Universität Hamburg
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CENTER
FOR EARTH SYSTEM RESEARCH
AND SUSTAINABILITY (CEN)

The Namibian Agricultural Sector Model (NASM)

Photo: Schneider, 2019, Namibia

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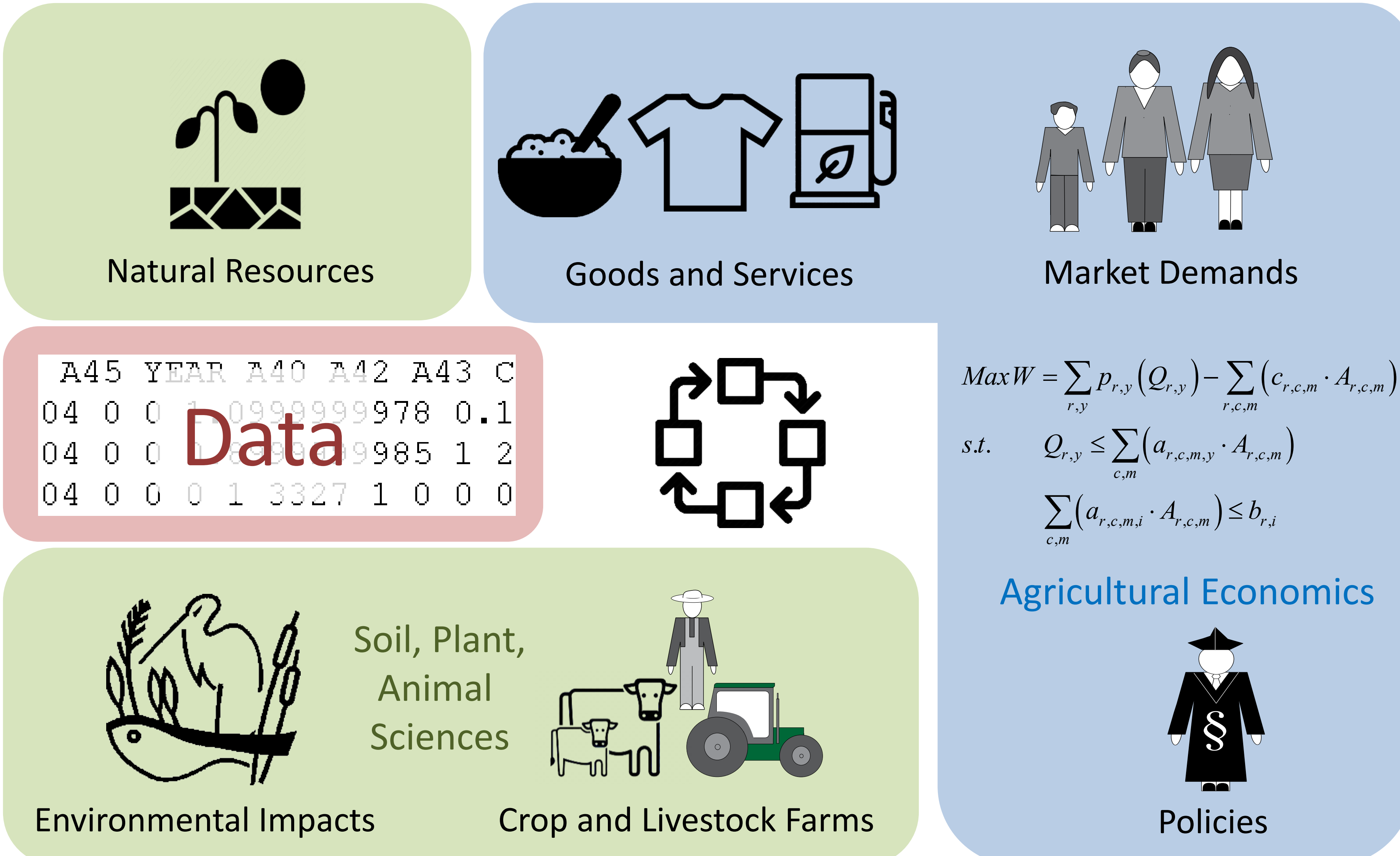
Topics

- What is an agricultural sector model?
- Why do we use it?
- Major components, Data requirements, and Mathematical structure
- Examples

I. What is Agricultural Sector Modeling?

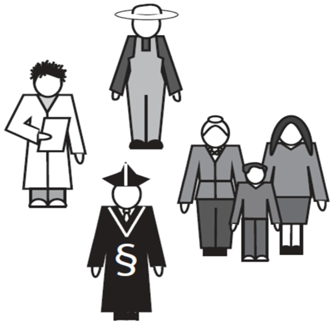


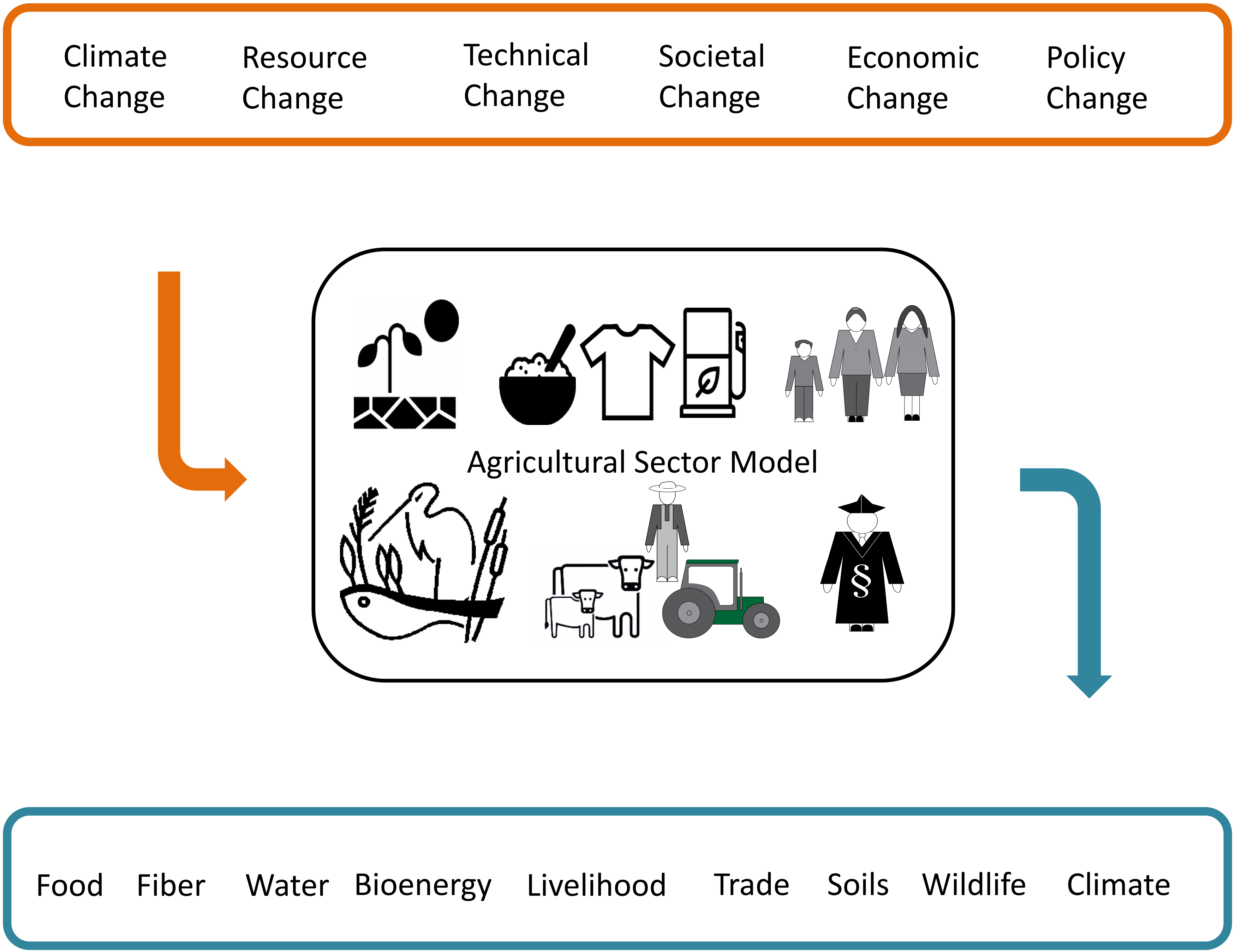
II. Why Agricultural Sector Modeling?

1. Agricultural development is important for businesses, economy, society, environment & sustainable development
2. Many agricultural externalities - private optimal decisions are not necessarily optimal for society
3. Local agricultural activities are increasingly influenced by international markets
4. Agricultural systems and natural resources are diverse and dynamic

Agricultural policies are justified ☑

Optimal regulations require transdisciplinary scientific guidance





Climate Change
Resource Change
Technical Change
Societal Change
Economic Change
Policy Change
Agricultural Sector Model
Food
Fiber
Water
Bioenergy
Livelihood
Trade
Soils
Wildlife
Climate

Source: UNDP - https://www.undp.org/content/undp/en/home/sustainable-development-goals.html

Research questions

Can we produce enough food for the entire human population, now and in the future at what price?

How does local agriculture respond to global change and what aggregate impacts are likely?

What is the optimal balance between food and non-food services from agriculture?

What are the environmental consequences of food production?

What contribution can agriculture make for the mitigation of environmental problems and resource scarcity?

Can we produce food in a sustainable way?

How should agriculture be regulated by policies?

History

(US) FASOM (Adams *et al.*, 1996a; Adams *et al.*, 1996b; McCarl *et al.*, 2000; Murray *et al.*, 2004)

(US) FASOMGHG (Lee *et al.*, 2005; Alig *et al.*, 2010)

(US) ASM (Chang *et al.*, 1992; Chen and McCarl, 2000; Schneider *et al.*, 2018)

(US) ASMGHG (McCarl and Schneider, 2001; Schneider and McCarl, 2003; Schneider and McCarl, 2005; Schneider *et al.*, 2007)

EUFASOM (Schleupner and Schneider, 2010; Lauri *et al.*, 2012; Zech and Schneider, 2019a; Zech and Schneider, 2019b; Lauri *et al.*, 2013)

GLOBIOM (Havlik *et al.*, 2011; Schneider *et al.*, 2011; Sauer *et al.*, 2010)

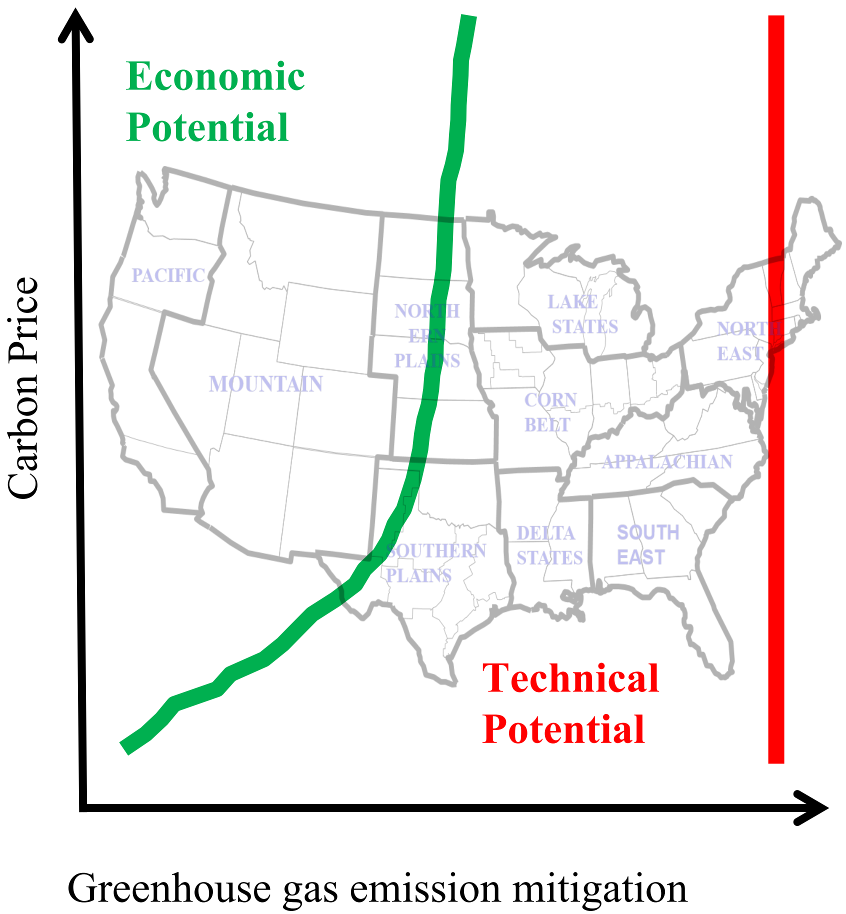
INDIA-ASM (Rasche *et al.*, 2016)

SPAIN-ASM (Choi *et al.*, 2015)

MALAWI-ASM (Kachulu, 2017; Kachulu, 2018; Kachulu *et al.*, 2018)

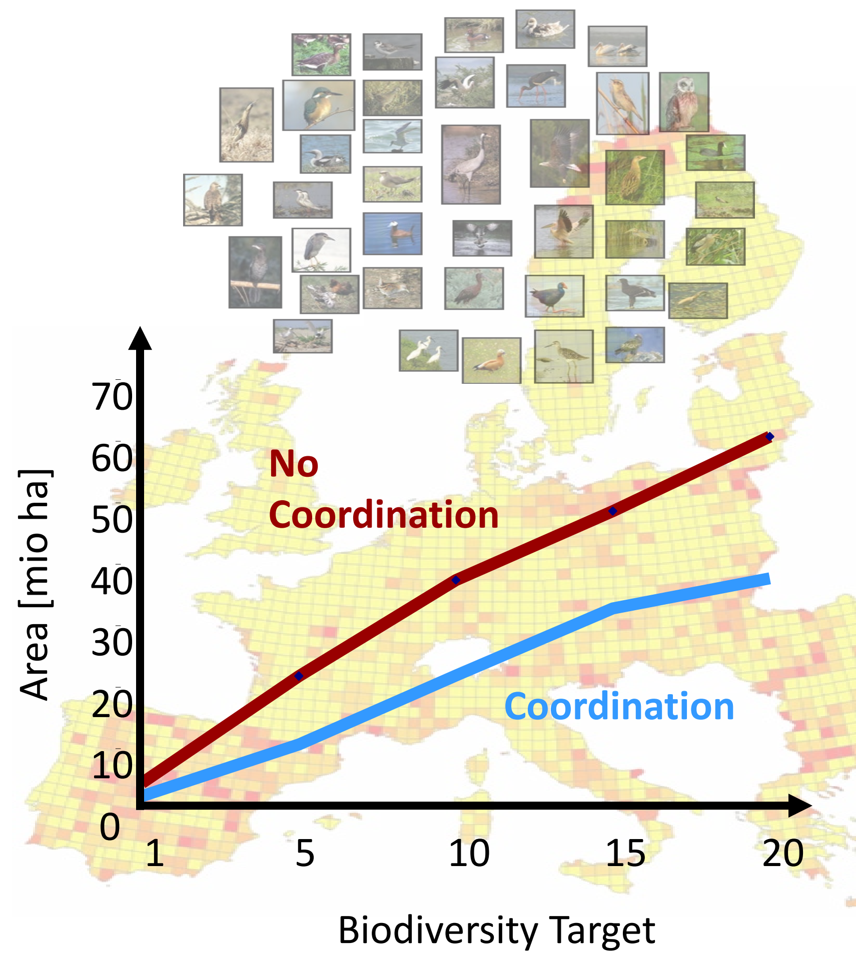
NAMIBIA-ASM (Jeong 2020, Master Thesis)

Agricultural abatement functions



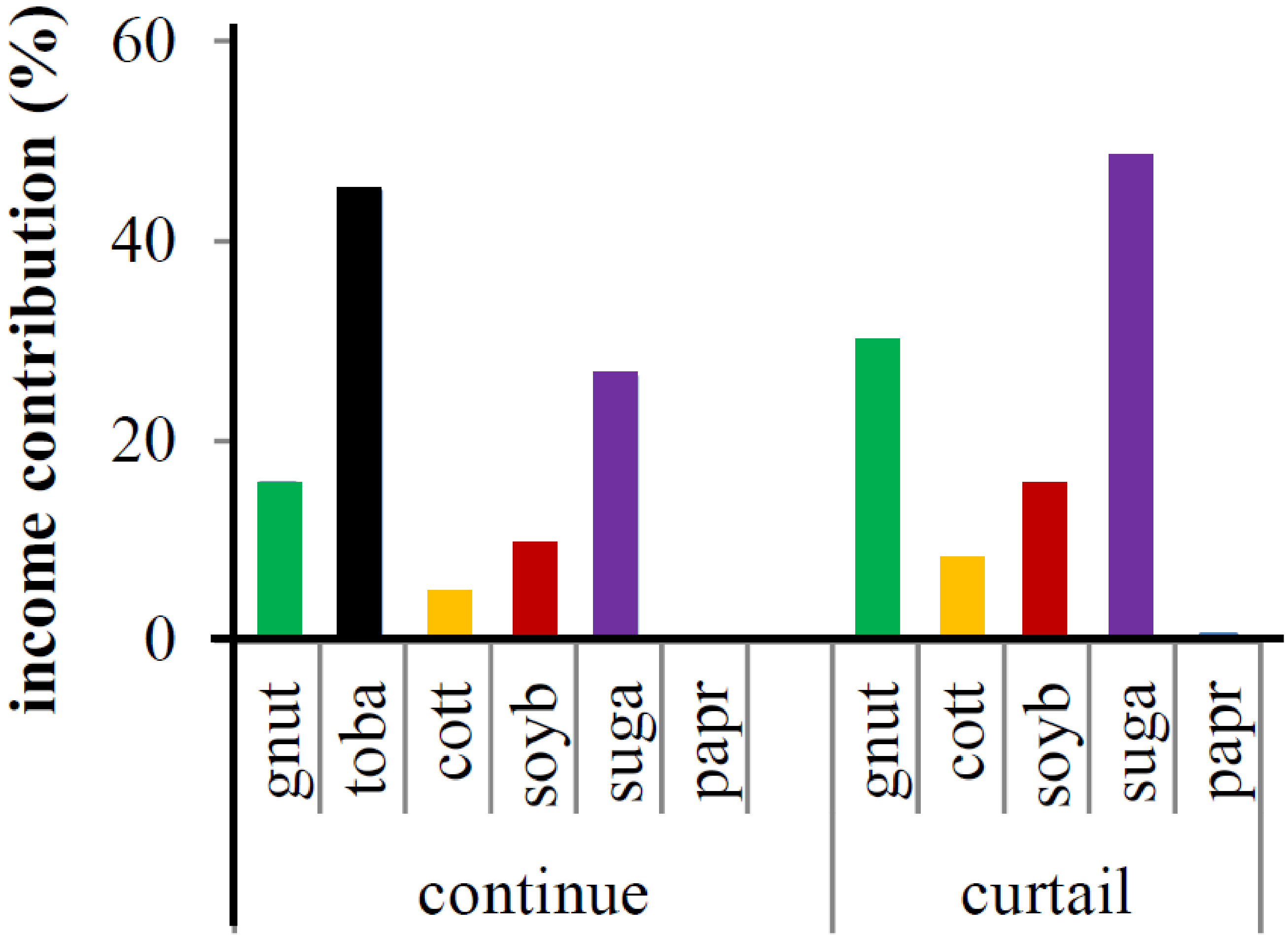
Modified from McCarl und Schneider, Science, 2001

Cost of biodiversity protection



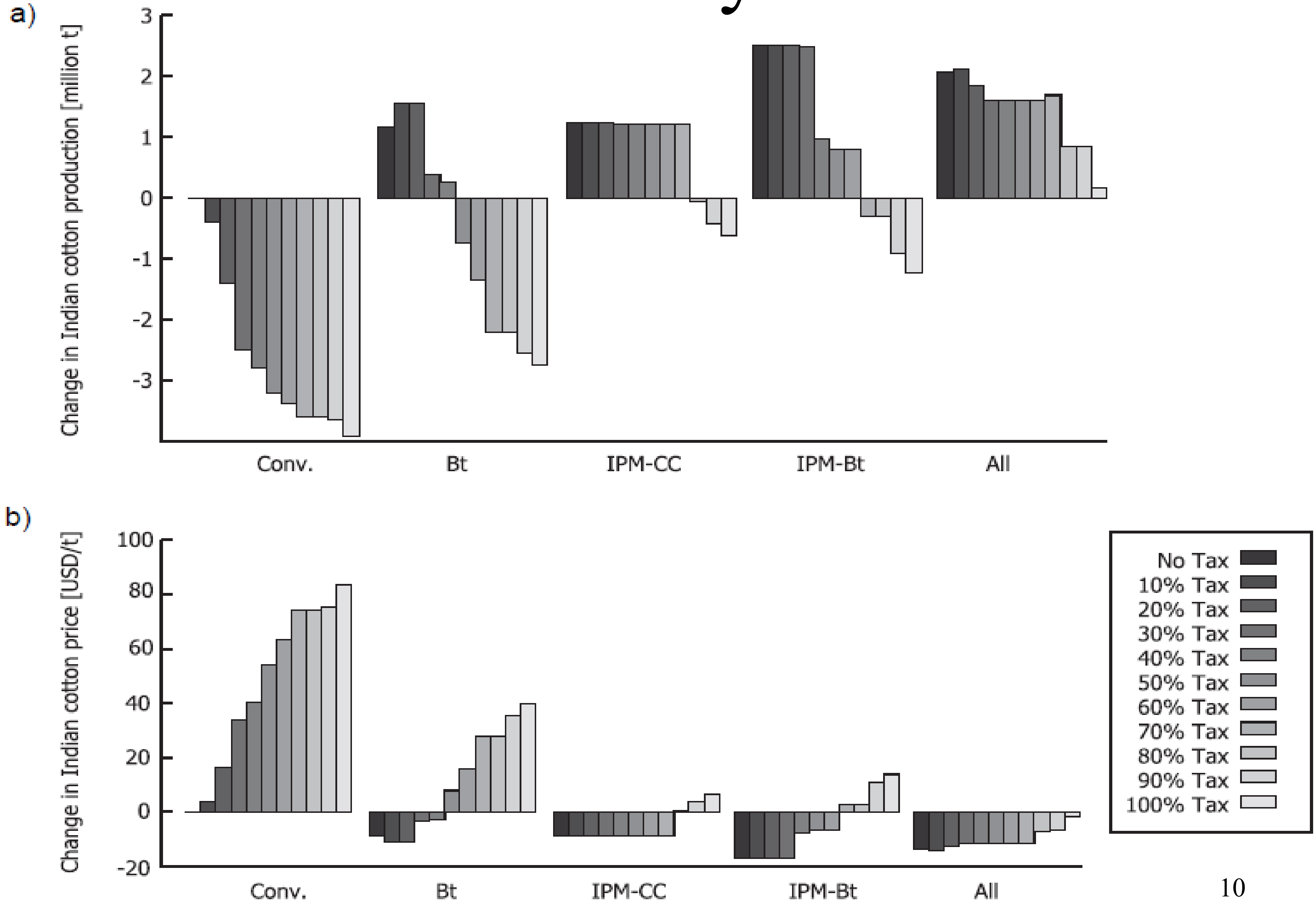
Modified from Jantke und Schneider, Environmental Conservation, 2013

Tobacco Policy in Malawi

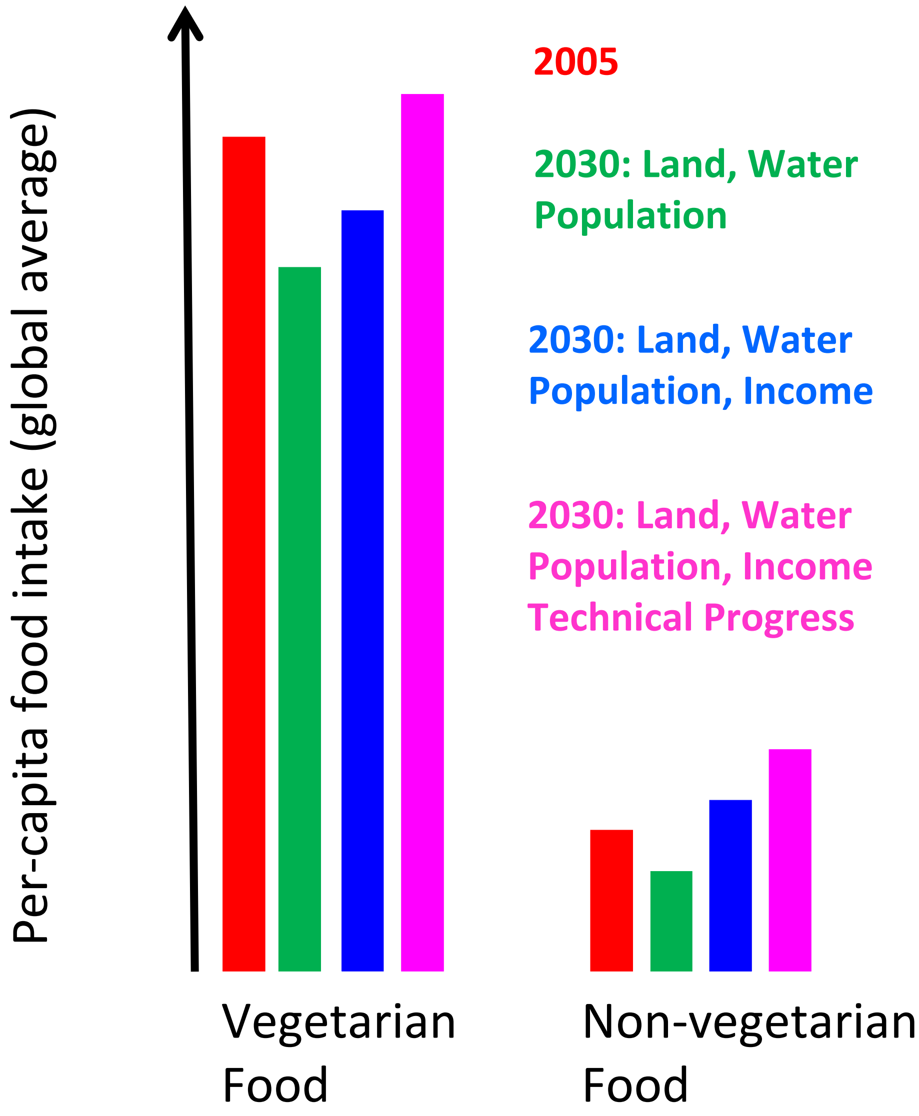


Source: Dr. Mutisungilire Kachulu, Food Security, Climate Change Adaption and Landuse Options for Smallholder Farmers in Malawi, Department of Geosciences (2017) pdf

Pesticide Policy in India



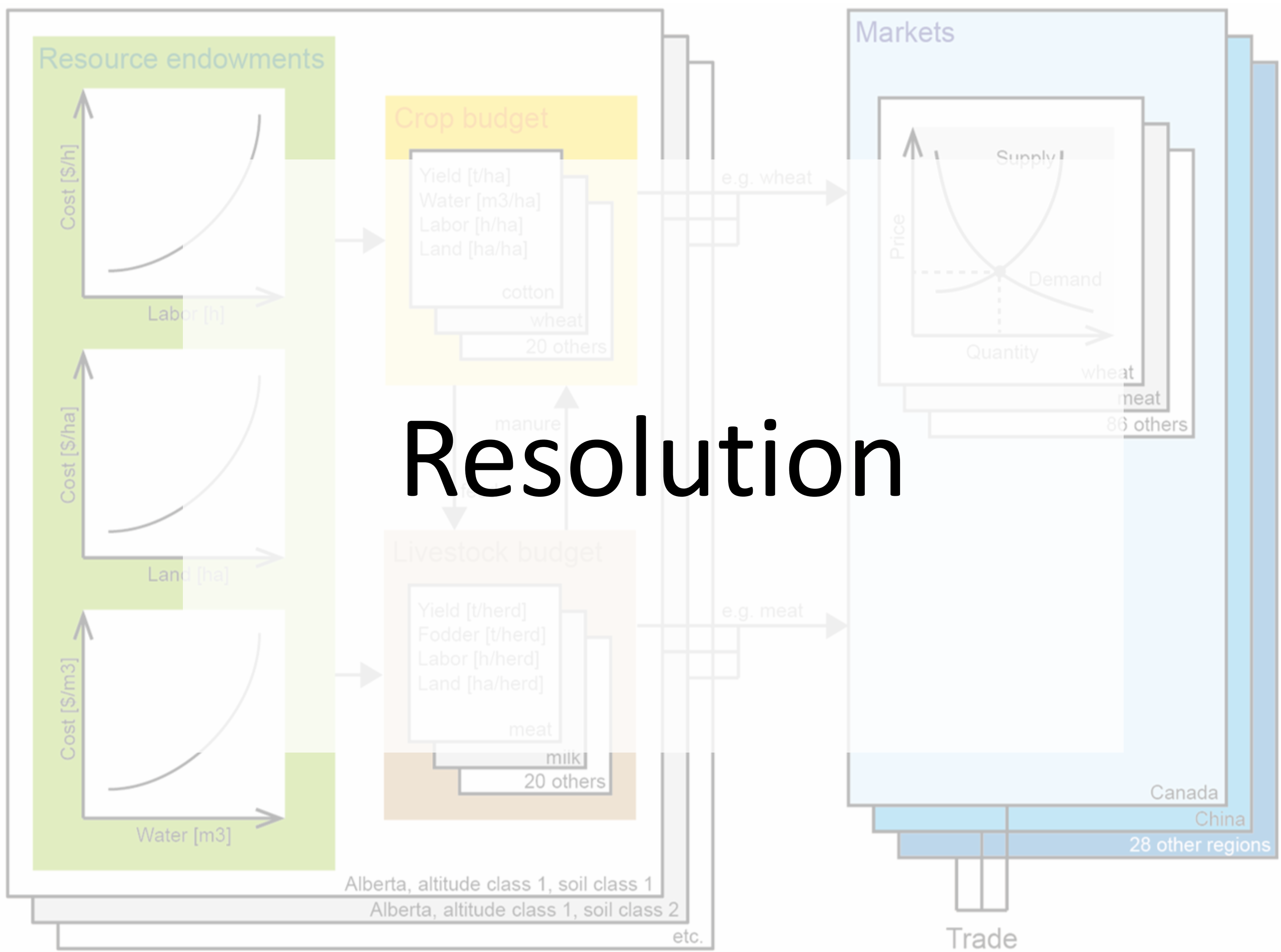
Source: Rasche et al. 2016 Pest Management



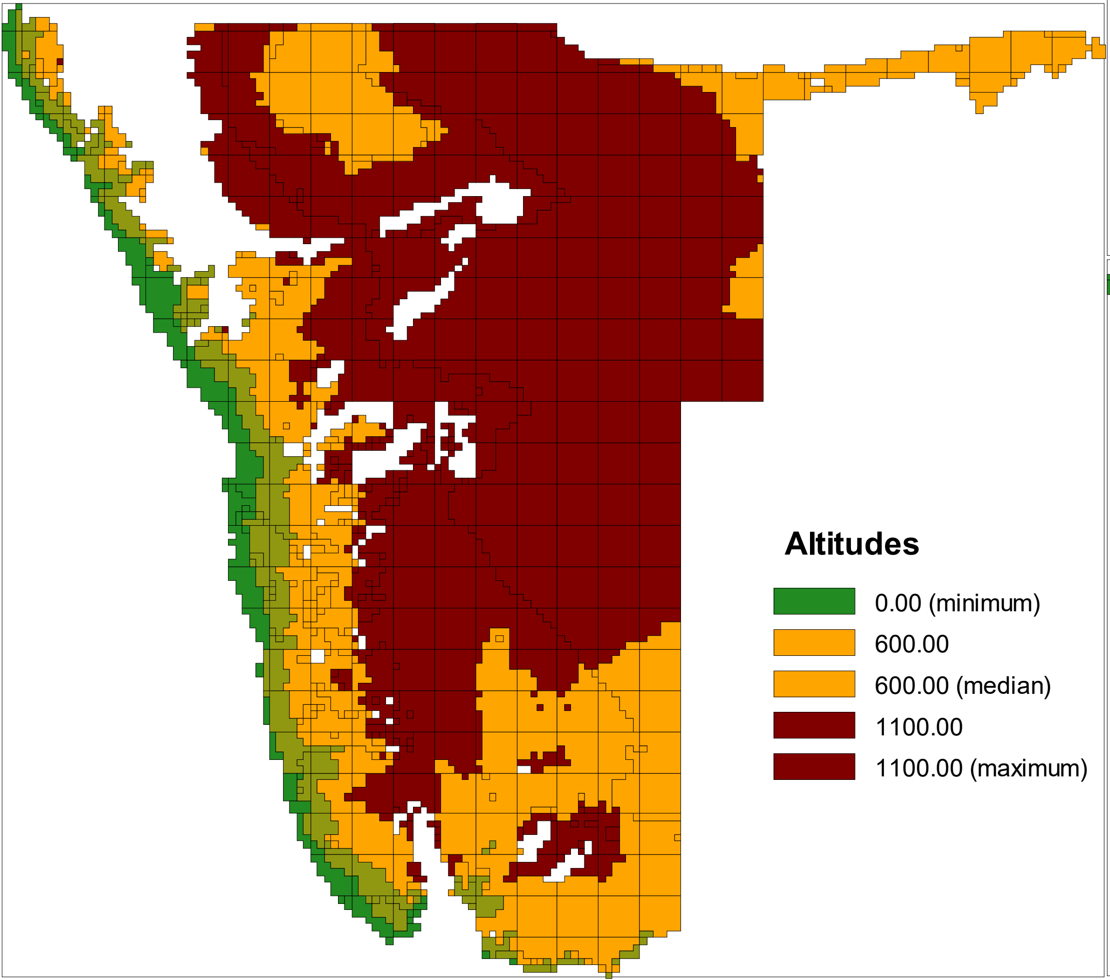
Global development and food security

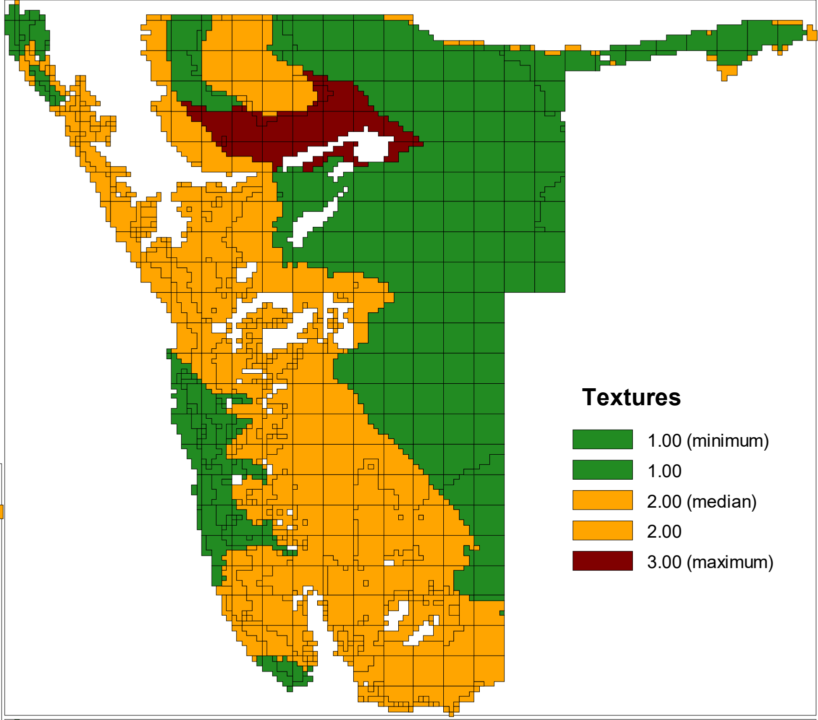
Modified from Schneider et al., Agricultural Systems, 2011

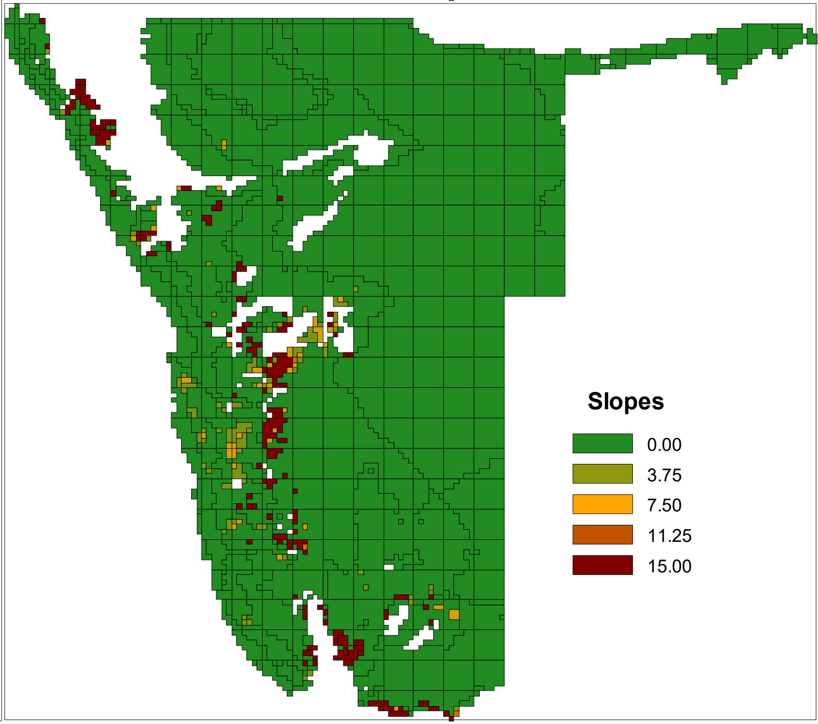
Resolution

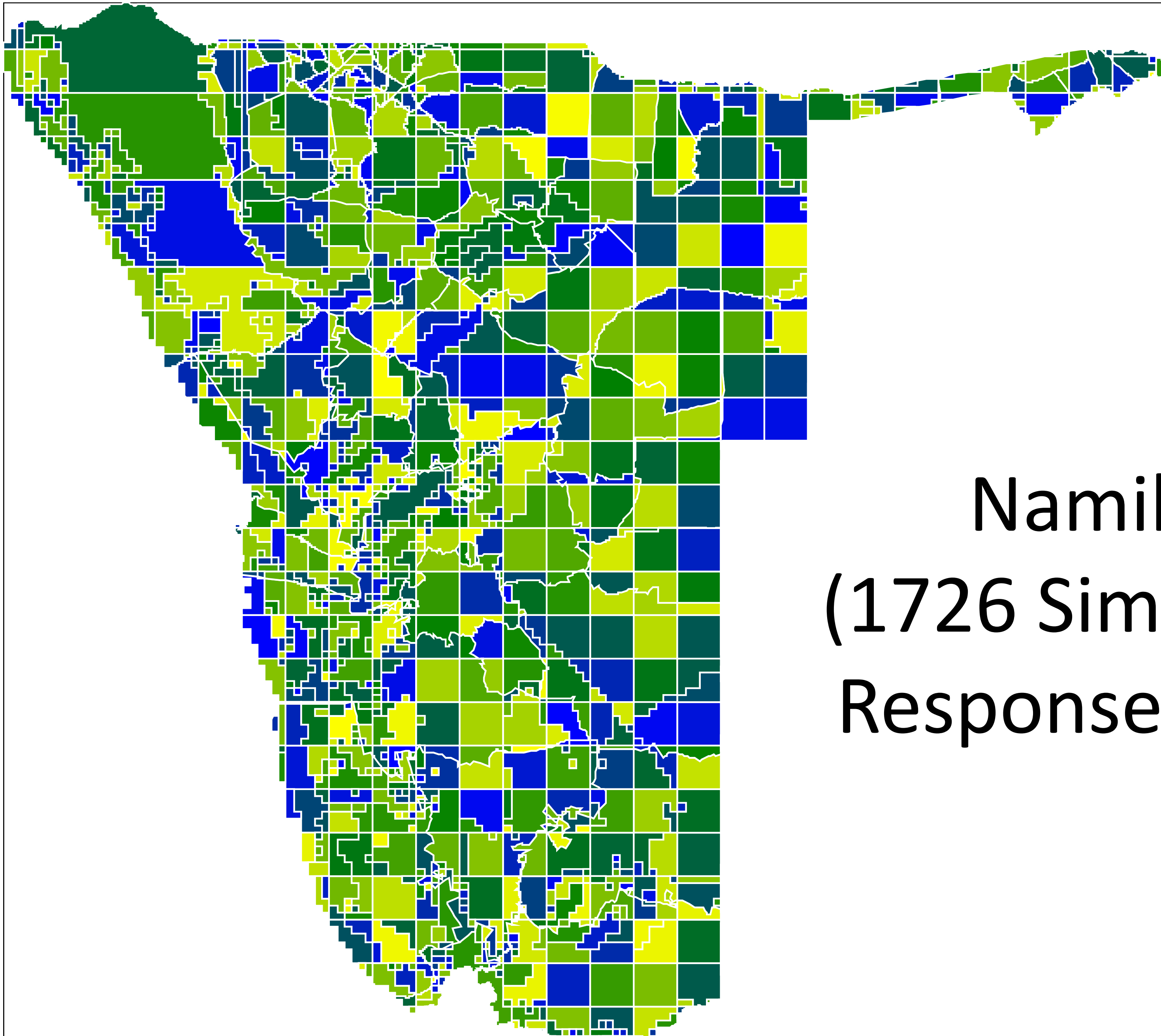

Resource endowments
Cost [$/h]
Labor [h]
Cost [$/ha]
Land [ha]
Cost [$/m3]
Water [m3]
Crop budget
Yield [t/ha]
Water [m3/ha]
Labor [h/ha]
Land [ha/ha]
cotton
wheat
20 others
manure
Livestock budget
Yield [t/herd]
Fodder [t/herd]
Labor [h/herd]
Land [ha/herd]
meat
milk
20 others
e.g. wheat
e.g. meat
Markets
Supply
Demand
Price
Quantity
wheat
meat
86 others
Canada
China
28 other regions
Trade
Alberta, altitude class 1, soil class 1
Alberta, altitude class 1, soil class 2
etc.

Namibia (737 Homogenous Response Units)

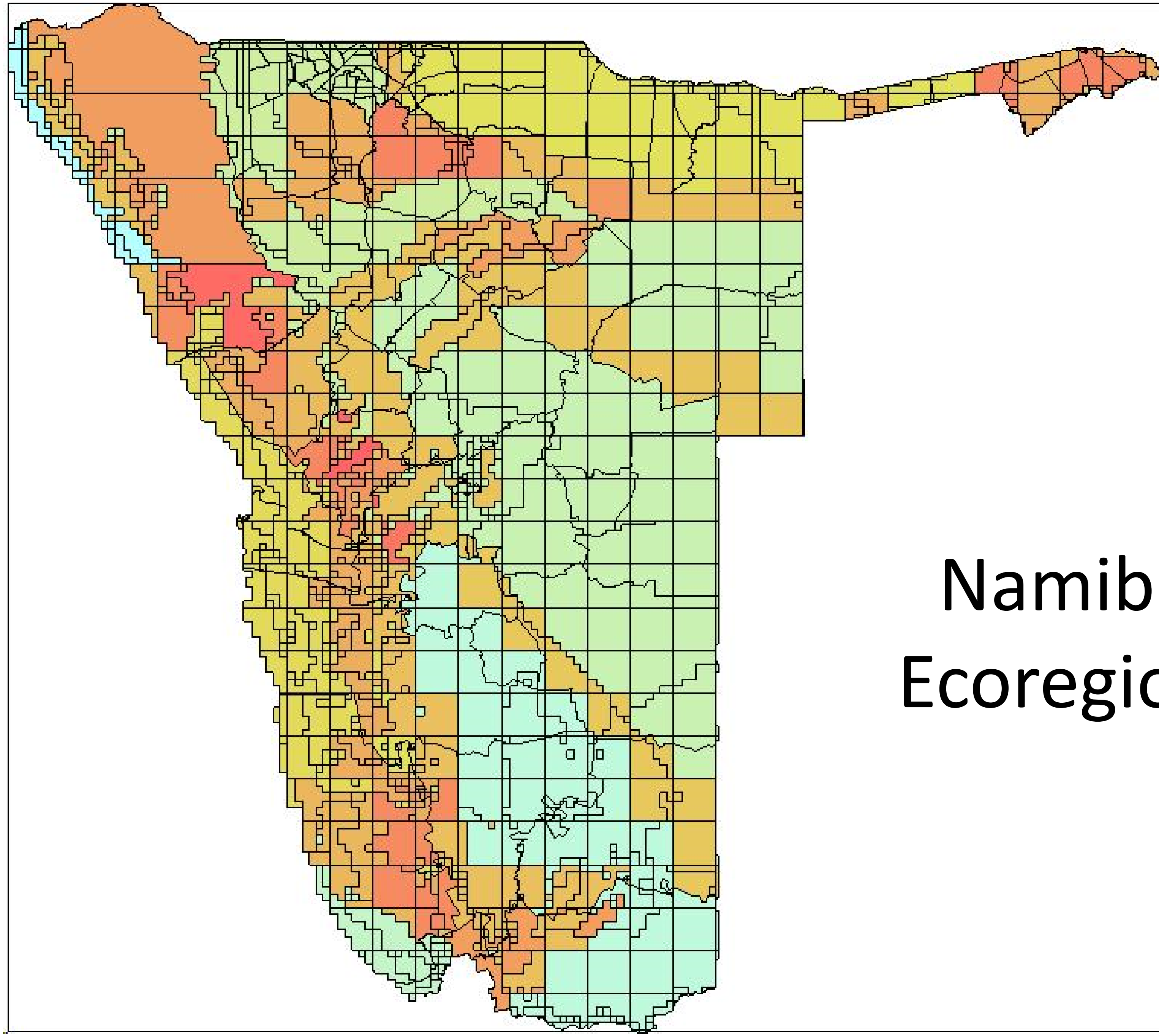








Namibia (1726 Simulation Response Units)



Namibia Ecoregions

Sorghum


Cow Peas


Cotton

Oats

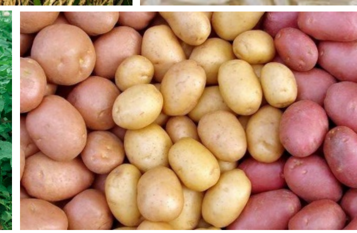

Rapeseed


Wheat

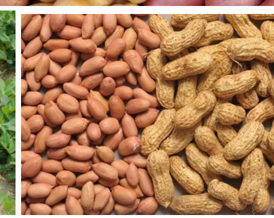

Sunflower


Rice


Potatoes

Groundnuts

Dry Beans


Chickpeas	
Sugarcane	
Sweet Potatoes	
Soybeans	
Millet	
Corn	
Barley	
Cassava	
Rye	
Legumes	

Dairy Bovine

Other Bovine

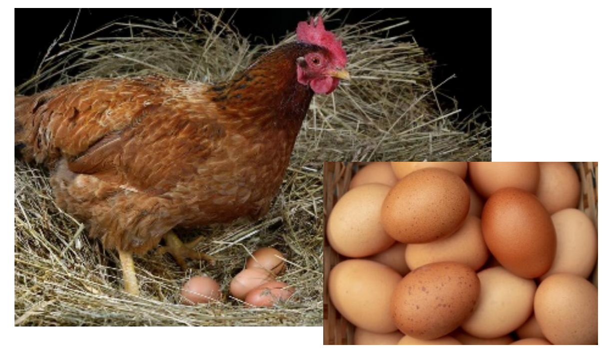
Pigs

Dairy Sheep and Goats

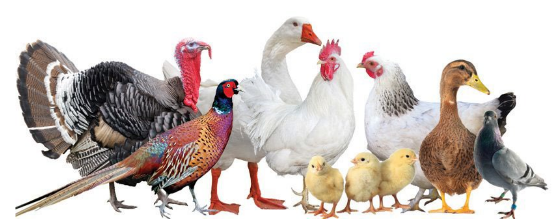
Other Sheep and Goats

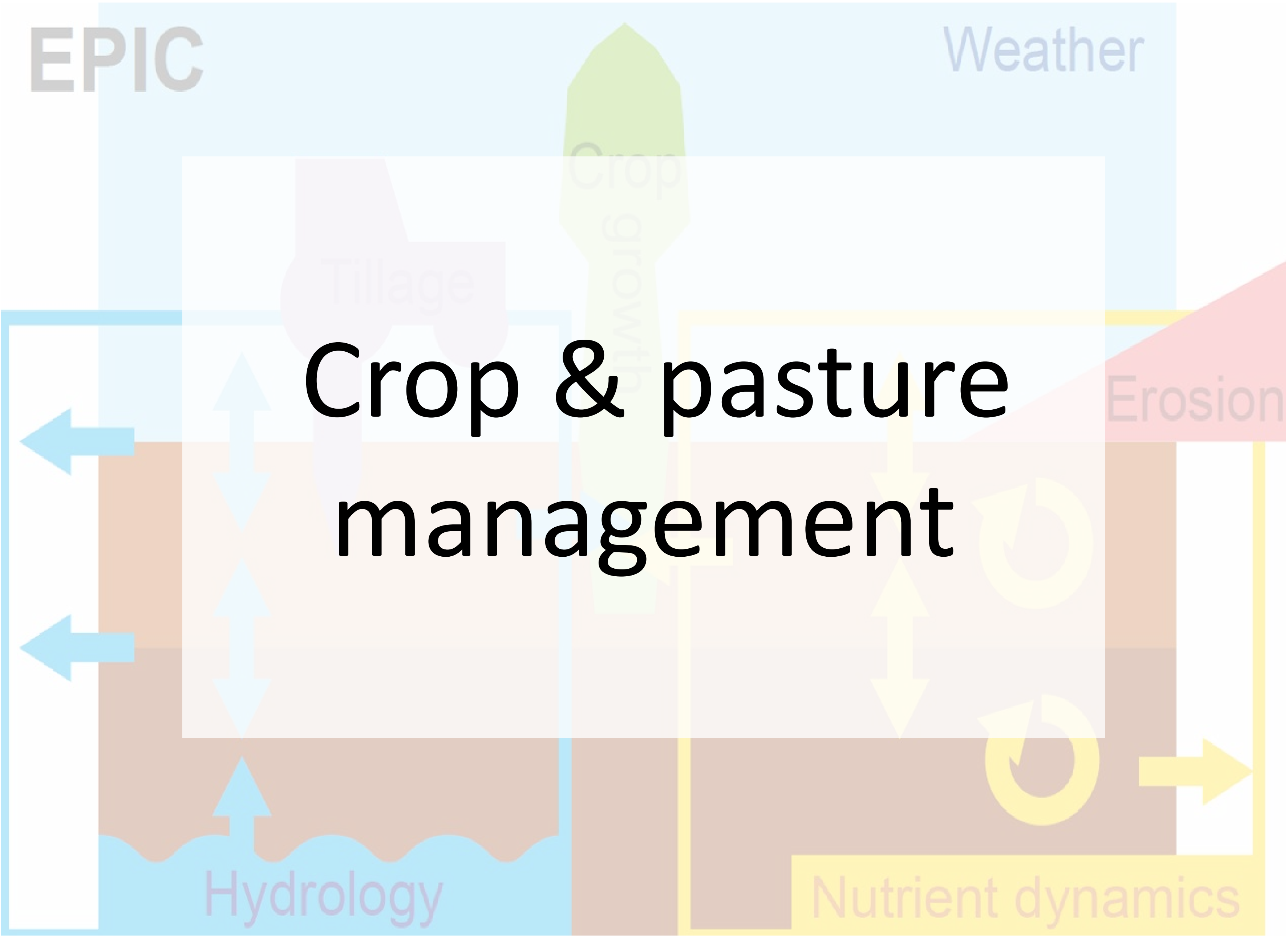
Poultry Broilers

Laying Hens



Other Poultry





Crop & pasture management

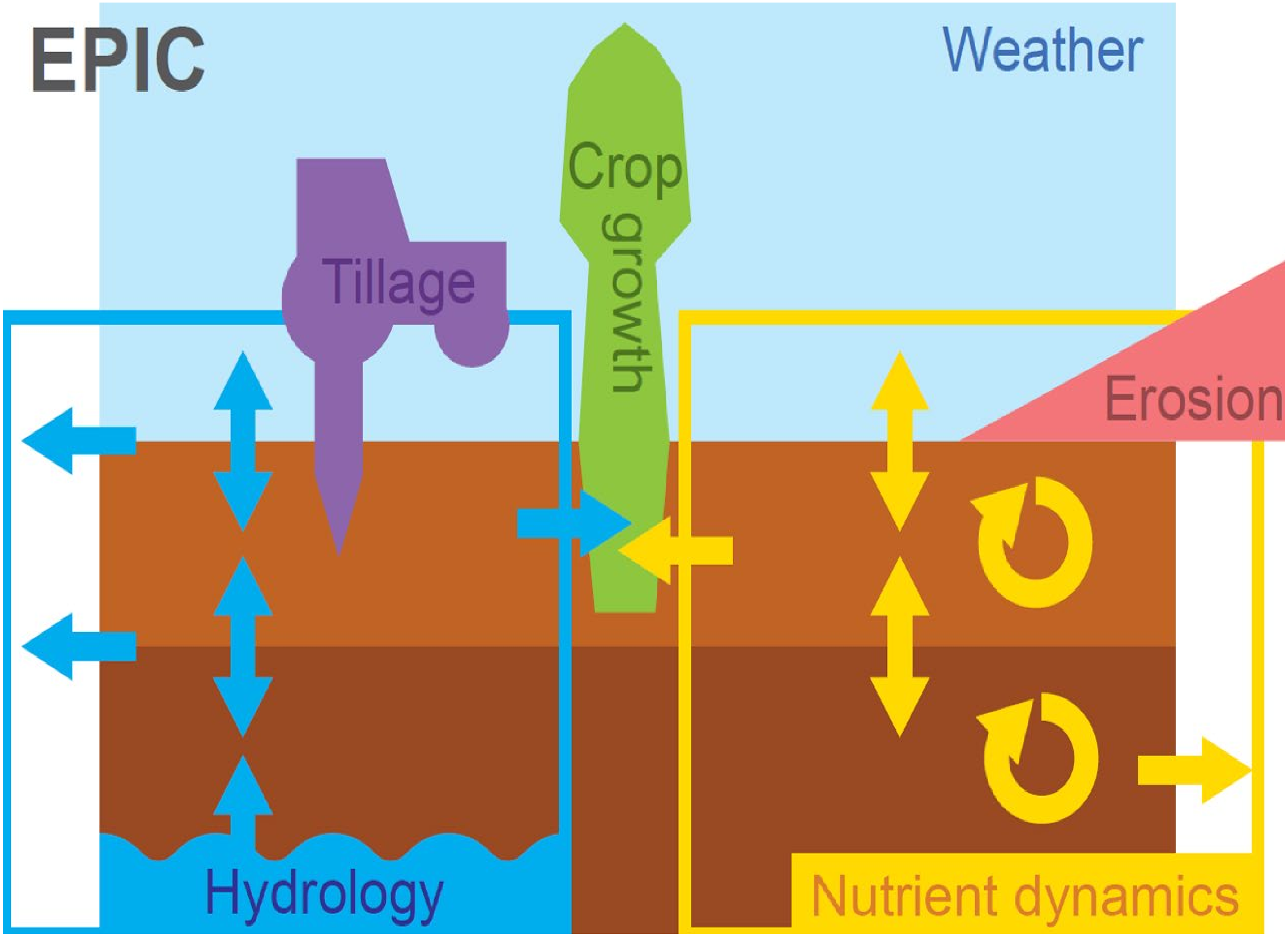
Crop Management Systems (Global Simulations)

high input systems with nitrogen fertilization rates that are based on pre-EPIC simulations. No irrigation.

irrigation systems - fertilization rates are 120% of HI. Irrigation levels are currently only crop specific and constant.

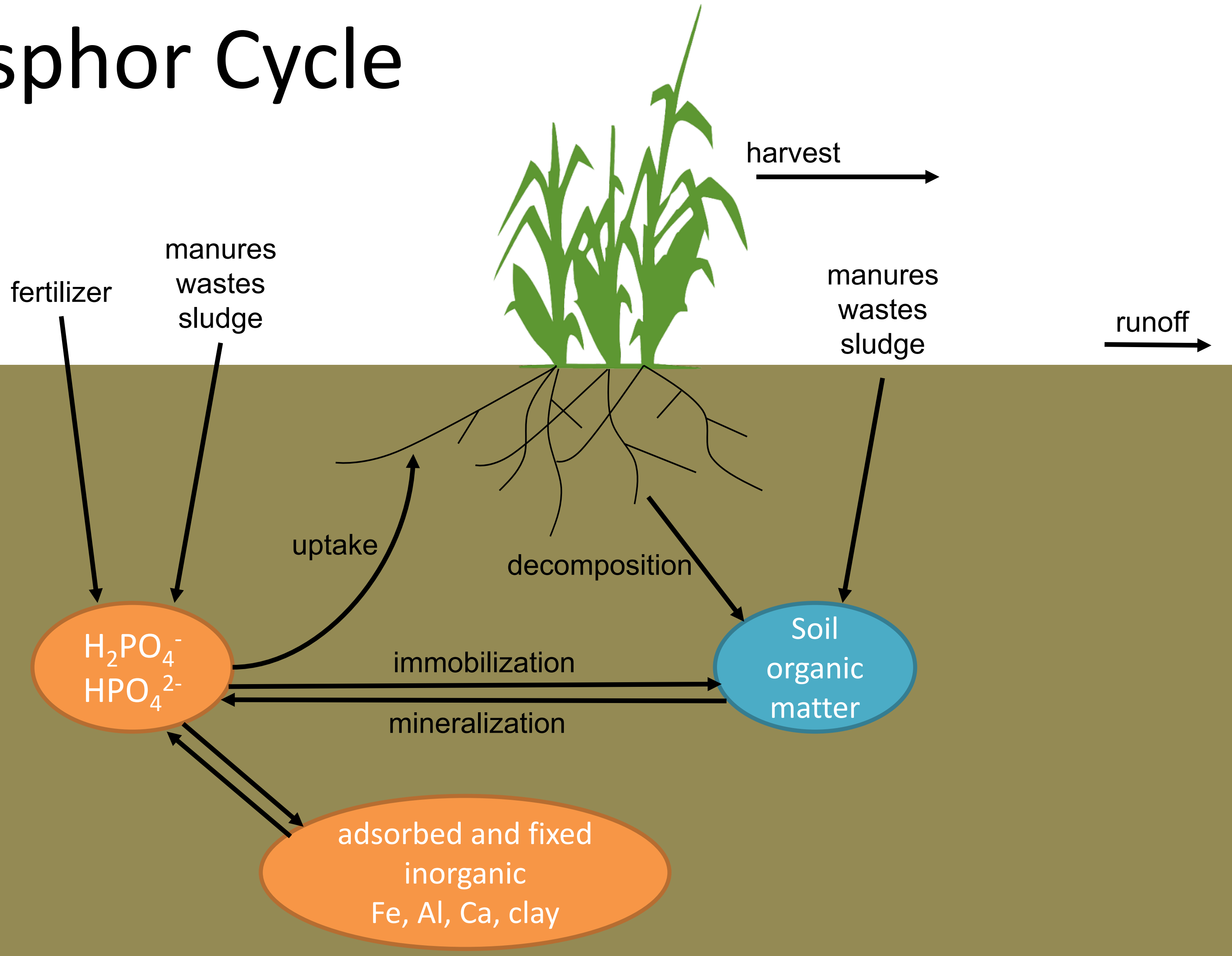
low input systems - fertilization rates are 50% of HI, no irrigation.

subsistence farming – no N fertilizations and irrigation.



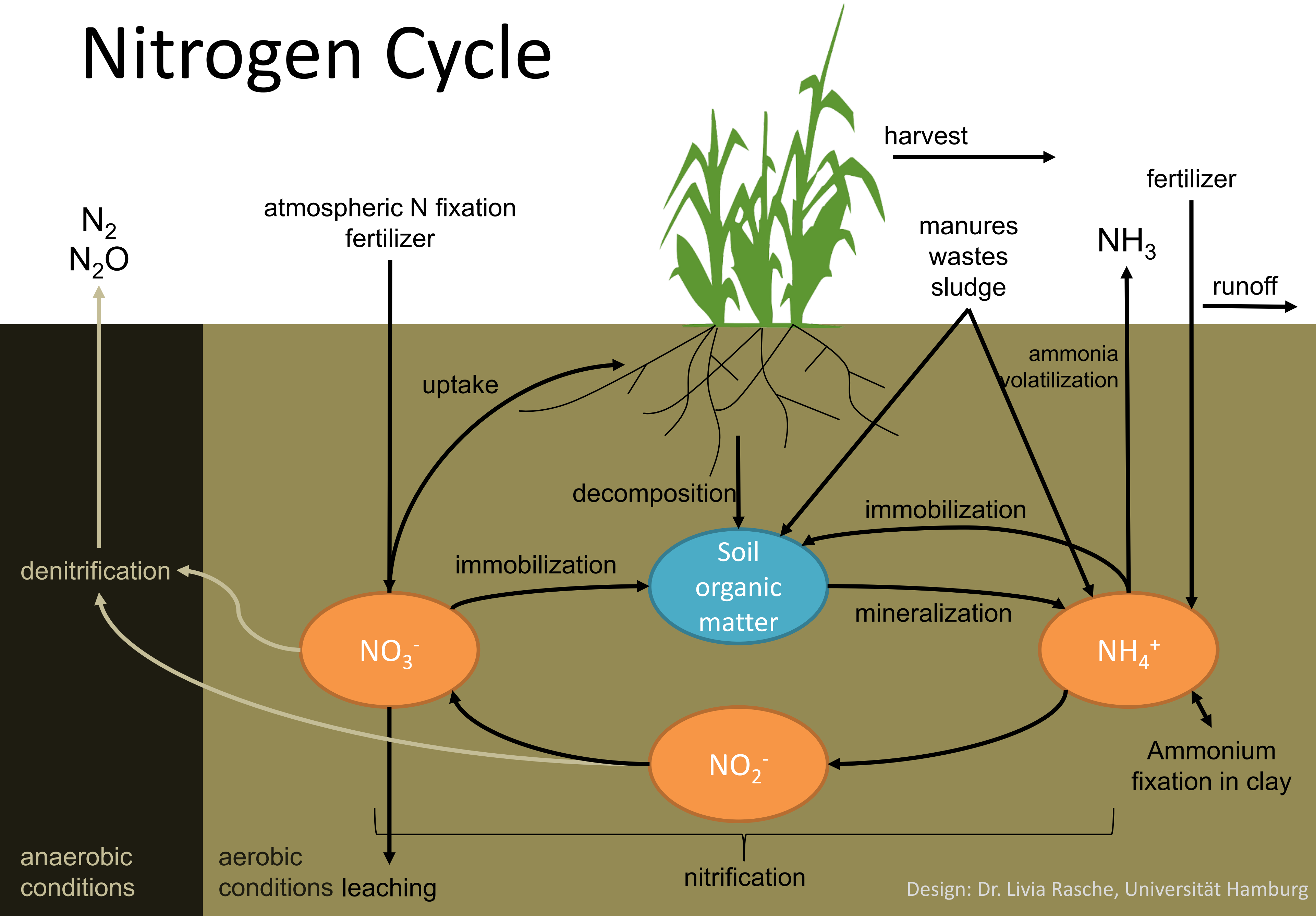
Design: Dr. Livia Rasche, Universität Hamburg

Phosphor Cycle

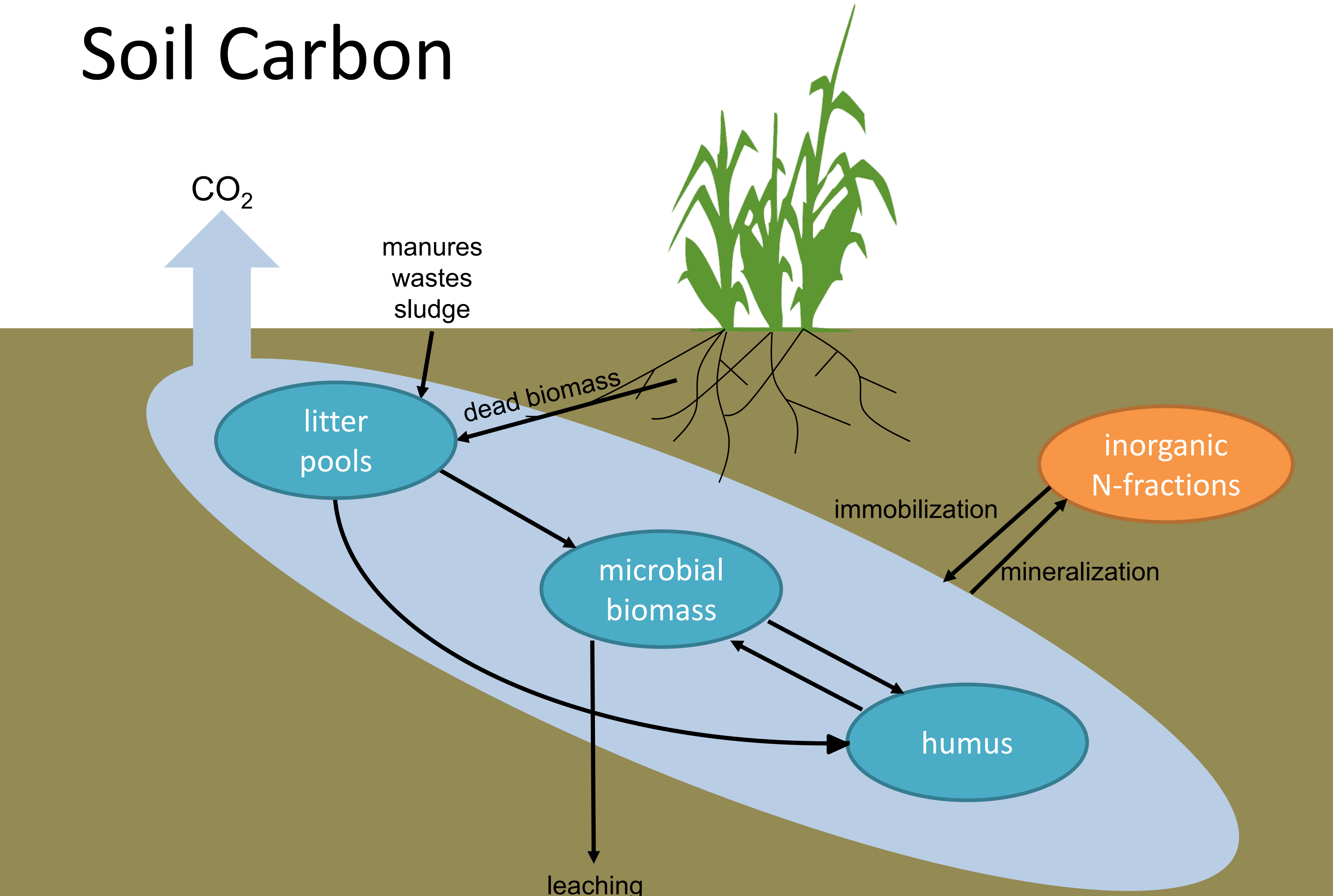


Design: Dr. Livia Rasche, Universität Hamburg

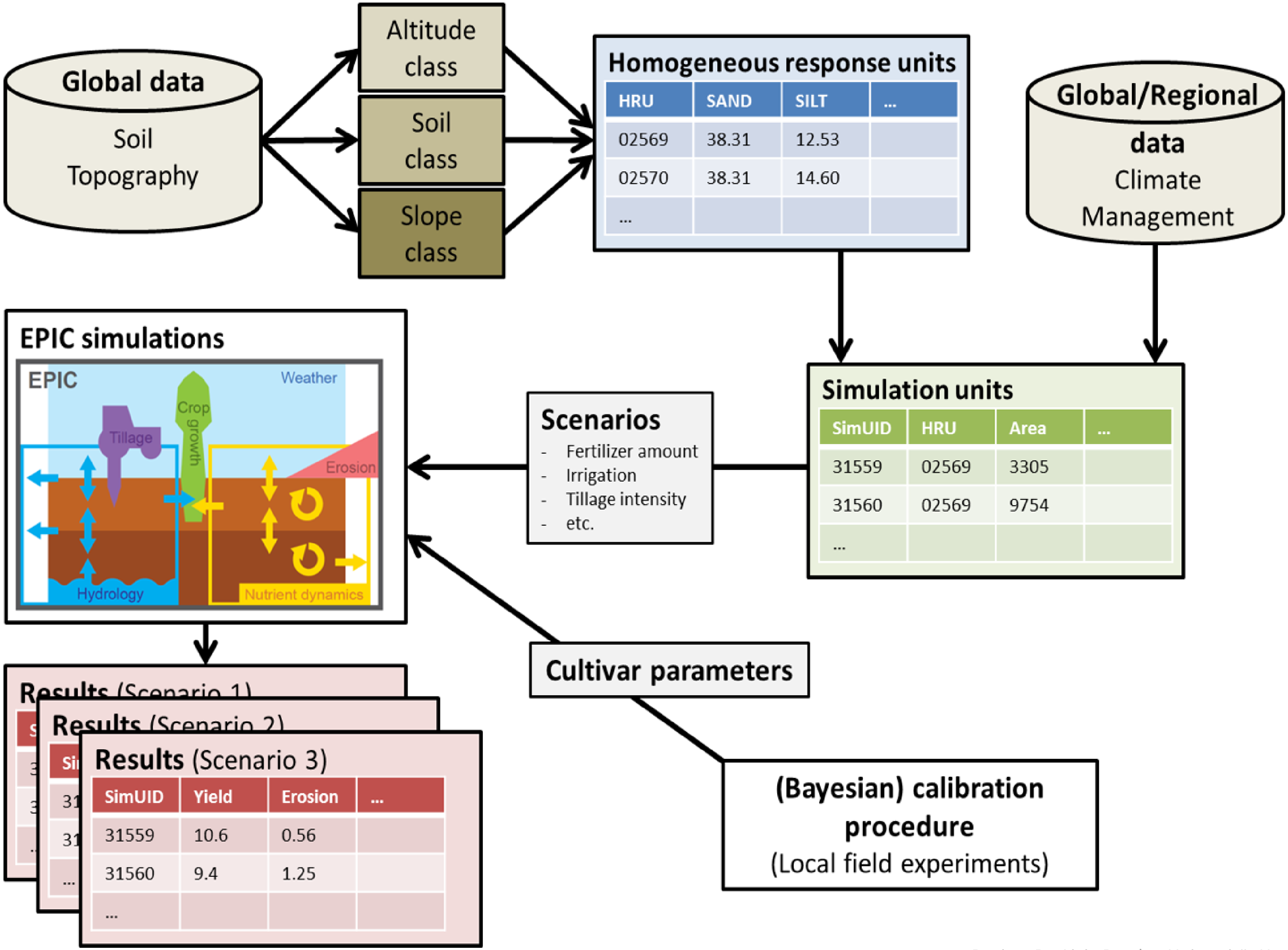
Nitrogen Cycle



Soil Carbon

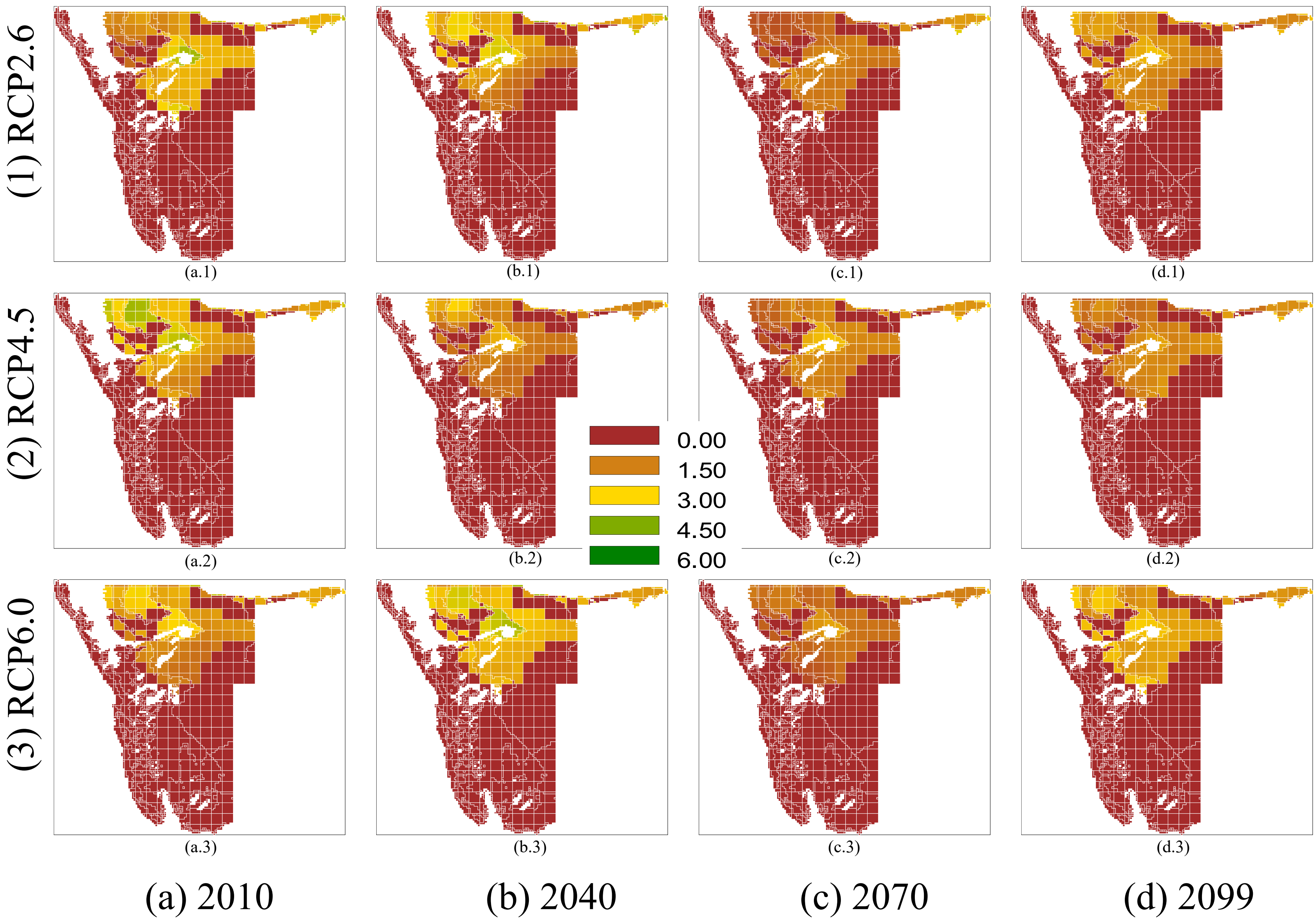


Design: Dr. Livia Rasche, Universität Hamburg

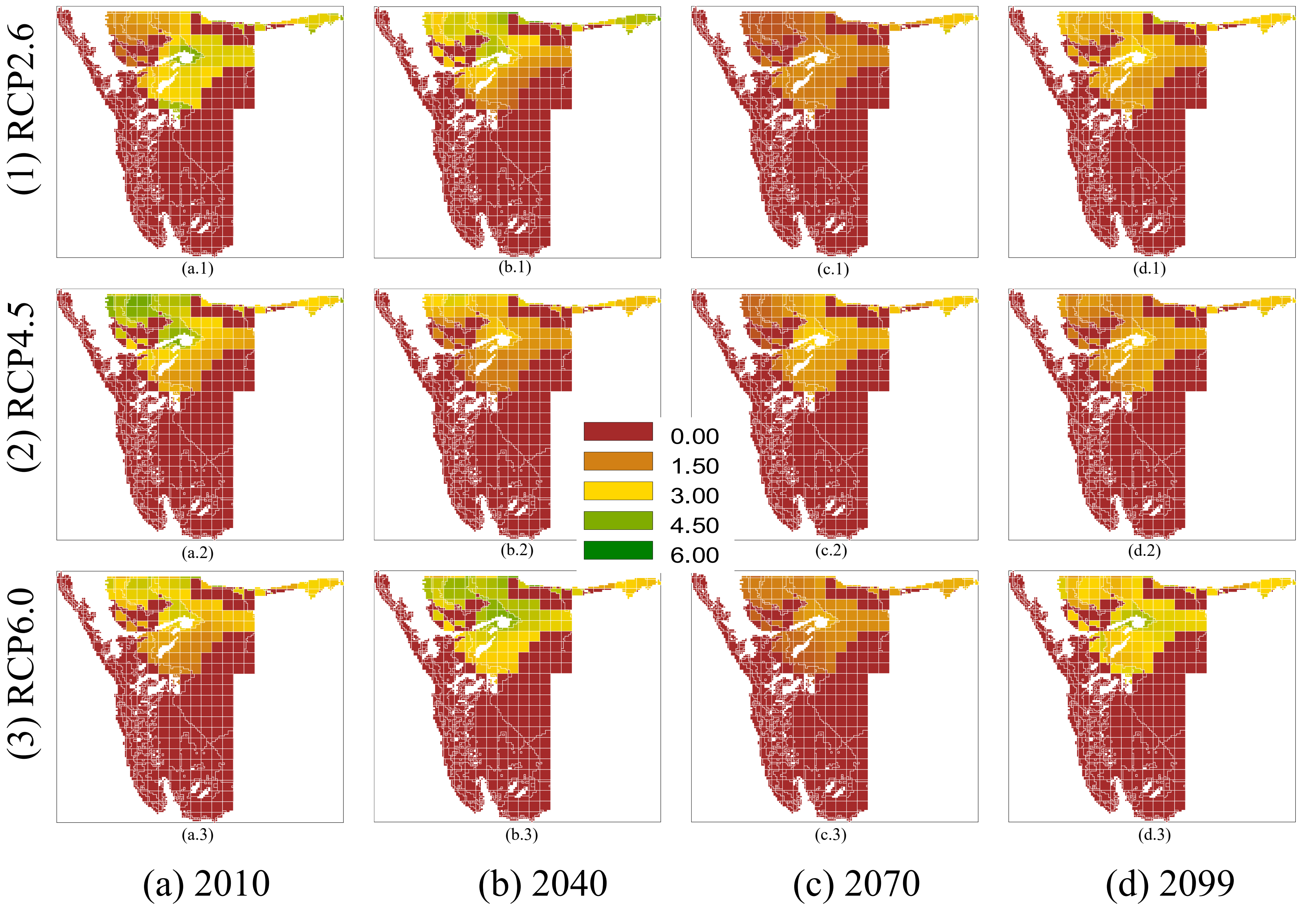


Design: Dr. Livia Rasche, Universität Hamburg

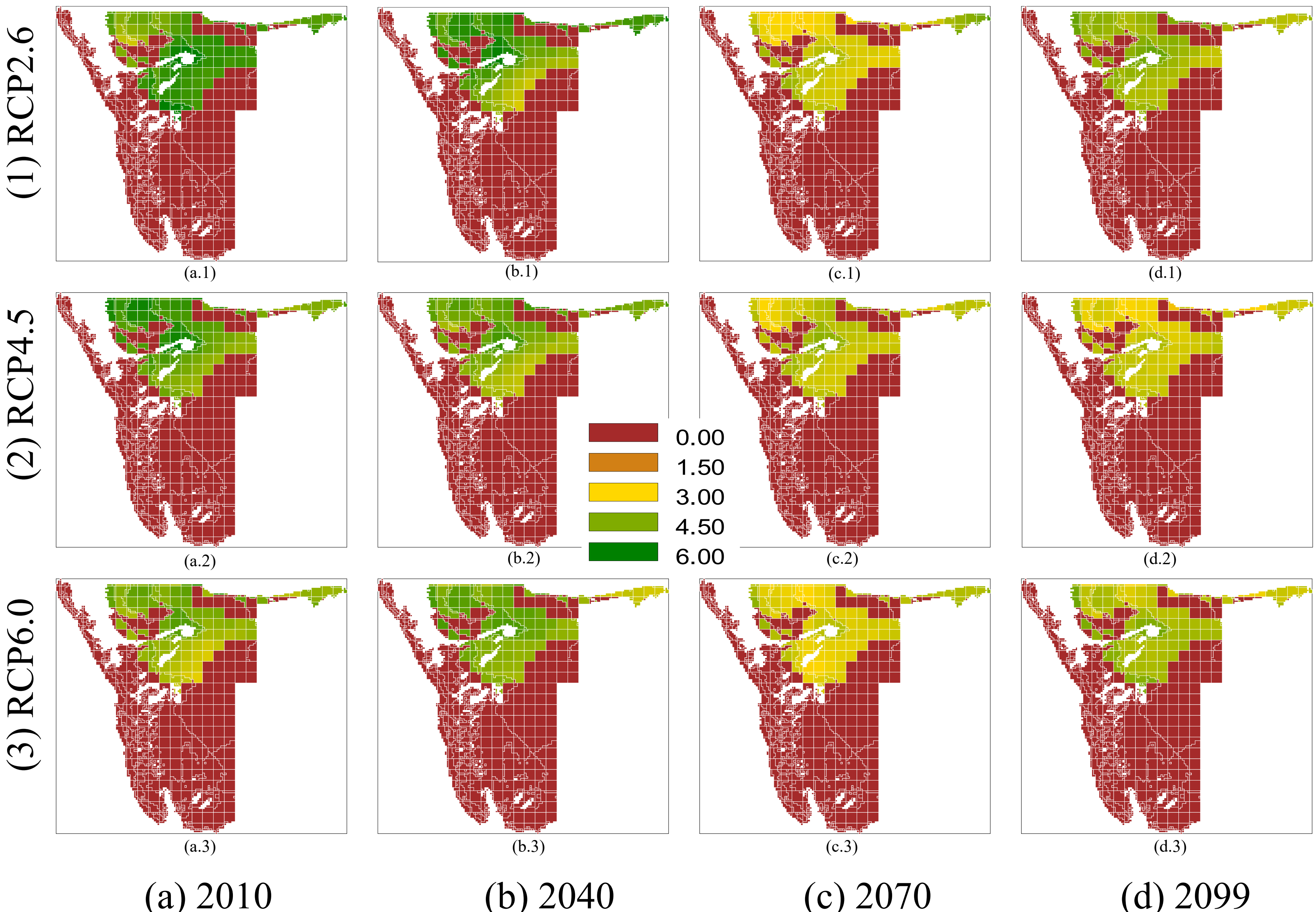
Crop Yields (t/ha): Subsistence Farming



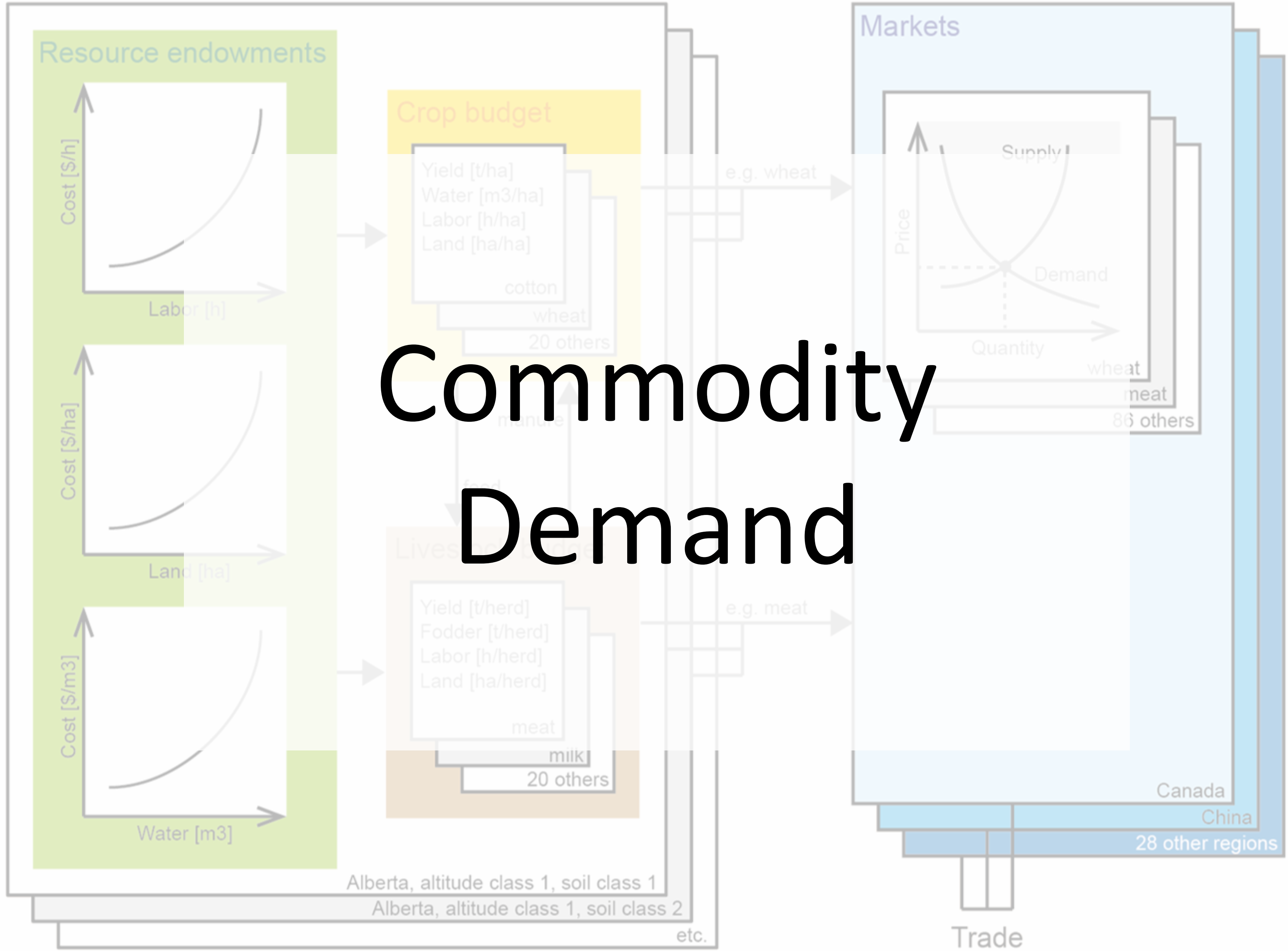
Crop Yields (t/ha): Fertilization



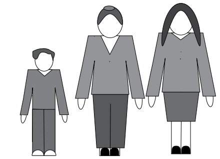
Crop Yields (t/ha): Irrigation

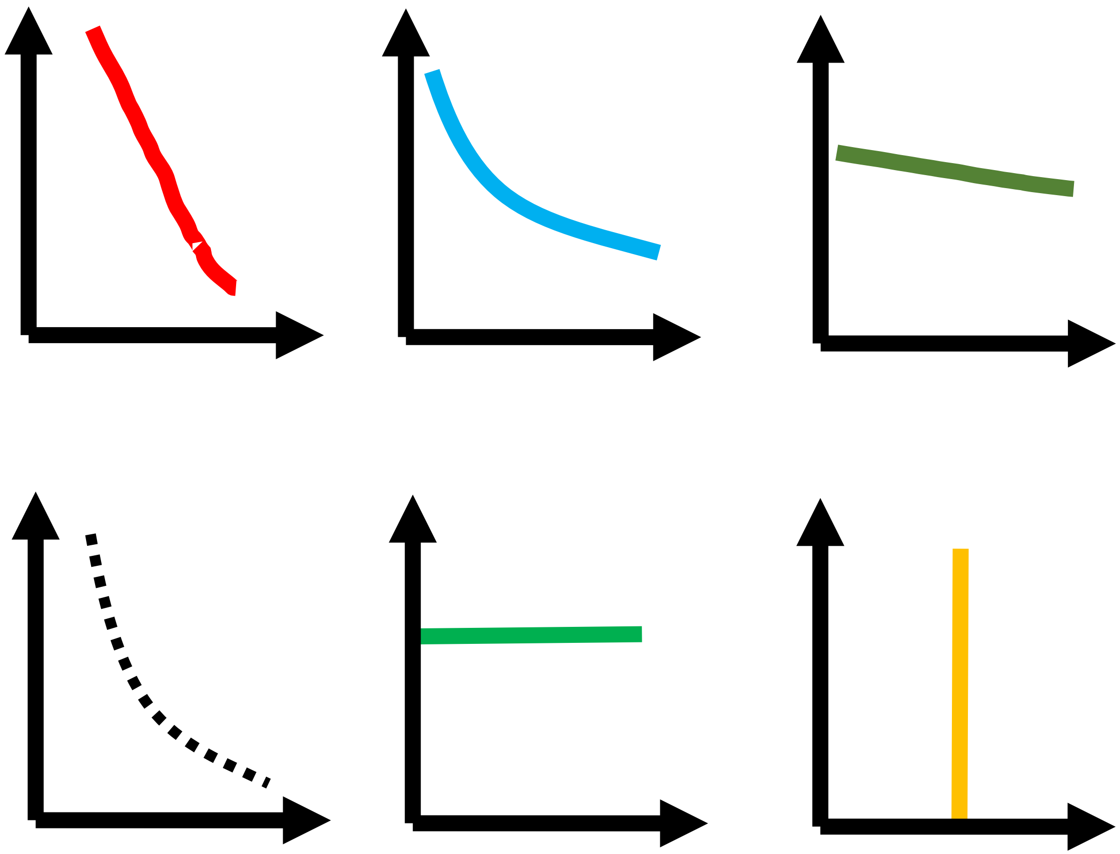


Commodity Demand



Demand Functions



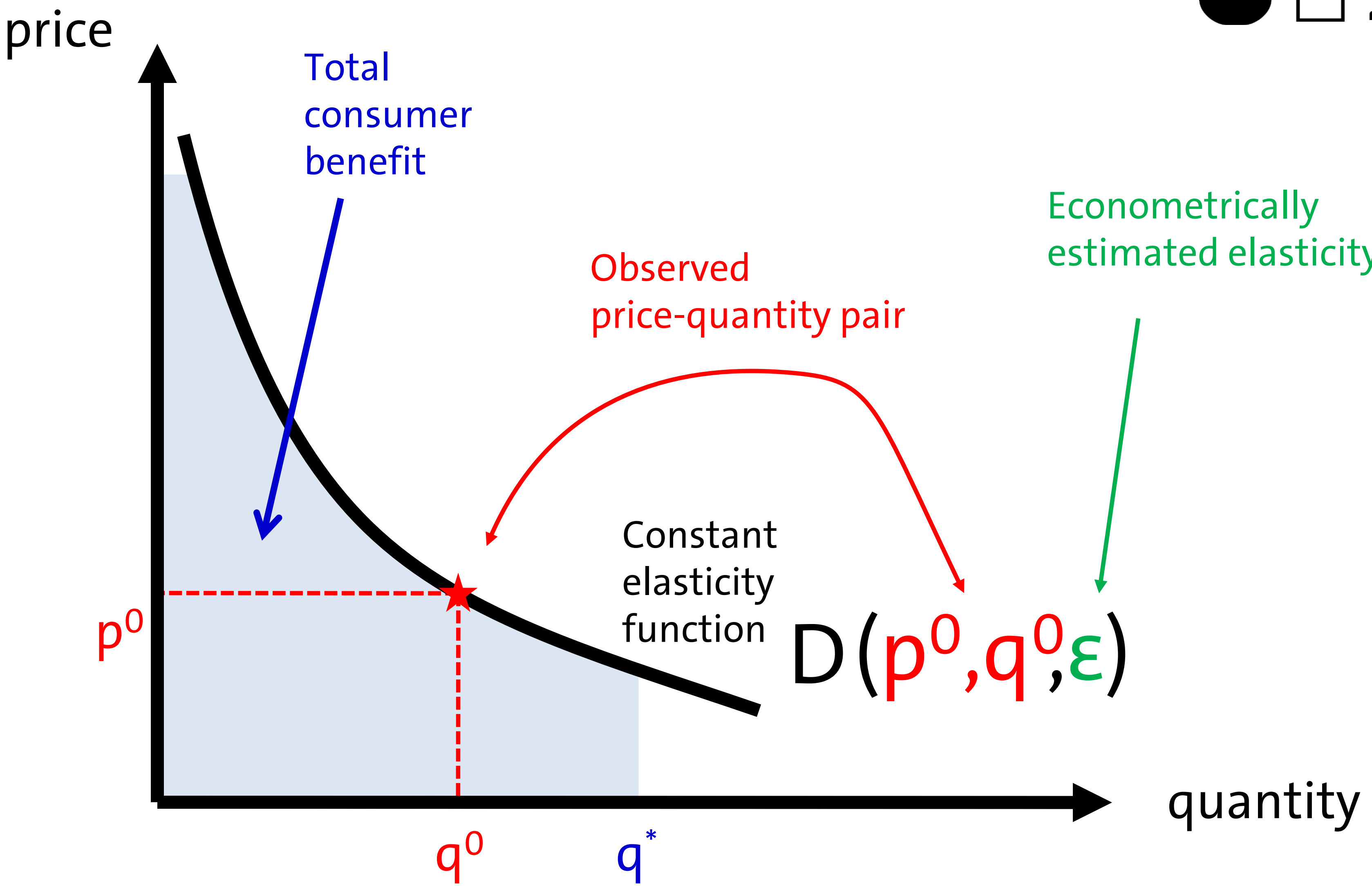


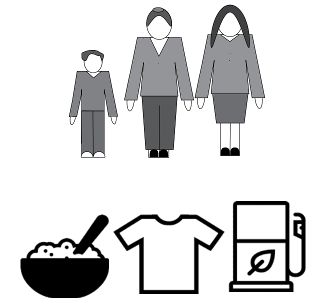
- Food
- Fiber
- Energy
- …
- C-Sequestration
- Biodiversity
- Externalities
- …

For all Commodities, Regions, Time Periods

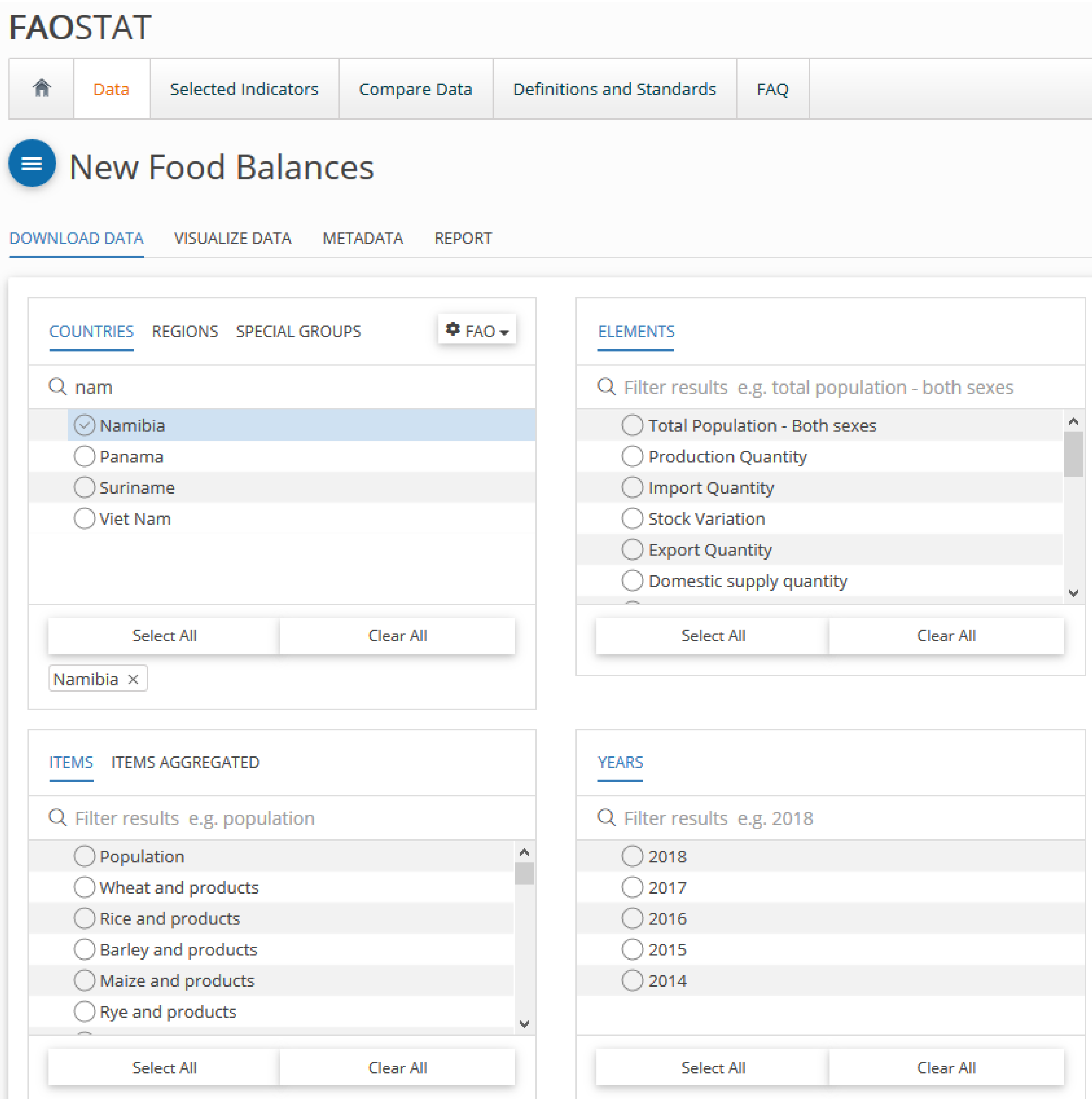
International Market Regions

Market Demand





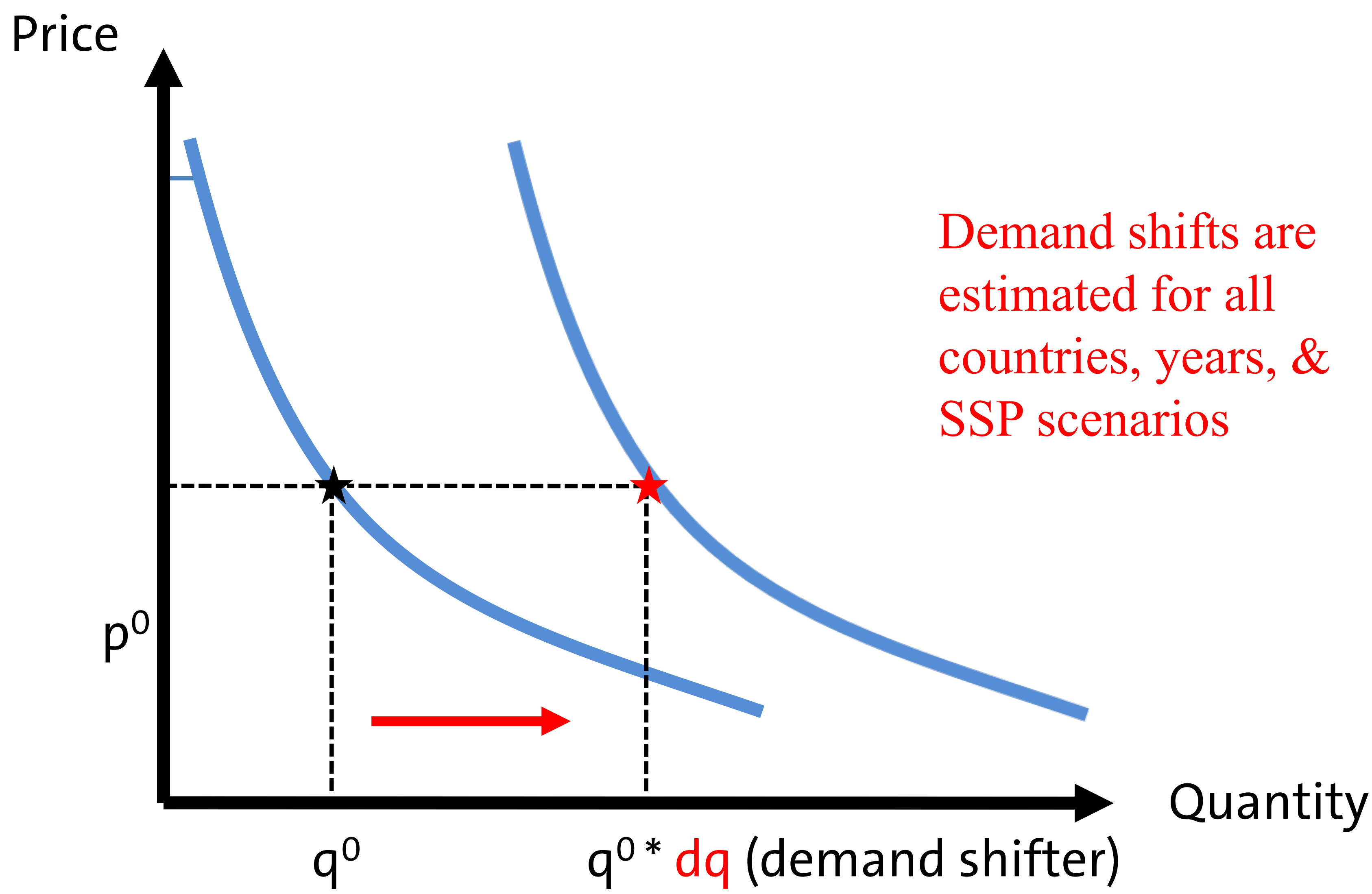
Market Data


FAOSTAT
Data
Selected Indicators
Compare Data
Definitions and Standards
FAQ
New Food Balances
DOWNLOAD DATA
VISUALIZE DATA
METADATA
REPORT
COUNTRIES
REGIONS
SPECIAL GROUPS
FAO
nam
Namibia
Panama
Suriname
Viet Nam
Select All
Clear All
Namibia ×
ELEMENTS
Filter results e.g. total population - both sexes
Total Population - Both sexes
Production Quantity
Import Quantity
Stock Variation
Export Quantity
Domestic supply quantity
Select All
Clear All
ITEMS
ITEMS AGGREGATED
Filter results e.g. population
Population
Wheat and products
Rice and products
Barley and products
Maize and products
Rye and products
Select All
Clear All
YEARS
Filter results e.g. 2018
2018
2017
2016
2015
2014
Select All
Clear All

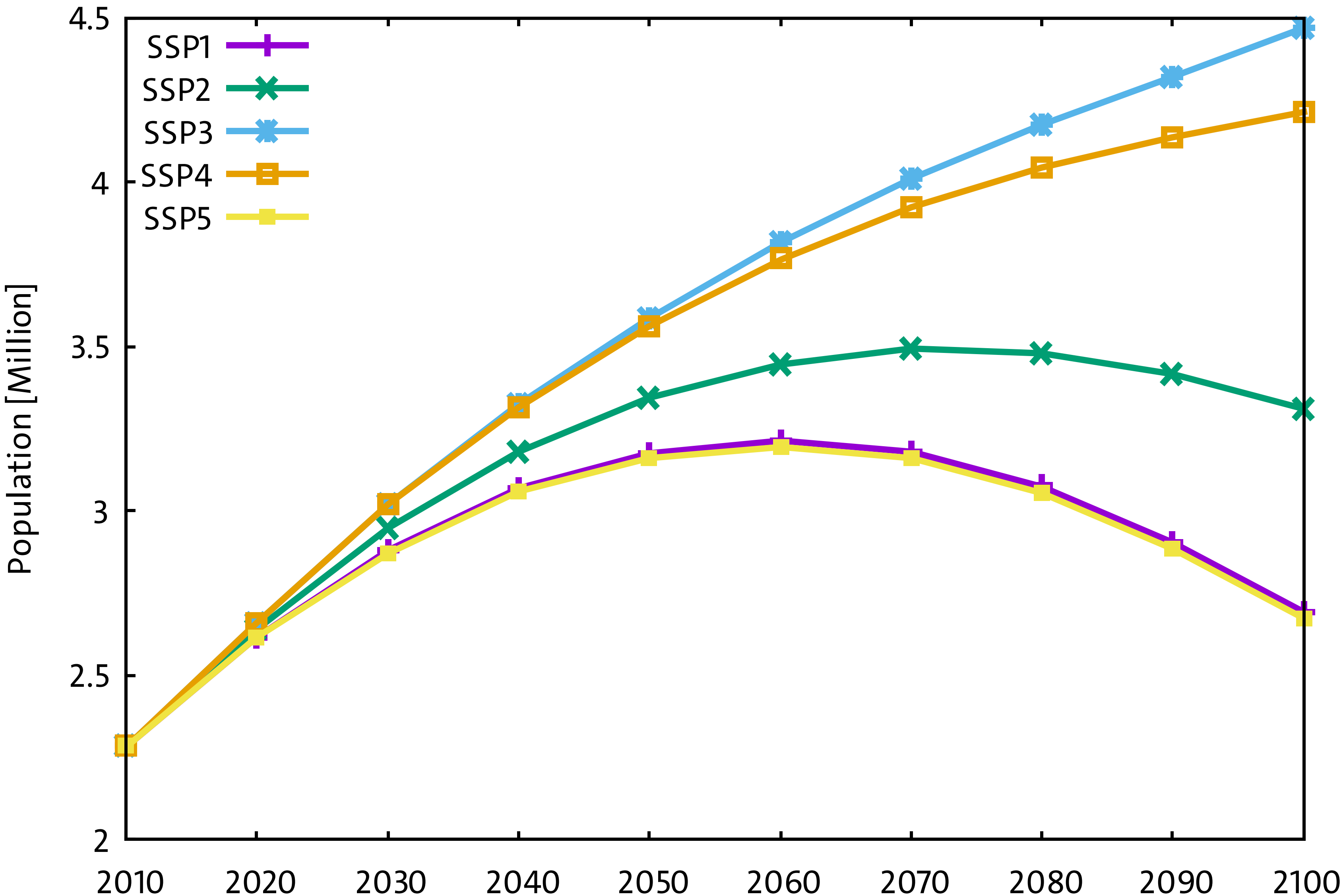
Market Data

	Namibia									
	Production									
	2010		2011		2012		2013		2014	
	Unit	Value	Unit	Value	Unit	Value	Unit	Value	Unit	Value
Eggs, hen, in shell	tonnes	3360	tonnes	3360	tonnes	3400	tonnes	3500	tonnes	3400
Eggs, hen, in shell (number)	1000 No	84000	1000 No	84300	1000 No	84500	1000 No	87500	1000 No	85000
Eggs, other bird, in shell	tonnes	1000	tonnes	1000	tonnes	1011	tonnes	1072	tonnes	1269
Eggs, other bird, in shell (number)	1000 No	760000	1000 No	760000	1000 No	760000	1000 No	760000	1000 No	1269220
Fat, cattle	tonnes	938	tonnes	919	tonnes	959	tonnes	951	tonnes	1012
Fat, goats	tonnes	97	tonnes	99	tonnes	99	tonnes	101	tonnes	87
Fat, pigs	tonnes	324	tonnes	348	tonnes	342	tonnes	344	tonnes	438
Fat, sheep	tonnes	312	tonnes	325	tonnes	321	tonnes	336	tonnes	293
Hides, cattle, fresh	tonnes	3938	tonnes	3859	tonnes	4028	tonnes	3994	tonnes	4249
Meat, bird nes	tonnes	4050	tonnes	4050	tonnes	4050	tonnes	4210	tonnes	4380
Meat, cattle	tonnes	35000	tonnes	34300	tonnes	35800	tonnes	35500	tonnes	37771
Meat, chicken	tonnes	11600	tonnes	12000	tonnes	12400	tonnes	12480	tonnes	8218
Meat, game	tonnes	6304	tonnes	6500	tonnes	6550	tonnes	6673	tonnes	6776
Meat, goat	tonnes	3720	tonnes	3780	tonnes	3792	tonnes	3840	tonnes	3316
Meat, pig	tonnes	4400	tonnes	4730	tonnes	4648	tonnes	4675	tonnes	5946
Meat, sheep	tonnes	12240	tonnes	12780	tonnes	12600	tonnes	13200	tonnes	11520
Milk, whole fresh cow	tonnes	115000	tonnes	115000	tonnes	118000	tonnes	120000	tonnes	110011

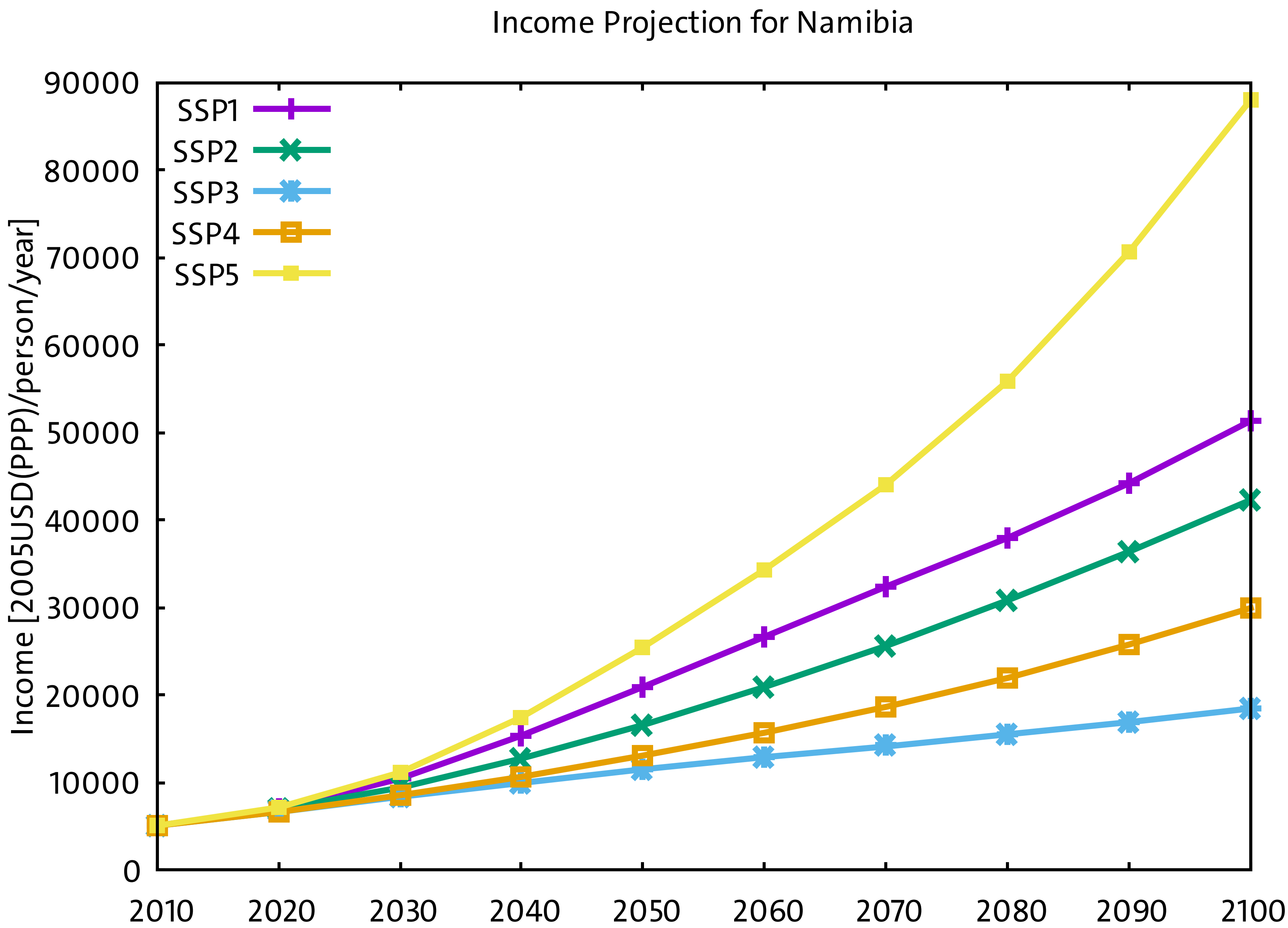
Market Demand Shifts



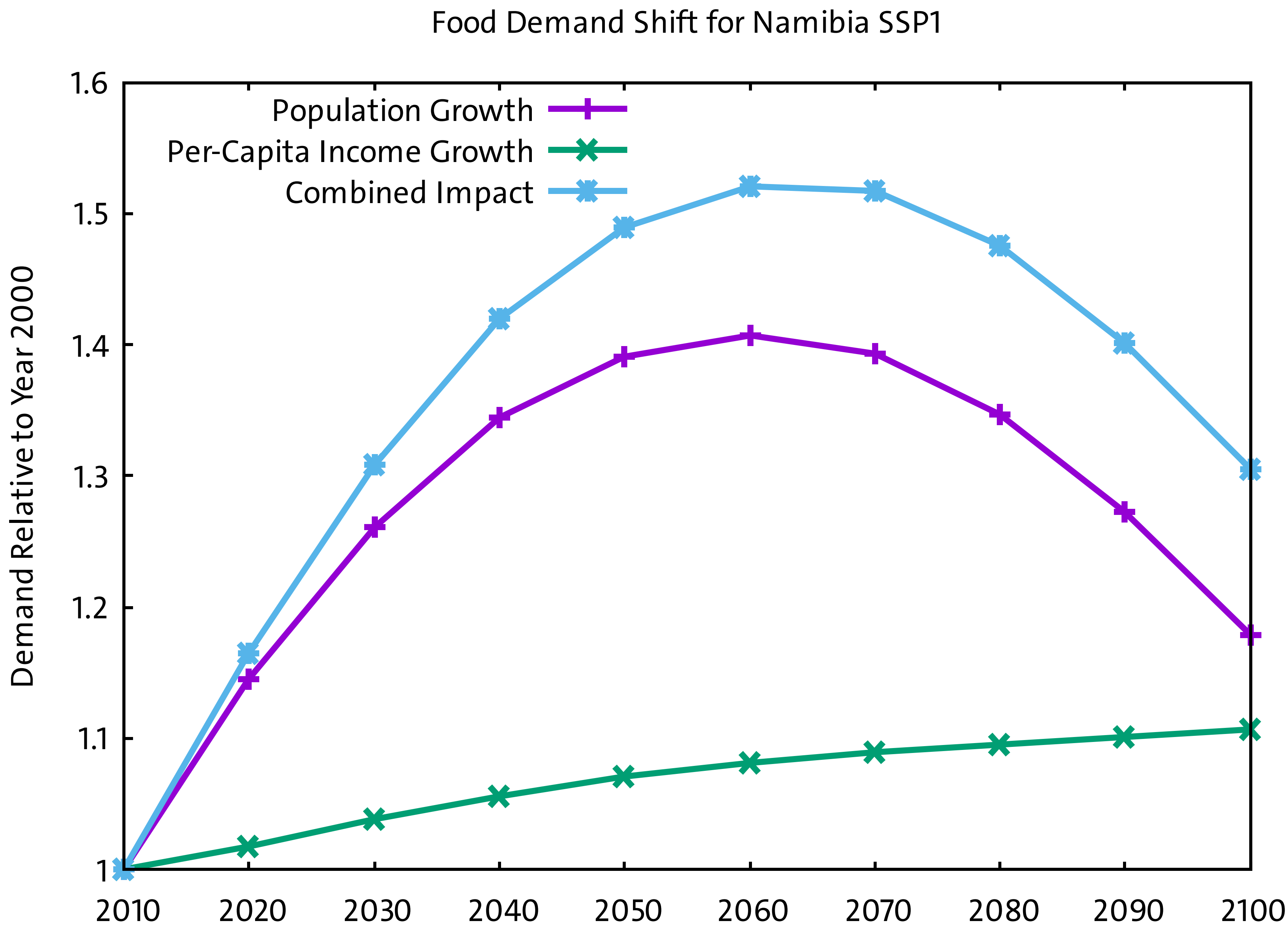
Population Projection for Namibia



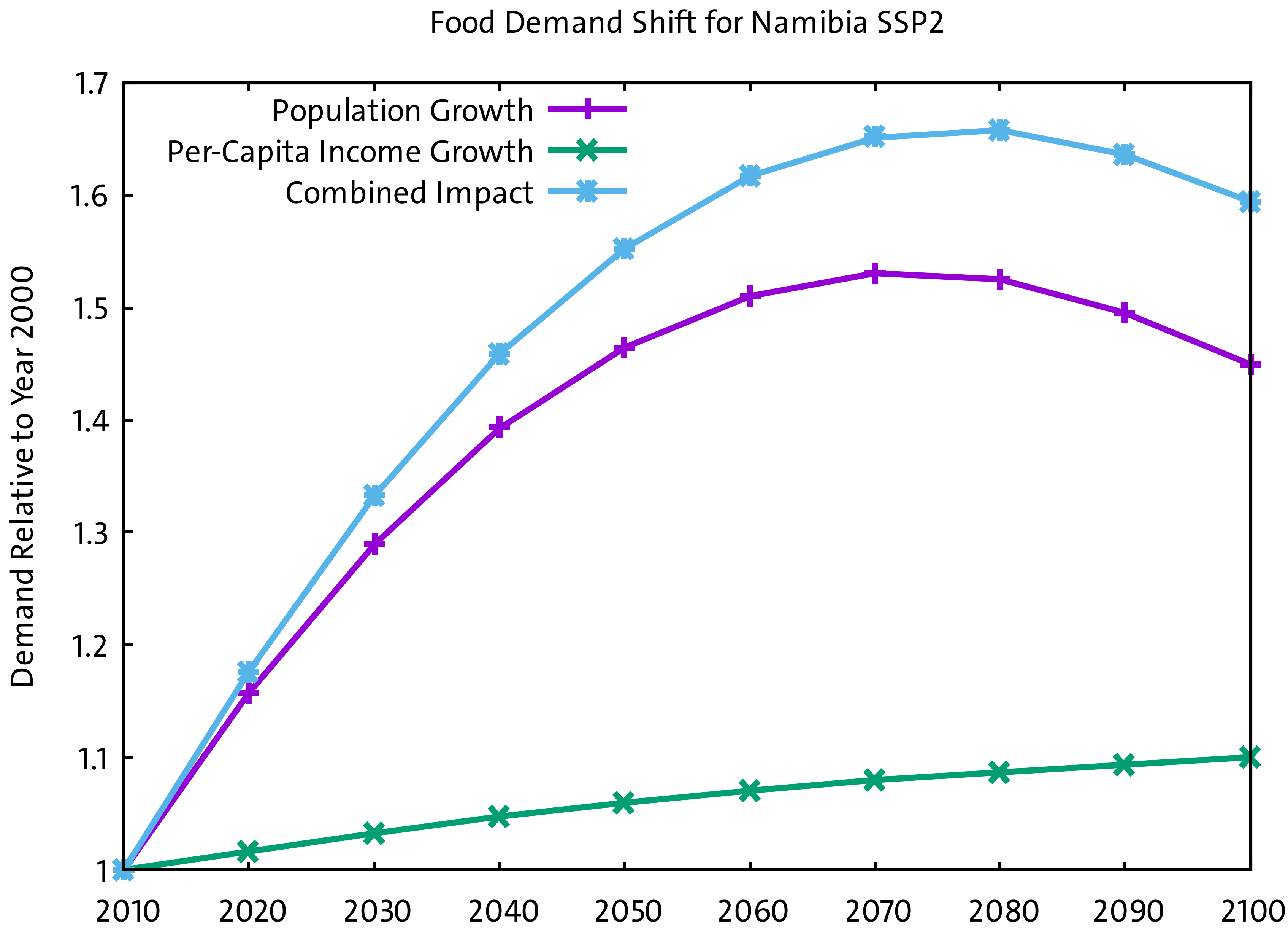
Comment Uwe: SSP specific projections of population and income growth and their impact on food demand are available for all countries

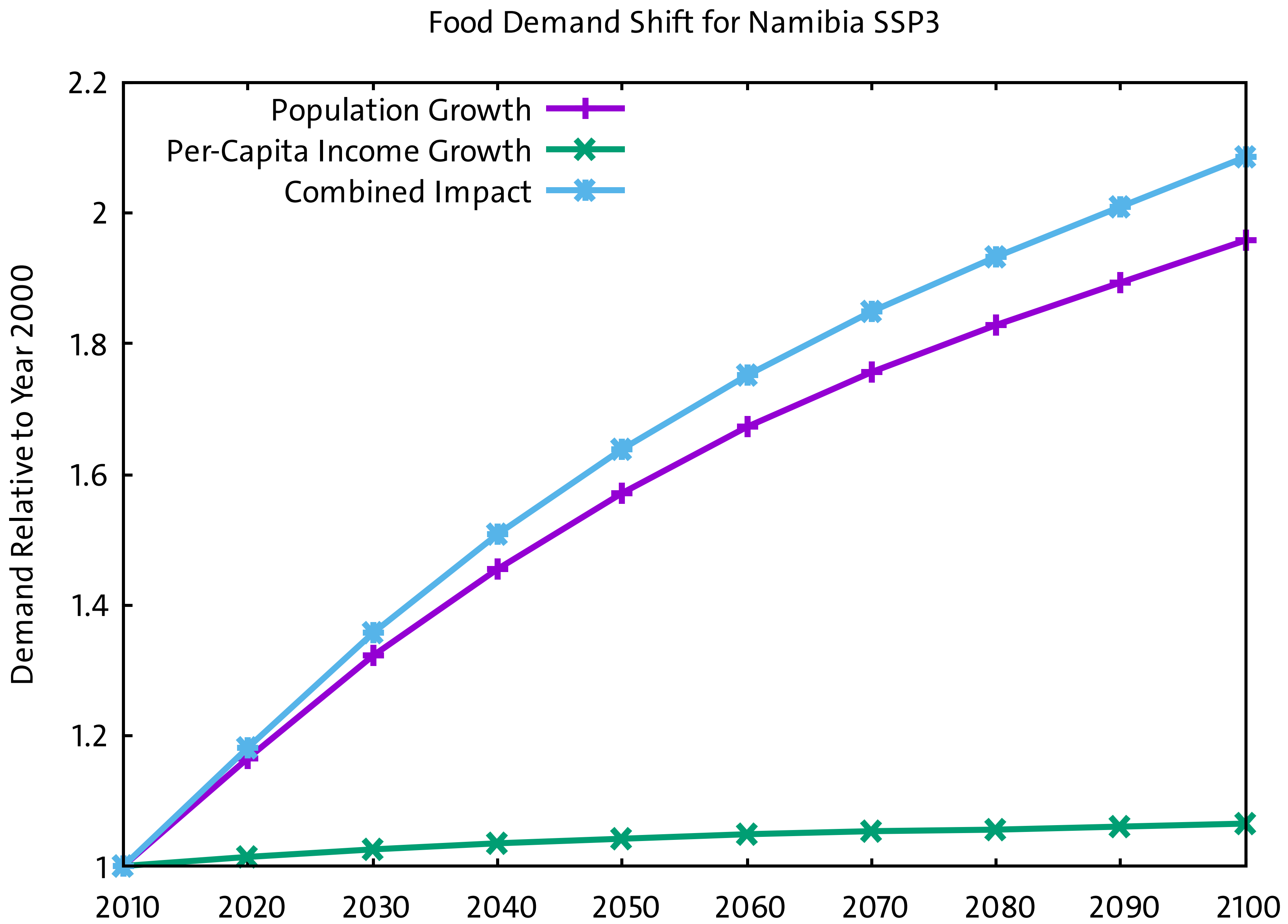


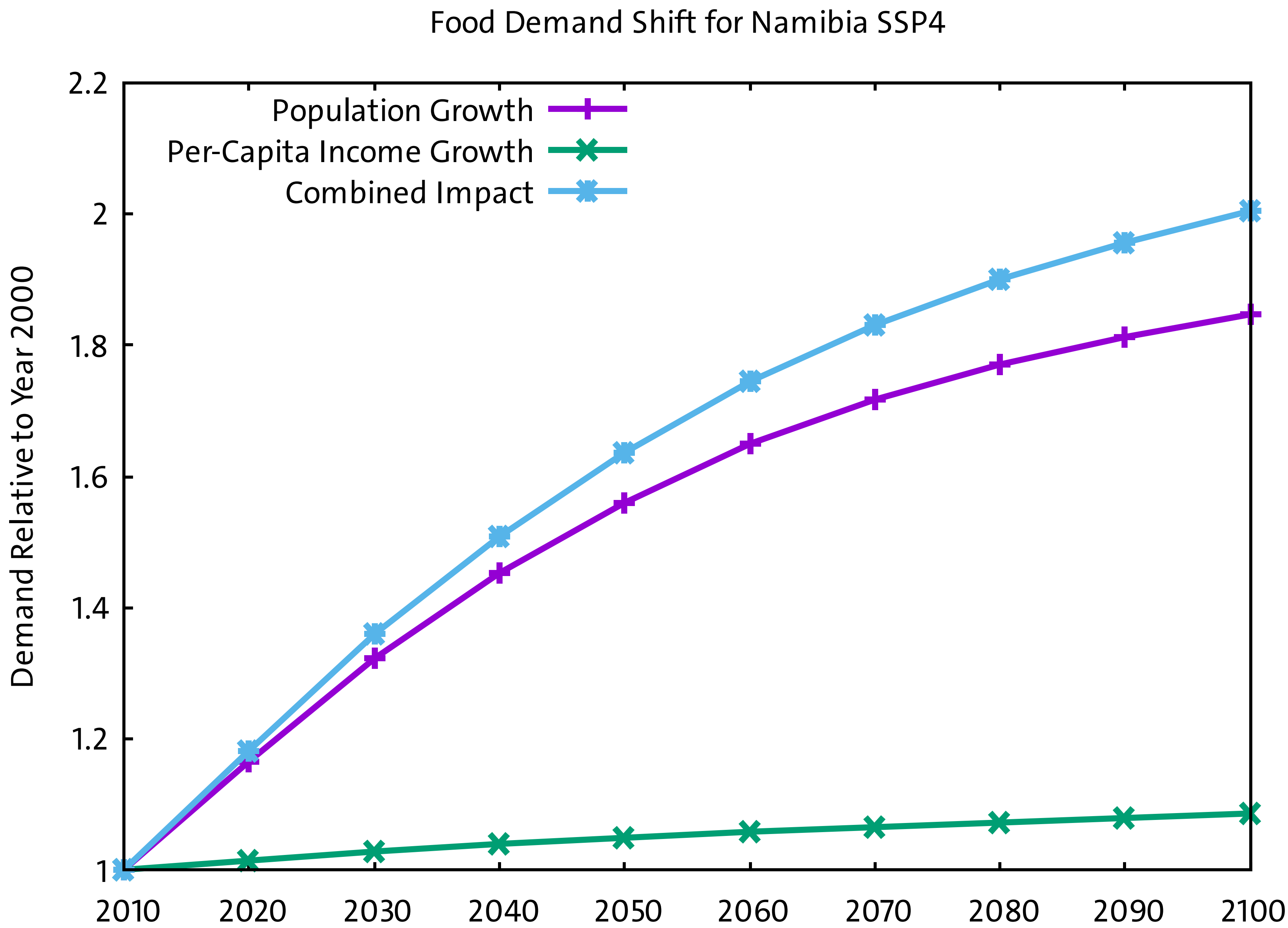
Income Projection for Namibia
Income [2005USD(PPP)/person/year]
SSP1
SSP2
SSP3
SSP4
SSP5
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100



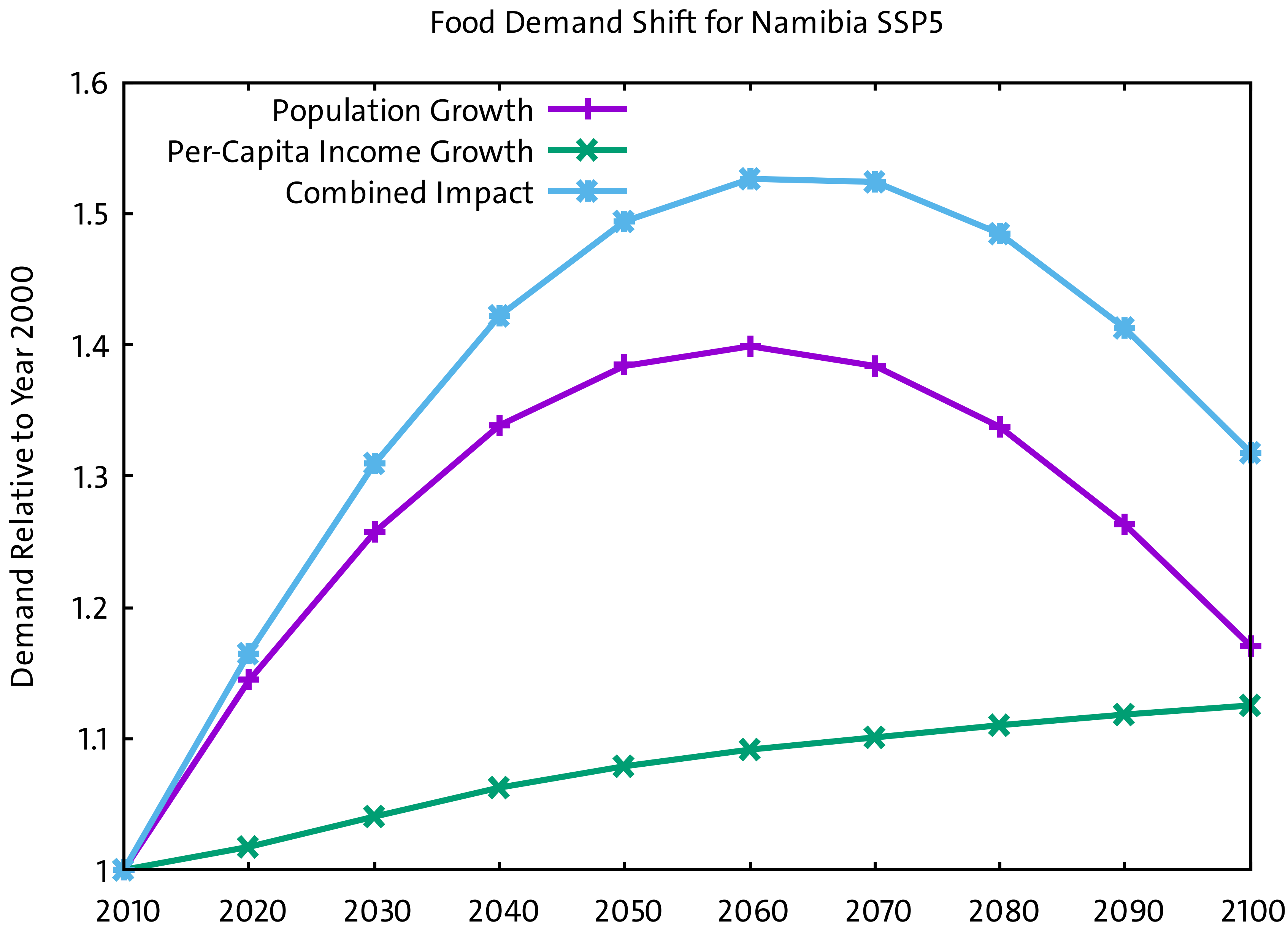
Food Demand Shift for Namibia SSP1
Population Growth
Per-Capita Income Growth
Combined Impact
Demand Relative to Year 2000
1.6
1.5
1.4
1.3
1.2
1.1
1
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100


Food Demand Shift for Namibia SSP2
Population Growth
Per-Capita Income Growth
Combined Impact
Demand Relative to Year 2000
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100

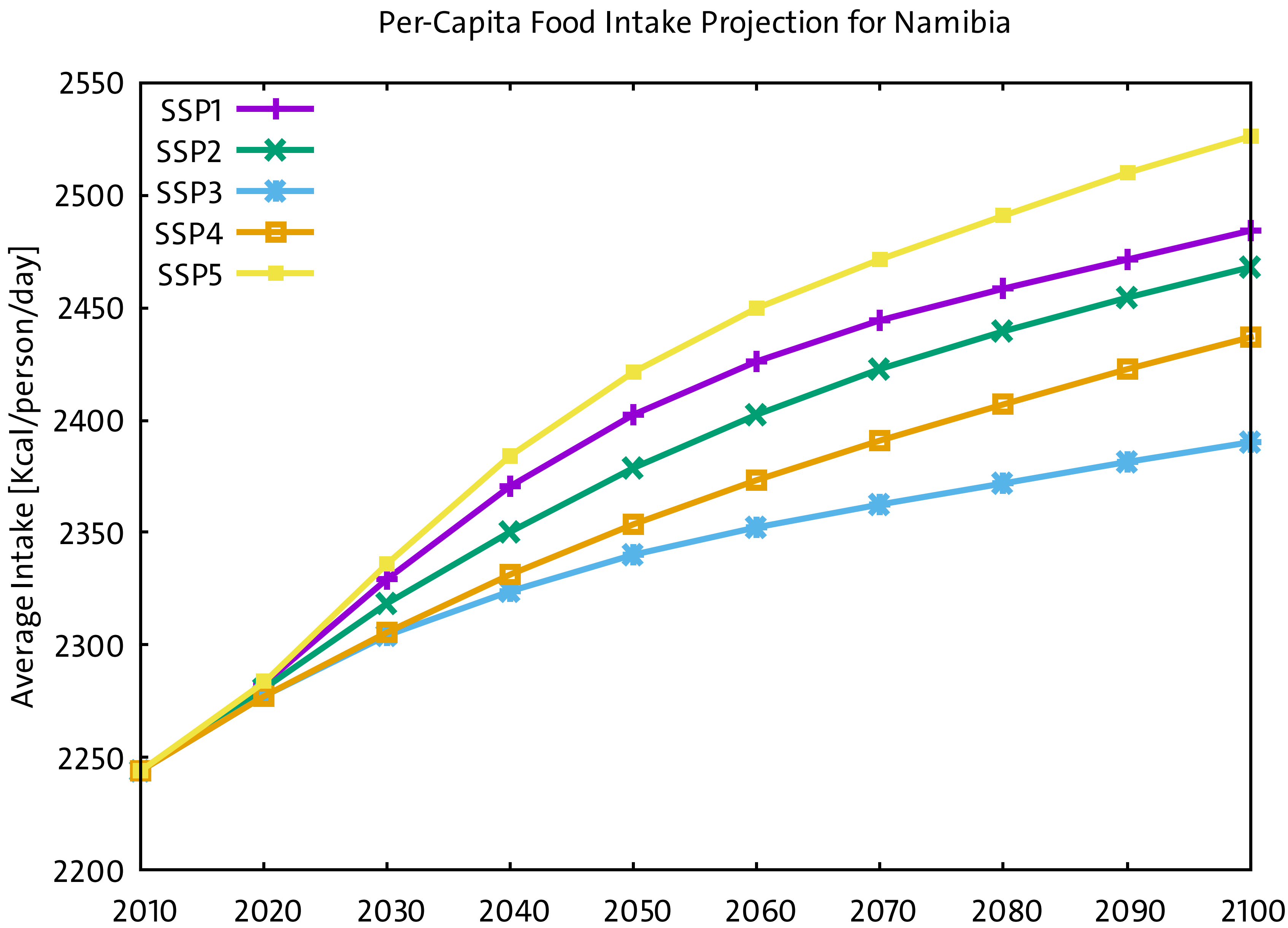

Food Demand Shift for Namibia SSP3
Population Growth
Per-Capita Income Growth
Combined Impact
Demand Relative to Year 2000
2.2
2
1.8
1.6
1.4
1.2
1
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100



Food Demand Shift for Namibia SSP4
Demand Relative to Year 2000
Population Growth
Per-Capita Income Growth
Combined Impact
2.2
2
1.8
1.6
1.4
1.2
1
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100

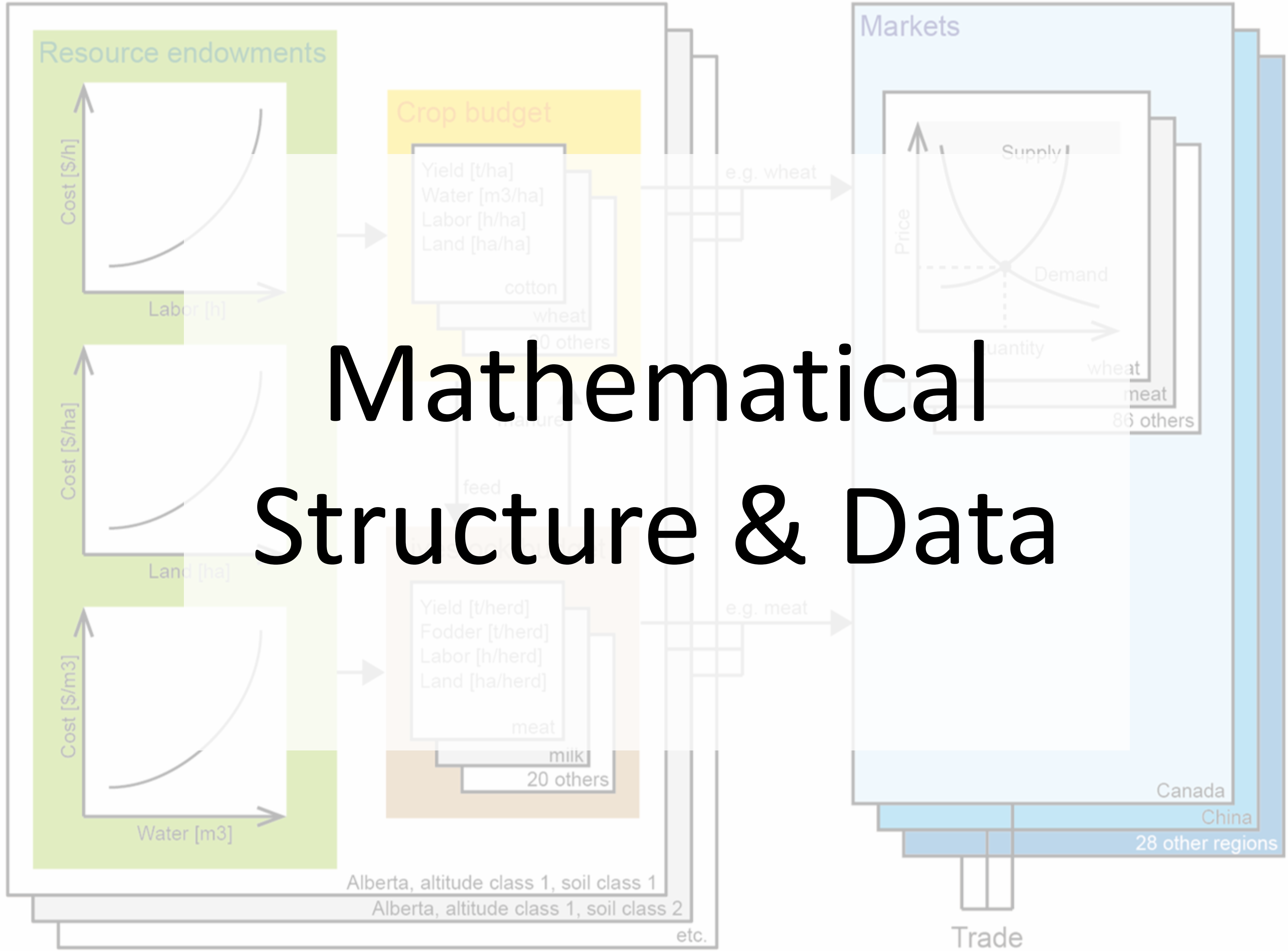


Food Demand Shift for Namibia SSP5
Population Growth
Per-Capita Income Growth
Combined Impact
Demand Relative to Year 2000
1.6
1.5
1.4
1.3
1.2
1.1
1
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100



Per-Capita Food Intake Projection for Namibia
Average Intake [Kcal/person/day]
SSP1
SSP2
SSP3
SSP4
SSP5
2200
2250
2300
2350
2400
2450
2500
2550
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100

Mathematical Structure & Data



Principle Mathematical Structure

$$\text{Max Global Welfare} = \sum_t \left(\partial_t \cdot \begin{pmatrix} \text{Consumer Surplus} \\ -\text{Production Cost} \\ -\text{Transformation Cost} \end{pmatrix} \right)$$

s.t.
Resource limitations
Technical efficiencies
Behavioral restrictions
Duality restrictions
Political constraints
Intertemporal relationships

Current NASM has
~ 20 Thousand Variables
~ 10 Thousand Equations

NASM: Mathematical Structure

Variables	Endogenous --- Human activities (decisions) or their impacts
Parameters	Exogenous --- Resource limits; Technology data (productivities, input intensities, emission coefficients, unit costs); Demand elasticities; Discount rates; Market prices; Observations
Equations	Mathematical relationships
Sets	Indexes --- Group similar variables, parameters, equations,

NASM: Important Variables

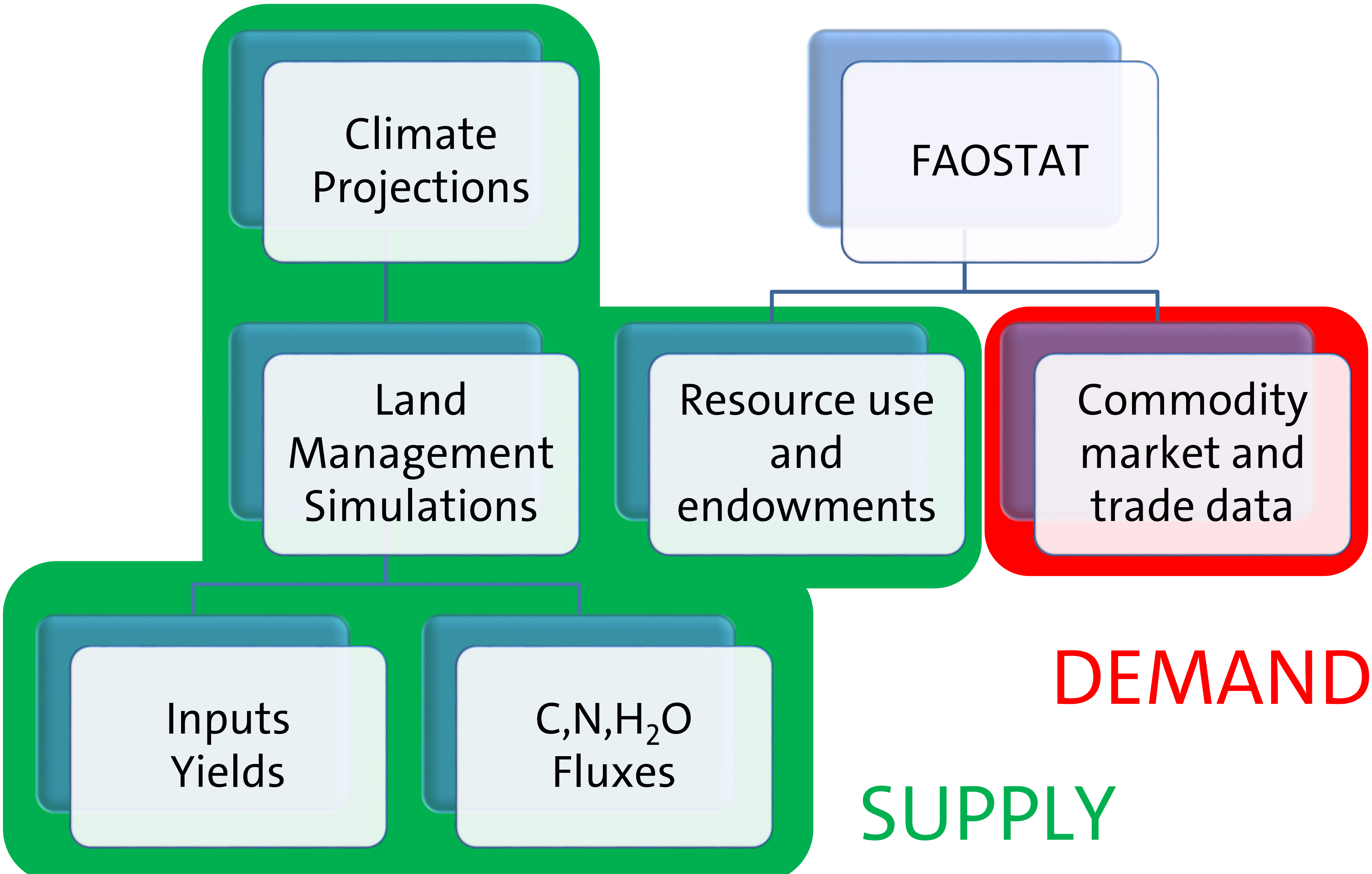
Control Variables	State Variables
Production (A)	Resource Use (U)
Trade (T)	Benefits / Costs
Processing (P)	Emissions (E)
Consumption (Q)	Welfare (W)

All variables are resolved over space, time, etc.

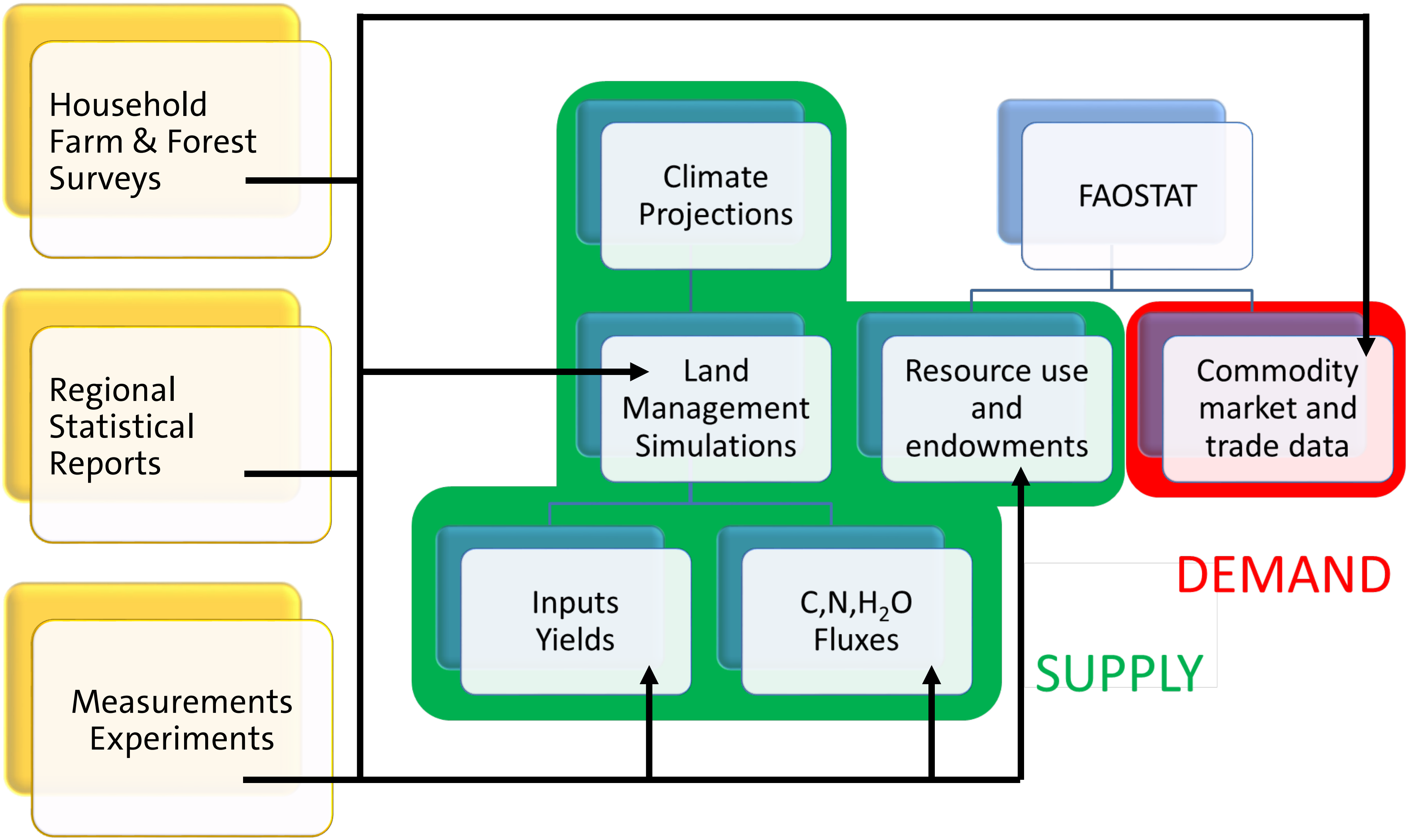
NASM: Mathematical Structure

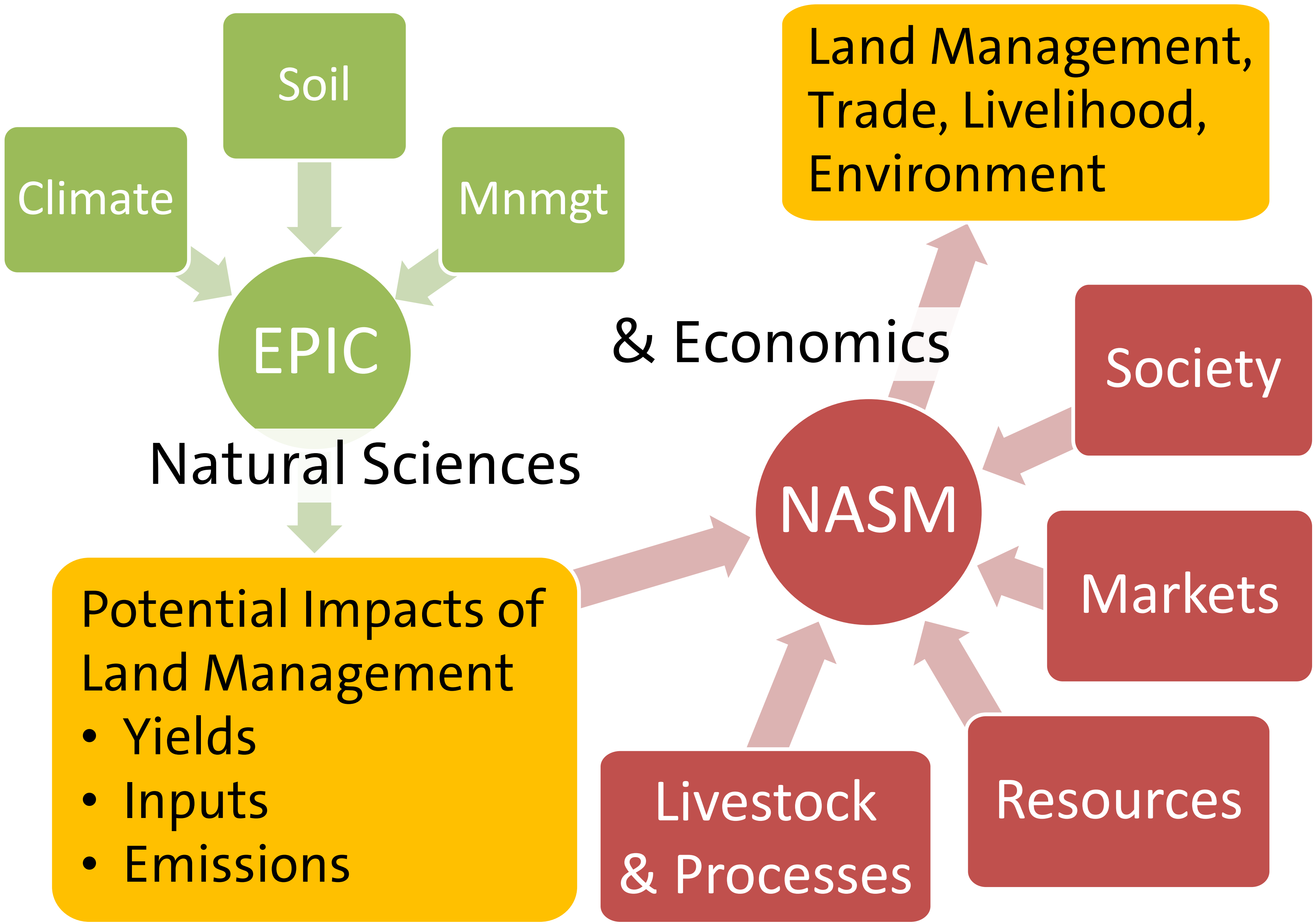
Variables	Endogenous --- Human activities (decisions) or their impacts
Parameters	Exogenous --- Resource limits; Technology data (productivities, input intensities, emission coefficients, unit costs); Demand elasticities; Discount rates; Market prices; Observations
Equations	Mathematical relationships
Sets	Indexes --- Group similar variables, parameters, equations,

NASM: Important Data Sources

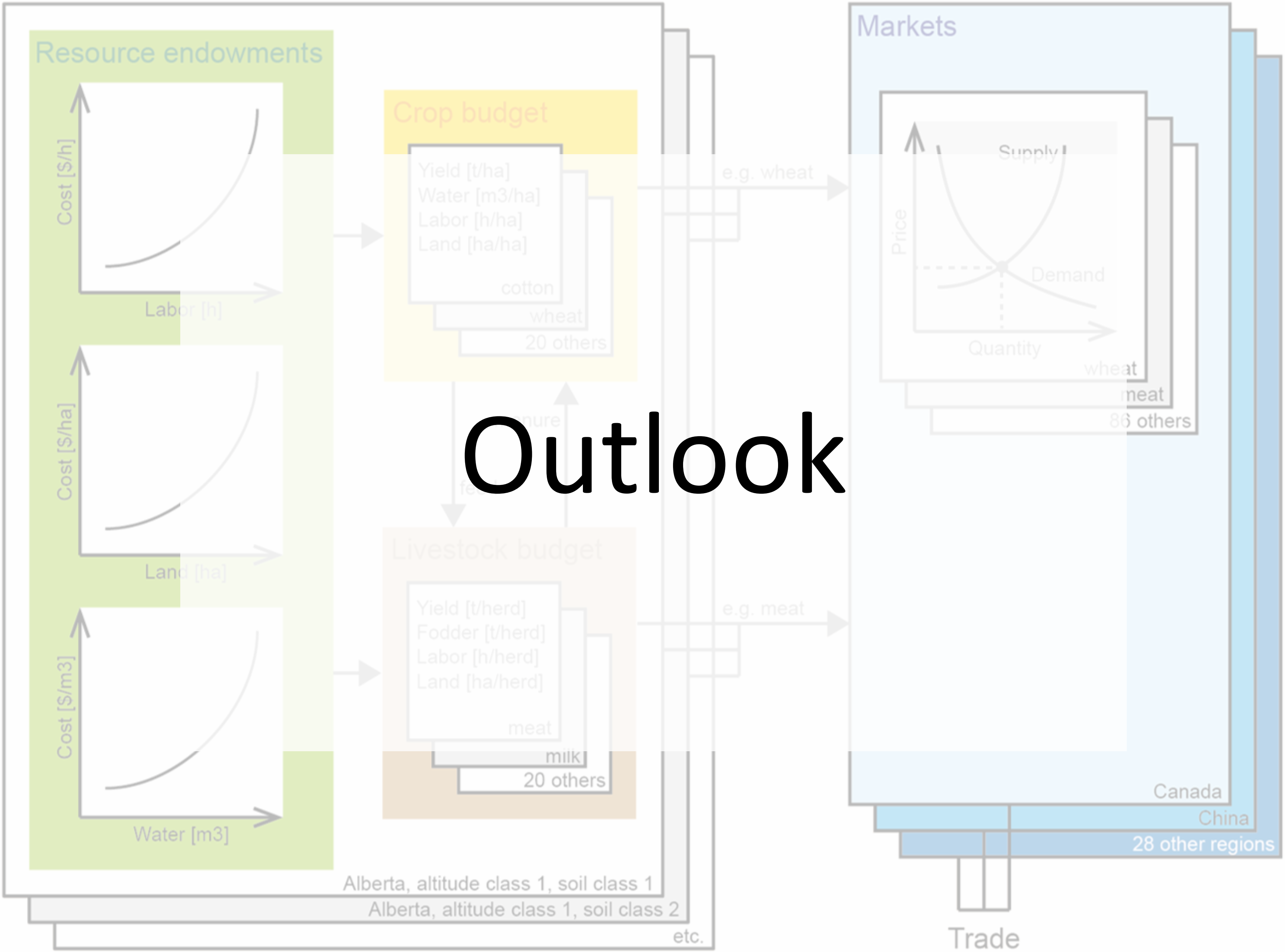


NASM: Important Data Sources




Soil
Climate
Mnmgt
EPIC
Natural Sciences
Land Management,
Trade, Livelihood,
Environment
& Economics
Society
NASM
Markets
Potential Impacts of
Land Management
• Yields
• Inputs
• Emissions
Livestock
& Processes
Resources

Outlook



Resource endowments
Cost [$/h]
Labor [h]
Cost [$/ha]
Land [ha]
Cost [$/m3]
Water [m3]
Crop budget
Yield [t/ha]
Water [m3/ha]
Labor [h/ha]
Land [ha/ha]
cotton
wheat
20 others
Livestock budget
Yield [t/herd]
Fodder [t/herd]
Labor [h/herd]
Land [ha/herd]
meat
milk
20 others
e.g. wheat
e.g. meat
Markets
Supply
Demand
Price
Quantity
wheat
meat
86 others
Canada
China
28 other regions
Trade
Alberta, altitude class 1, soil class 1
Alberta, altitude class 1, soil class 2
etc.

Applications to Namibia

- Impact of climate change
- Impact of new varieties (e.g. legumes)
- Farm livelihood assessments
- Food security assessments
- School children nutrition
- Impact of international developments
- Impact of policies (agricultural, trade, climate, environment)


Further development
Expanding diversity of population group on different criteria
Income
Education
Spoken language
Including the aspect of biodiversity and ecosystem preservation
Analysing consequences of potential conflicts, such as land use
Kalei po nawa
Okuhepa Ndangi
Ni itumezi
Thank you
감사
Dankie
Gangans