land cover change – *under development*



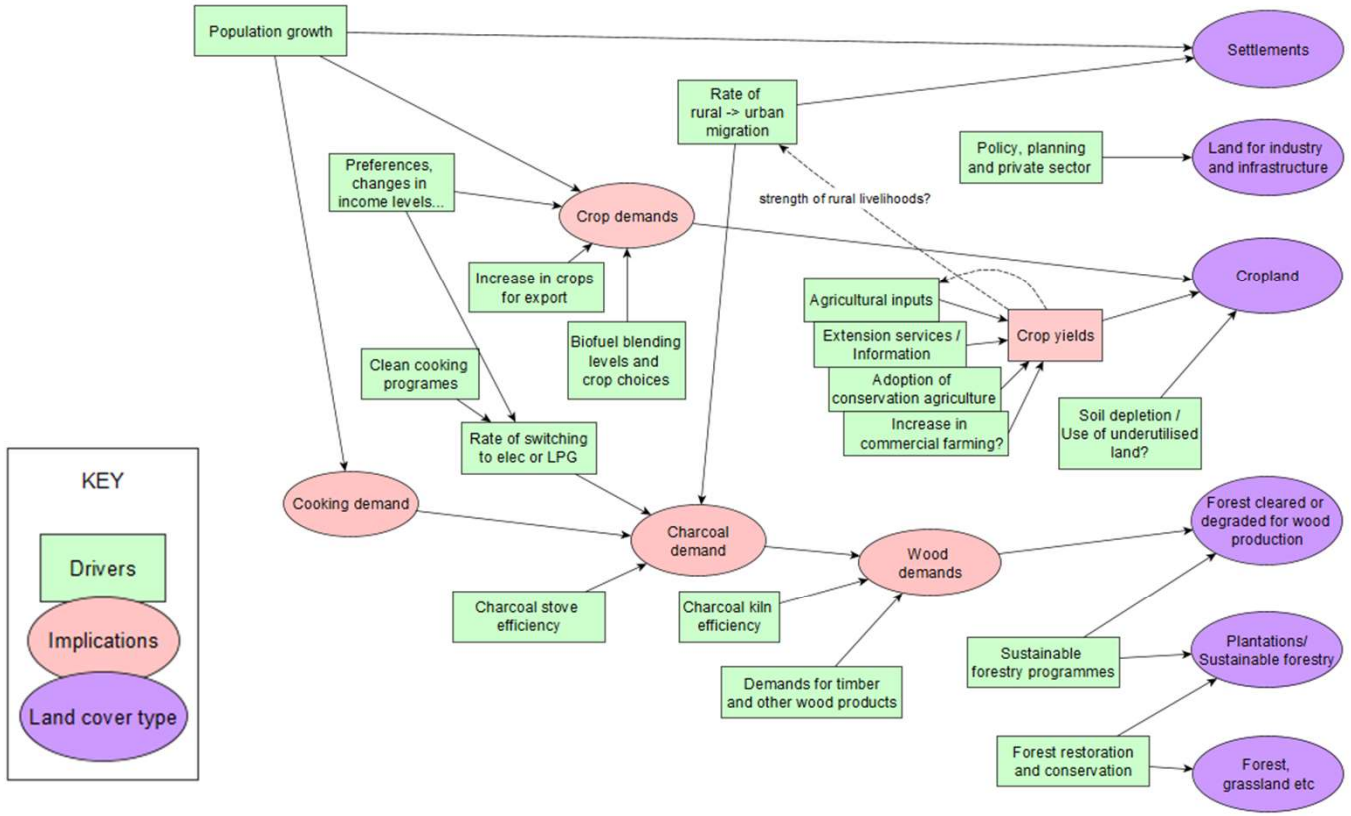
Conversion between land cover types

Changes to GHG emissions and sinks

Changes to biomass resources

Land cover change system

Initial mapping of drivers and implications leading to land cover change – *under development*



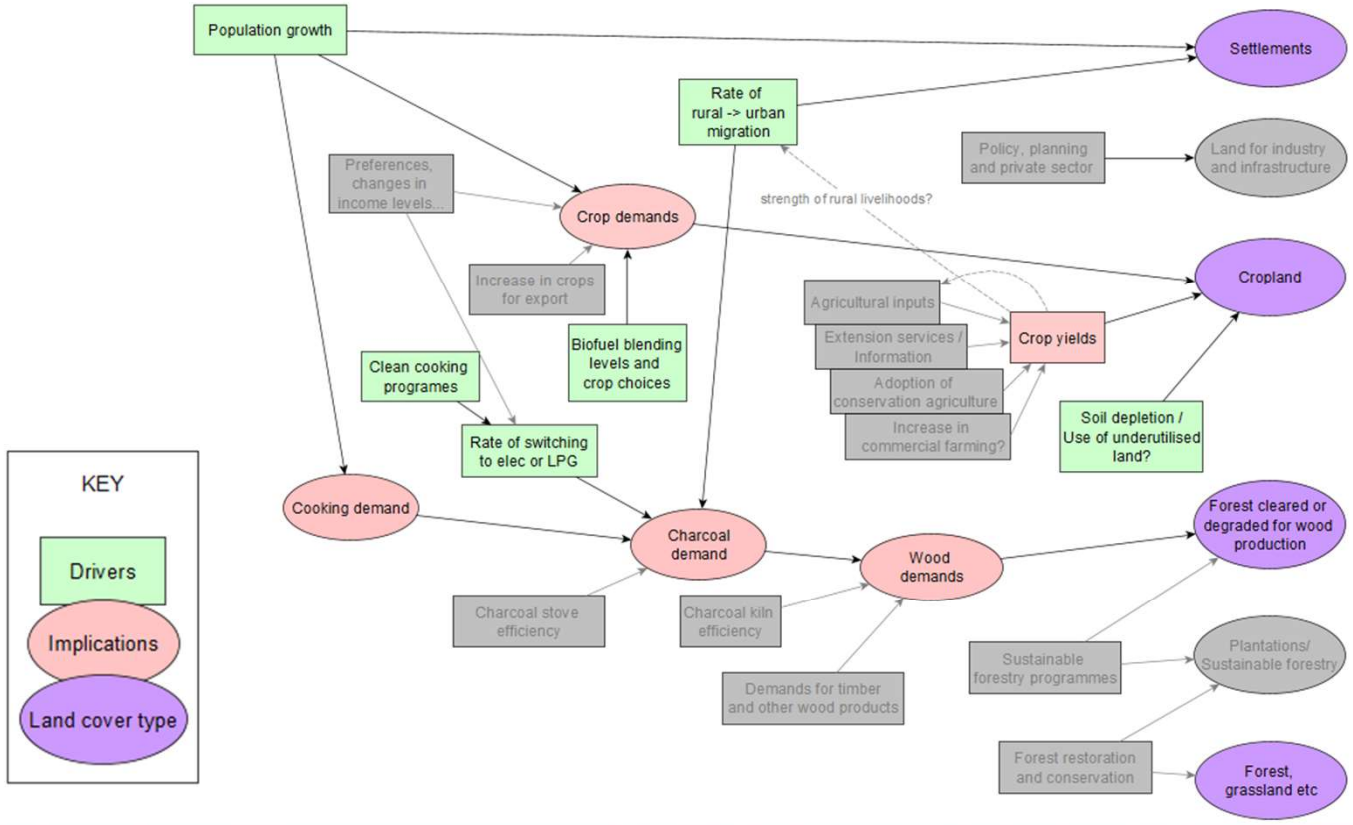
Your thoughts?

Please make notes on your printed copies

Model concept

Land cover change system – our modelling

Elements we are modelling – *so far…*



The model calculates:

Conversion between land cover types

GHG emissions and sinks

Biomass resources

Historic Land Cover Change

The model is based on historic data of land cover change

Source: Phiri et al (2023) - Agricultural expansion into forest reserves in Zambia: a remote sensing approach

Table 4. Landcover change metrics across Zambia between 2000 and 2018.

		Land cover (2018)						
Area (ha)		Forest	Cropland	Grassland	Water bodies	Wetland	Settlement	Total
Initial	Forest	43,674,907	2,776,979	763,340	13,161	6,581	177,674	47,412,642
Land cover	Cropland	407,992	5,455,251	250,060	0	0	46,064	6,159,366
(2000)	Grassland	32,903	302,704	18,734,739	0	6,581	26,322	19,103,248
	Water bodies	0	0	0	197,416	0	0	197,416
	Wetland	0	0	6,581	0	1,816,223	0	1,822,804
	Settlement	6,581	0	13,161	0	0	546,183	565,925
Total		42,122,382	8,534,934	19,767,880	210,577	1,829,384	796,243	75,261,400

Model structure

The tool models future land cover change (LCC):

It includes representation of a set of "LCC processes"

We set the values of various inputs i.e. "drivers"

The model calculates the rates of these processes:
- Expansion of settlements
- Expansion of agricultural land
- *Wood removals due to charcoal production*
- *Regeneration of deforested areas*

It uses assumptions about the types of land that are converted when the processes occur
  - (based on historic data from Phiri et al, 2023)

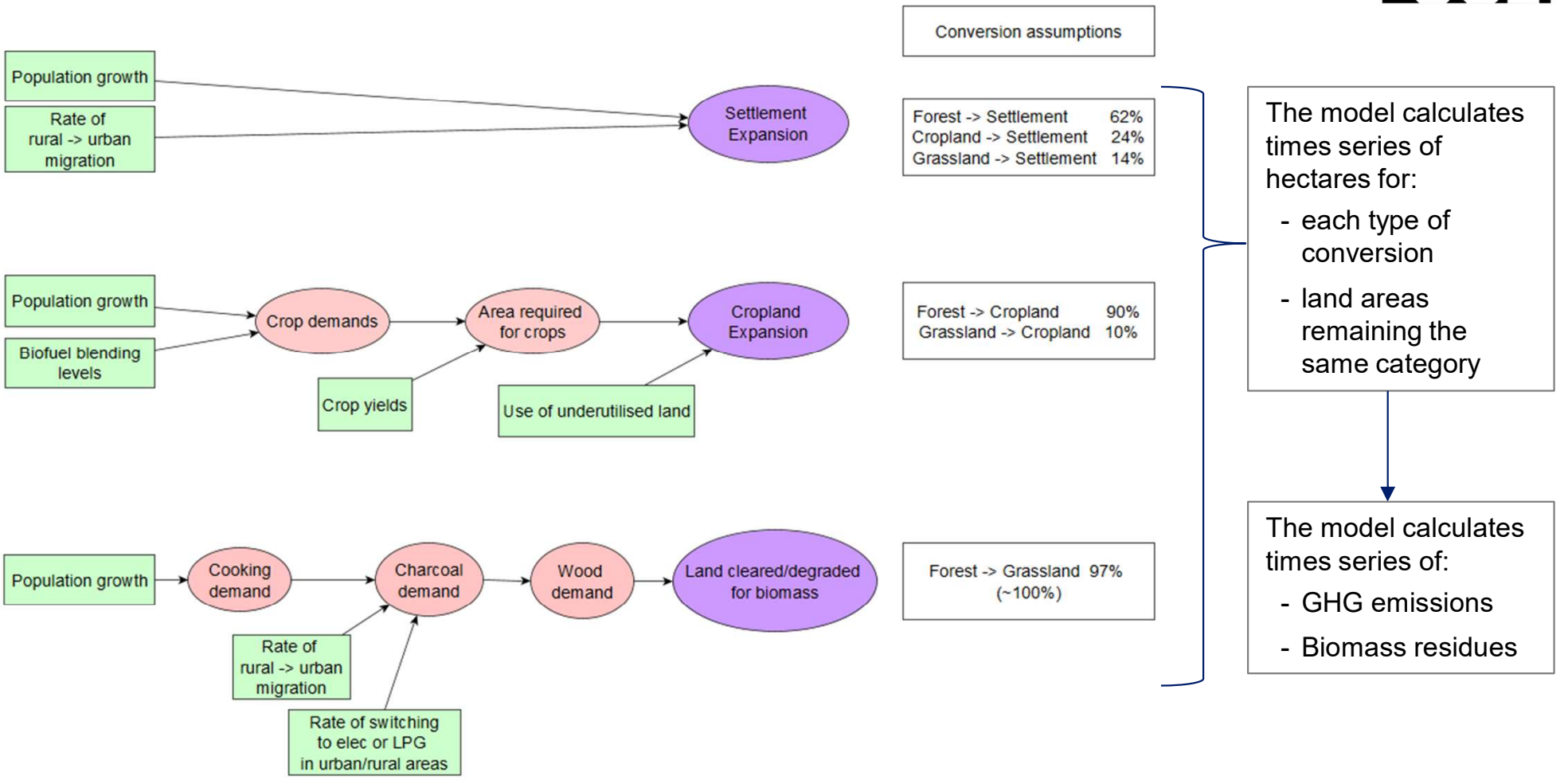
And produces a projection of future land cover change.

Then calculates:

- GHG emissions
  - We have derived LCC emissions factors based on numbers of standing trees (Data from ILUA)

- Biomass from crop residues
  - Based on factors from Bioenergy and Food Security Assessment (MoE & FAO, 2020)

Model Structure



Example research questions

Considering individual processes:

- How much expansion of settlement or cropland might we expect, given future growth of population?
- How much LCC would be driven by different levels of production of cash crops or timber?
- What biomass feedstocks could be produced for given levels of crop yield and area?

Considering trade-offs:

- What crop yield improvements would be needed to provide feedstocks for E10 and B5 biofuel blending, without driving forest loss?
- Which drivers have a bigger impact on land cover change?

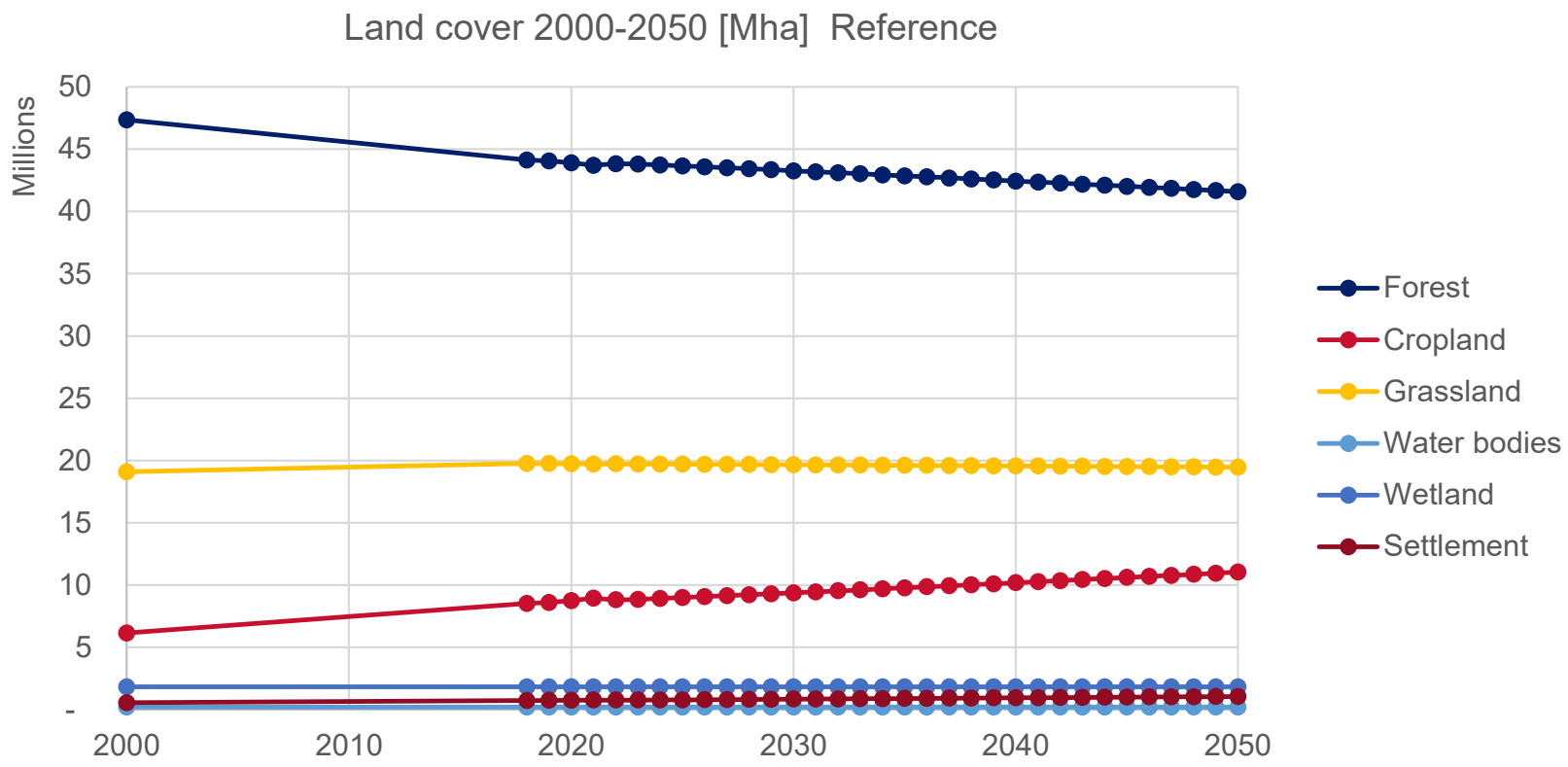
Exploring holistic scenarios:

- How could clean cooking interventions reduce wood demands (and land cover change)?
- What would be the land cover and GHG emissions pathways associated in alternative scenarios of development?
  - E.g. scenarios of “Prioritise nature“ vs “Prioritise production”
  - Or scenarios of “Centralised” vs “Decentralised” governance and infrastructure

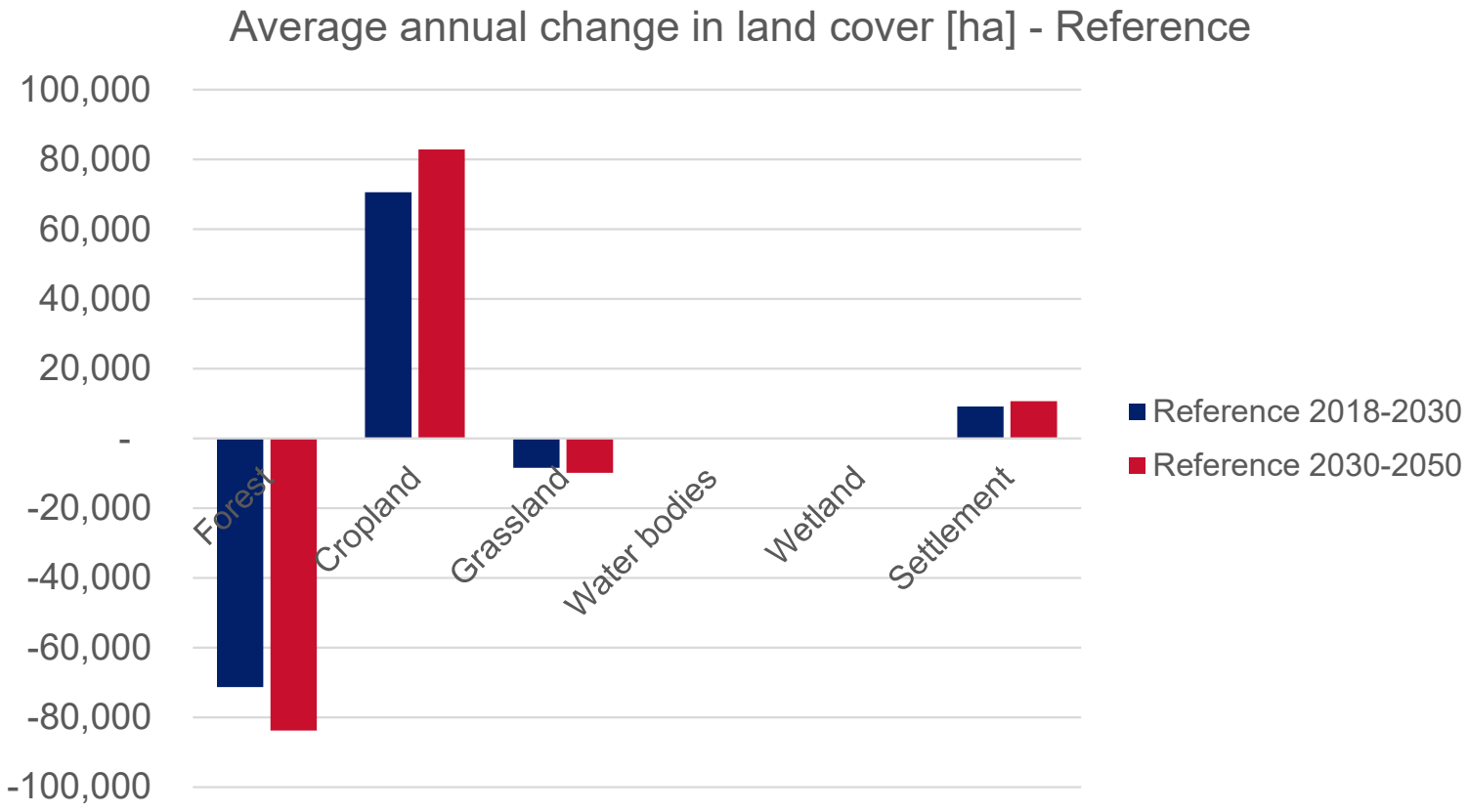
Example inputs

Process	Drivers	Scenario values		
		Reference	**Scenario 1 "worst case for forests"**	**Scenario 2 "best case for forests"**
Expansion of settlements	Population growth (same for all scenarios)	Increase from 18 million in 2018 to 37 million in 2050		
	Rate of urbanisation i.e. annual growth rate of urban population	Historic trend continues 3.8% in 2030 2.7% in 2050	High urbanisation 5% in 2030 4% in 2050	Low urbanisation 3% in 2030 1% in 2050
Expansion of crop land	Population growth (same for all scenarios)	Increase from 18 million in 2018 to 37 million in 2050		
	Biofuel blending	None	E10 by 2030 – sugarcane B5 by 2030 – soybeans	None
	Yields	No increase from 2018	No increase from 2018	All multiplied by 1.5 by 2030
	Proportion of expansion that uses under-utilised land	0%	0%	20%

Example results – Land cover change



Example results – Land cover change



The detail...

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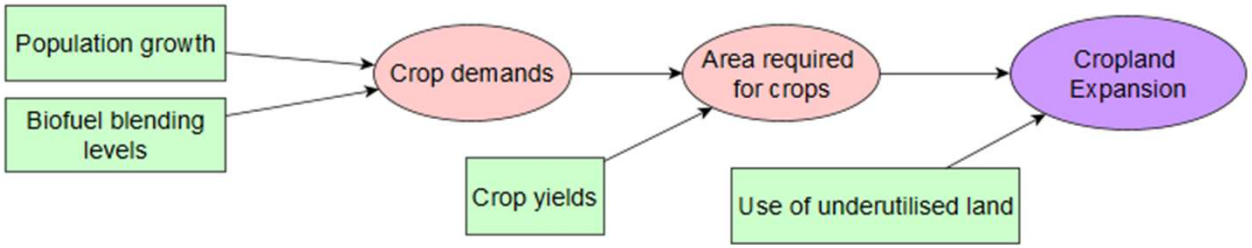
Expansion of settlement land

The model represents:
- Population growth
- Rural to urban migration

It assumes:
- Continued rising population density in urban areas

Questions:
- What should we assume for urban population density?
- Is it important to represent movement as well as overall urbanisation?
- Driven by what e.g. farmblocks, mining…?

Expansion of cropland



Forest -> Cropland	90%
Grassland -> Cropland	10%

The model represents:

- 12 crop groups
- Increasing demands due to rising population
  - Assumes per capita demands are constant
- Increasing demands for biofuel crops
  - Blending targets and crop choice
- Increasing yields – *see detail slides*
- Opportunity to prioritise use of "underutilised land" – *see detail slide*

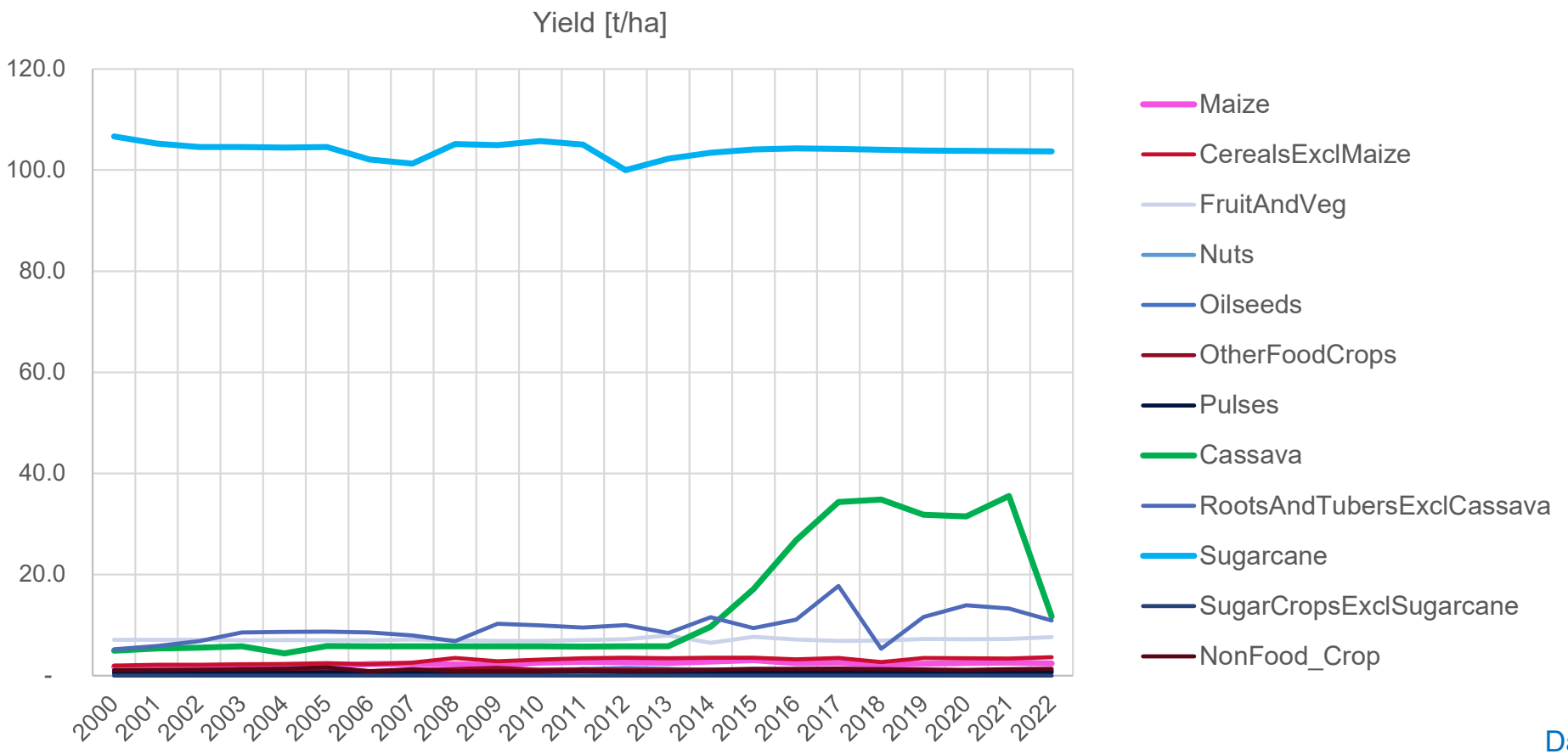
Not accounted for:

- Changing demands for crops due to changing diets / increasing wealth
- Changes to levels of imports and exports
- Soil degradation

Questions:

- How important are these elements?
  - Increasing self-sufficiency
  - Increasing cash crops (for export)
  - Other drivers of demand?
- How should livestock be modelled?
- What levels of crop yield improvements should be modelled?
- How could we model soil degradation?
- And underutilised land?

Cropland – Yields



Data source: FAOSTAT

Cropland – Yields - Farm archetypes

	Low yields	**High Yields**
Low GHG emissions	<u>1 – Traditional small-scale farming</u> *[Most small-scale farmers currently in this category]* Lack of good info on soil types & weather forecasts Lack of money for inputs – so insufficient use of fertilisers and pesticides Everything done manually - tilling etc Inappropriate timing of seed sowing, application of fertilisers and pesticides and harvesting Lack of water No intercropping, cover crops Not much good crop rotation	<u>2 – Small-scale with conservation agriculture</u> *[Small-scale farmers could transition to this.]* Minimum tillage Using crop residues for mulching - no chemical fertilisers and water loss Organic fertilisers - from livestock Less irrigation needed. Any irrigation is solar-power. Manual weeding and pesticide application. Good intercropping with legumes etc and cover crops Good crop rotation - improves nutrient content of the soil, and good for water retention and soil structure Good choice of crop for the soil type Agroforestry
High GHG emissions	<u>3 – Traditional small-scale with additional inputs</u> *[E.g. when price of maize was set high by the FRA and new farmers started planting]* Lack of good info But more money for inputs High use of chemicals and gasoline-power machines and irrigation but inappropriately timed Little intercropping, cover crops, crop rotation Irrigation?	<u>4 – High input farming</u> *[Commercial farming is currently like this. Small-scale farmers could transition to it.]* Good info Money for inputs High use of chemical fertilisers - enough at the right time - appropriate for the soil Appropriate timed irrigation using gasoline-powered irrigation systems Appropriate pesticides applied using gasoline drone (Large-scale farms) Diesel power tractors for tilling, weeding, harvesting etc

Cropland – Under-utilised land?

Estimates of cropland:
- Satellite data indicates ~8 Mha in 2018 (Phiri et al, and ILUA II)
- WAVES (2022) natural capital accounts = 2.5 Mha in 2018
- Production statistics say ~2.8 Mha is cultivated (ZamStats, FAOStats)

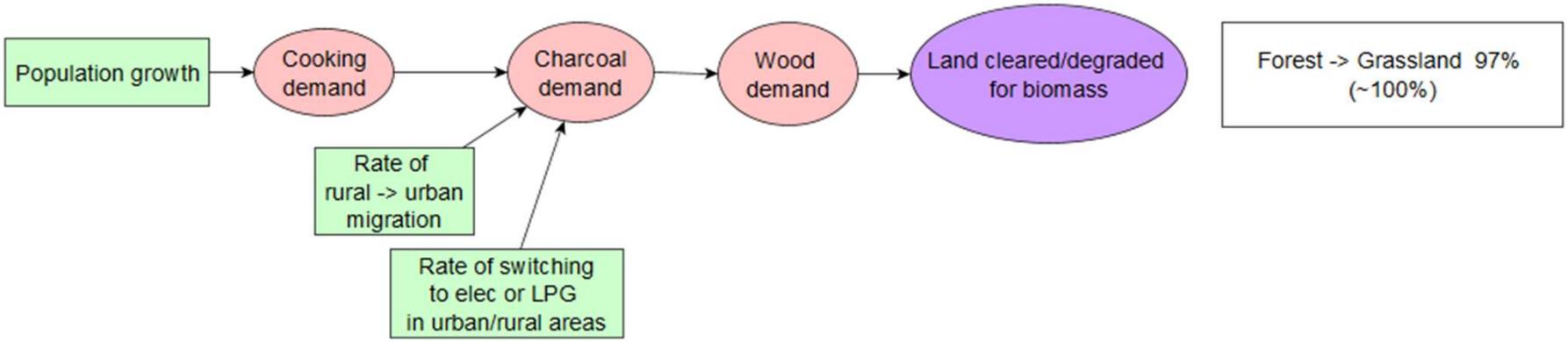
We understand the difference is due to:
- Land left fallow
- Land that is left uncultivated due to floods, droughts…?
- Shifting agriculture systems
- Degraded land
- Where cultivation is limited by inputs in certain years?

The model allows a lever to say a portion of cropland expansion could happen on ‘underutilised land’.

What would it take to use this land?

Could this be represented in the model?

Woody biomass



The model represents:

- Wood demands for charcoal production

Not yet accounted for:

- Additional drivers of wood demand for charcoal: kiln efficiency
- Additional drivers of wood demand for other
- Forest degradation or deforestation due to wood demands
- Plantations and sustainable forest management

Questions:

- When/to what extent does charcoal production drive deforestation vs degradation?
- What other drivers of deforestation should be modelled?
- Sustainable forest management
  - What types are there and to what extent do they reduce deforestation?
  - Data?

Woody biomass

Charcoal deforestation vs degradation?

- WISDOM report (2014)
  - Analysed demands and supply potential
  - Charcoal causes forest degradation around urban areas
  - But it doesn't need to cause deforestation, as potential sustainable supply exceeds demands

- Sedano et al (2022)
  - Analysis of satellite imagery including kiln scars
  - Charcoal production drives removal of aboveground biomass and loss of tree cover
  - In areas increasingly far from urban centres
  - The charcoal generated as a byproduct of agricultural expansion is not enough to meet the annual charcoal demand of Lusaka.
  - Less than 25% of the land cleared is used as cropland after 7 years.

- CIFOR (2020)
  - "Woodfuel production and trade are blamed for woodland loss in Zambia, and charcoal production alone has been shown to contribute to close to 25% of the 300,000 ha/year of forests lost (Kalinda et al. 2008; Vinya et al. 2013)."
  - "Woodfuel value chains in Choma District are currently characterized by a lack of sustainable practices, including unplanned cutting"

- Recent study by CEEEZ

Sustainable forestry, regeneration, other processes

Sustainable forestry
- What types are there?
- How and how much do they reduce deforestation?

Regeneration of abandoned cropland and degraded/lost forest
- What types are there? Natural and assisted?
- What grows where?
- How long does it take?

What land use change processes are we missing?
- Expansion of mining
- ?

Next steps – model development

What should we prioritise?

What data is available?

Improving existing elements:

E.g.
- Land cover types – more detail on forest types
- Expansion of settlements
- Expansion of crop land
- Woody biomass
- Other drivers of deforestation
- Forest regeneration
- Results metrics

Adding new elements:

- Other processes needed?

Future phases:

- Regional detail?
- Spatial modelling?

Next steps - applications

Our plans

- Clean cooking scenarios
- Centralised vs Decentralised scenarios

Further Questions

- What kind of research questions would you like to explore with this tool, or something similar?
- How is best to publish this and make it available for others to use?
- Would you like to be involved?

THANK YOU FOR TAKING PART

Stay in touch, follow up, or ask us questions at:

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Thank you!