

Modelling as a tool for evaluating agricultural systems' dynamics and the use of natural resources

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Outline

- The broad context of agricultural development
- Integrated assessment modelling and scenario analysis
- Three very brief examples: household, regional, global levels
- Outlook and challenges

The broad context of agricultural development



The global context

- Population to reach almost 9 billion over the next three decades
- Getting richer and urbanised
- Changing diets (e.g. increased demands for livestock products)
- Many changes occurring: climate, economics, technology, resource availability, ...
- Systems are changing ... but

→ **can the poor benefit from these changes?**

→ **can we change without compromising food security, ecosystems services, and livelihoods?**

Livestock and global change: Disease emergence and distribution

- Major global changes in the distribution of vector-borne diseases to new “warmer” habitats (blue tongue of sheep in Europe, “highland” malaria in Africa)

- 75% of emerging or re-emerging diseases are from animals

- Increasing disease risk due to complexity and scale of market chains, intensification of production systems

Emerging and re-emerging infectious diseases, 1996-2006



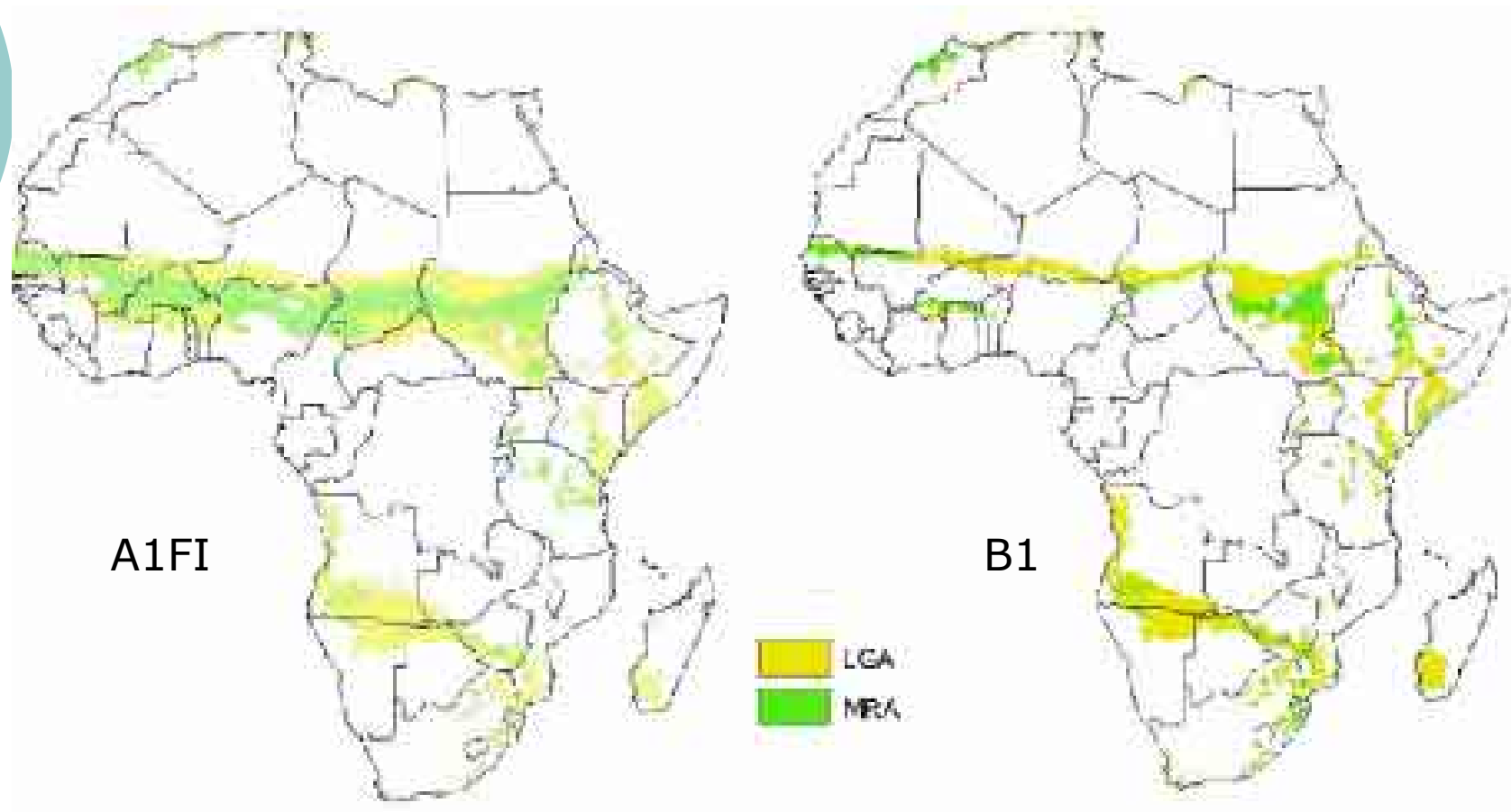
Livestock's contribution to anthropogenic greenhouse gas emissions

Parameter	Value	Comments
Livestock's contribution to climate change in CO ₂ equivalent	18 percent	Including pasture degradation and land-use change
Livestock's share in carbon dioxide emissions	9 percent	Not considering respiration
Livestock's share in methane emissions	37 percent	
Livestock's share in nitrous oxide emissions	65 percent	Including feed crops

Livestock's contribution to livelihoods

- > 600 million poor people in Africa, Asia and LAC depend on livestock
- > 1 billion people rely on livestock-based livelihoods
- >1.3 billion people are employed in livestock enterprises
- Livestock provide small farmers and pastoralists with one of their very few sources of regular income
- Livestock have many roles: food, wealth, capital, nutrients, traction, diversification, risk reduction, ...

LGA (arid-semiarid livestock) and MRA (arid-semiarid mixed) system areas projected to undergo >20% reduction in Length of Growing Period to 2050 (HadCM3 model)



Likely impacts on agriculture

- Crop productivity projected to decrease for 1-2 °C temp rise (overall yields may fall 10-20% to 2050, some places more, some places gains)
- Shifts in distribution, severity, types, of crop and livestock diseases
- Changes in biodiversity (e.g. plant composition of pastures and rangelands)
- Changes in water availability and hydrology
- Complex interactions with human health issues

A highly differentiated world?

Economic growth and market demand

- Increase in demand for agricultural products is mostly in developing countries
- Growth in niche markets (organics, locally-produced products) in developed countries
- Rising incomes and expectations in developing countries

Environment

- Intensification of production systems is having global environmental consequences
- GHG emissions from the South are often modest, but most of the deleterious impacts will be felt there

Poverty and equity

- Livestock income and assets will be major drivers of poverty alleviation in sub-Saharan Africa (not in the N)
- Evidence of increased inequity and marginalisation of the poor in Asia, Africa

Integrated assessment modelling and scenario analysis



Why model?

- Use for manipulations and experiments that are impractical, too expensive, too lengthy or impossible (in real-world social and economic systems)
- Address dynamic complexity (“emergent properties”) of systems in a way that reductionist science may not be able to do
- Identify “best management” strategies (through optimization)
- Study the long-term effects of options (predictions, projections)

What can models produce?



“Predictions”

- Point prediction: temperature in Brasilia tomorrow
- Behaviour: trends, patterns in space and time
- Differences: system response with/without an intervention

“Understanding”

- Best bet: optimised performance of the system (N application rate)
- Trade-offs: household income and range condition
- Syntheses: what do we know about these processes, and which are still black boxes?

Understanding how livestock systems may continue to change and evolve ...

- For designing a more coherent and dynamic research and policy agenda that benefits the poor and sustains the environment
 - For targeting research investments more appropriately
 - For trying to bridge the technology adoption gap
 - For helping farmers adapt to change

Towards integrated assessment

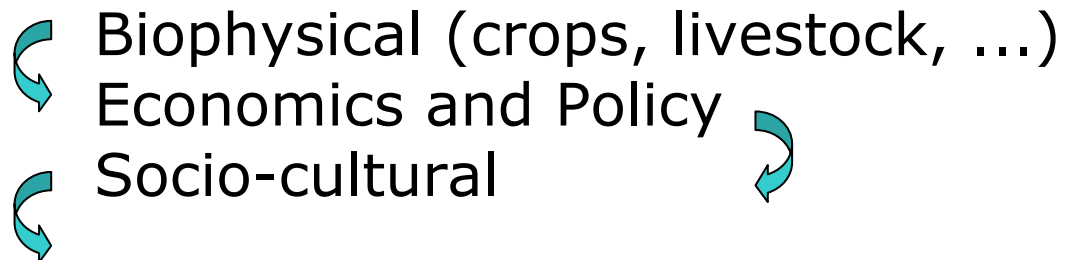
- In the search for policy and technology options that help to alleviate poverty and sustain livelihoods, is it possible to balance ecosystem integrity, food security, and human well-being?
- Linkage of different types of models together, that have the required sensitivities, to run scenario analyses that look at a wide range of options under different conditions.
- Ultimately, requires understanding of why it is that people make the resource management and livelihood decisions that they do.

Integration

Spatial Integration



Systems Integration



(Sectoral integration ...)

Integrated assessment

Combining models of different types into a coherent tool for assessing effects of change

- Biophysical simulation models (crops, livestock, ecosystems, ...)
- Socio-economic household models (resource allocation decisions)
- Agricultural sector models (costs and prices)
- General circulation models (climate and weather)
- ...

Integrated models at different scales

Scale	Type of model	Types of decisions
World	Multi-market models Social Accounting Matrices Spatial global assessment models (IMAGE, climate change models) Moderate to low detail	Supply & demand of agricultural products Emissions Energy use Land use
National/Regional	Multi-market models Econometric models Spatial land-use models Social Accounting Matrices Moderate to low detail	Supply & demand of agricultural products Land-use change and natural resources (feeds, pastures crops) Incomes by sector Hotspots of change Multi-stakeholder decision-making

Integrated models at different scales

Scale	Type of model	Types of decisions
Landscape	Rangeland models Spatial land-use models Hydrological models Ecosystems models Agent-based models Moderate to high detail	Primary productivity Carrying capacity Natural resource degradation Livestock dynamics, output Biodiversity, nutrient flows Multi-stakeholder decision making Trade-offs
Household	Econometric models Mathematical programming Systems dynamics, simulation Agent-based models Moderate to high detail + component models (livestock nutrition, crop and grassland growth, etc)	Household income Food security Nutrient flows Technology choices Land-use decisions Trade-offs

Using scenario science to assess different futures: one way to deal with uncertainty

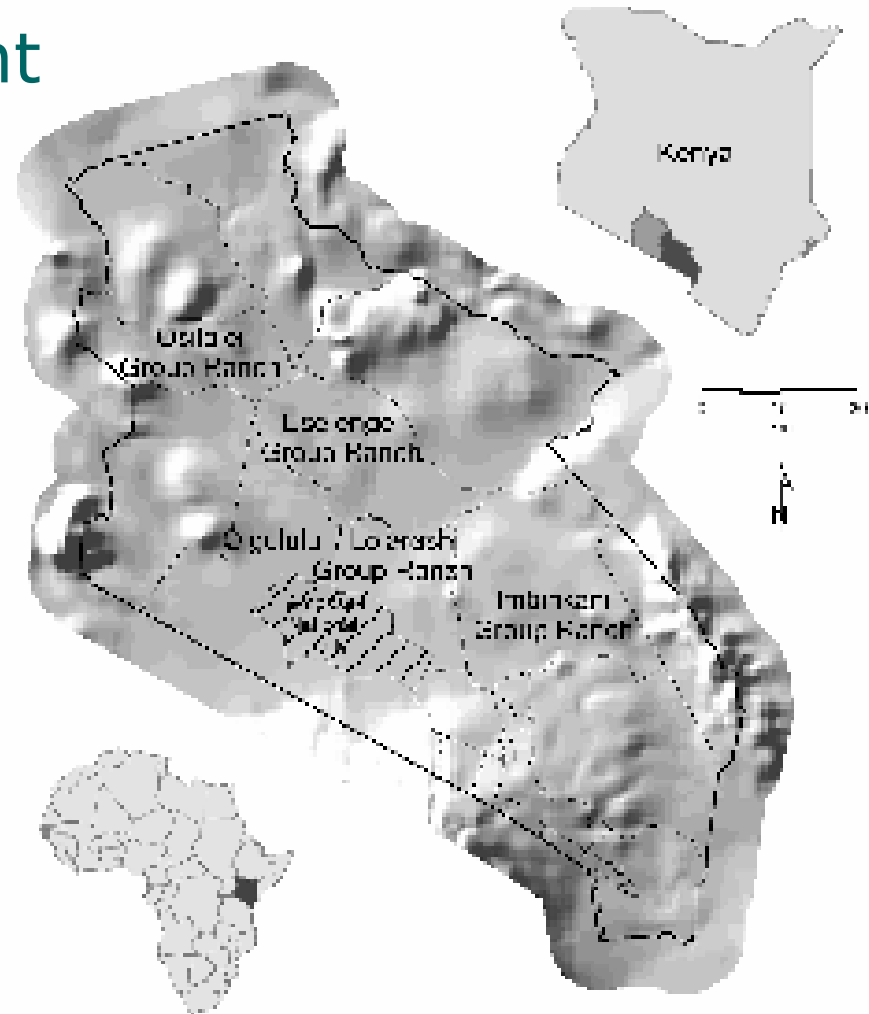
- Key drivers tend to push systems in certain directions
 - how may systems evolve?
- Scenarios: stories with plausible cause-and-effect links that connect a future condition with the present
- Use scenarios to
 - understand the significance of uncertainties
 - illustrate what is possible and what is not possible
 - identify strategies that may work across scenarios
 - learn what to avoid and uncover new opportunities

Scenario analysis can help in evaluating possible impacts on livestock keepers


- How may livestock systems evolve?
- What may happen to pastoral systems (fragmentation, settlement, etc)?
- How can livestock keepers get linked into the global economy?
- If there is a retreat from globalisation, what will happen to food security in the tropics?

An example at the household level

Integrated assessment
in Kajiado District,
Kenya: Trade-offs
between agro-
pastoralists, livestock
and wildlife



Modeling a coupled natural and human system



The linked
SAVANNA and
DECUMA
models

Results of scenario analyses

Under most circumstances, subdivision (restricting cattle & wildlife movement):

- Results in substantially fewer livestock that can be maintained
- Decreases wildlife numbers also
- Increases household food insecurity

To maintain current food security and income levels with increasing population, climate variability and landscape fragmentation:

- Livelihood strategies will need to change
- Can household numbers be reduced to keep herd sizes stable?

An example at the regional level

Trajectories of change of crop livestock systems in central Kenya to 2025

Understanding what the drivers of change may be, and what the choices may be for producers



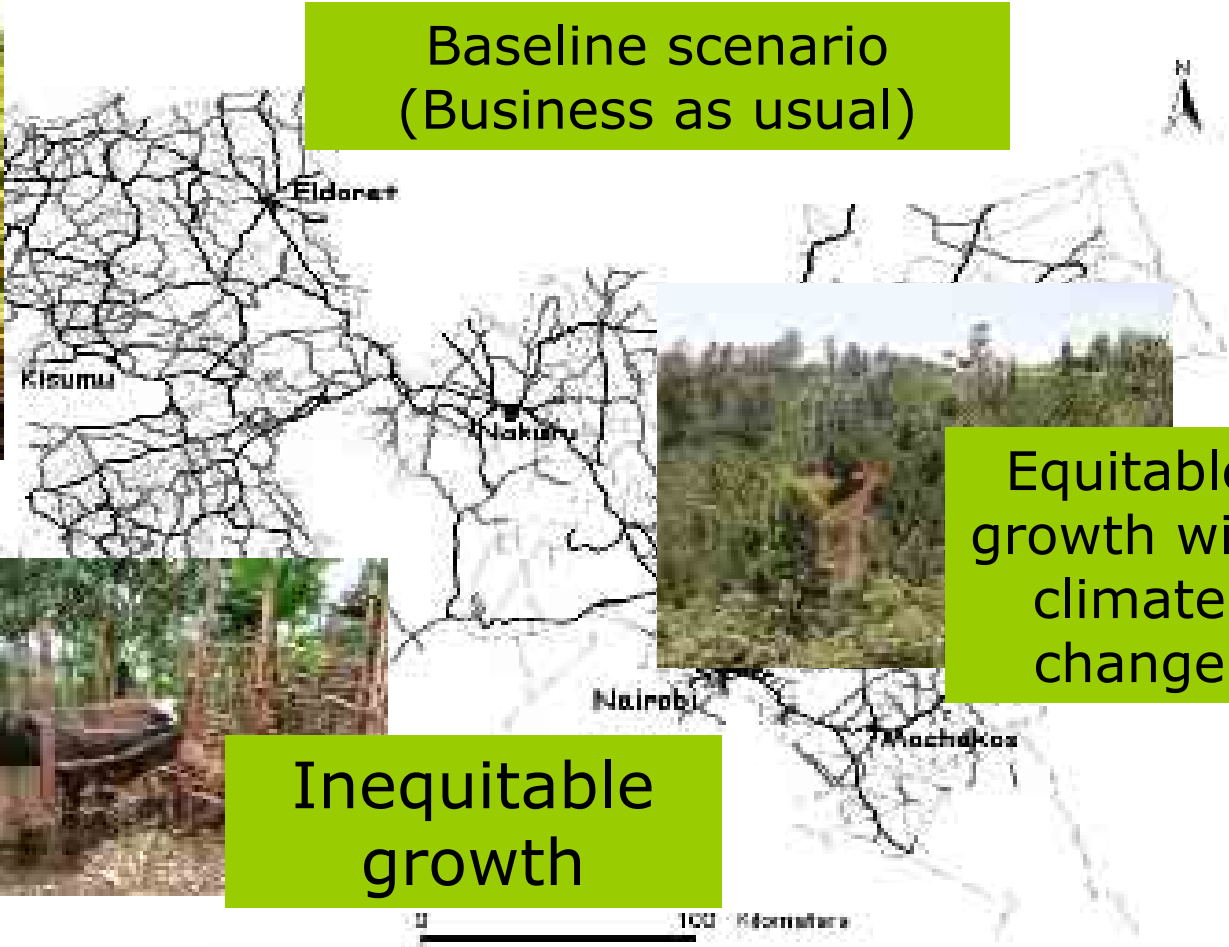
Alternative images of how the future might unfold

Qualitative narratives about future development pathways

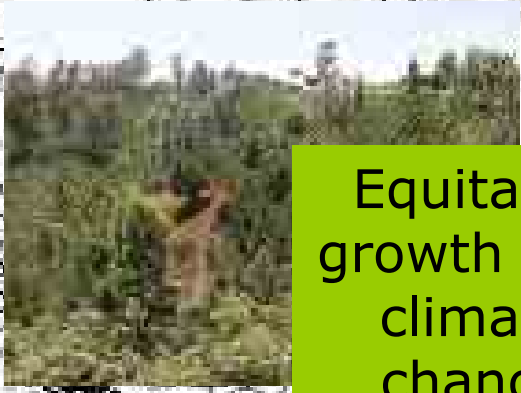
Quantitative formulations based on modelling and available data



Equitable growth



Baseline scenario
(Business as usual)



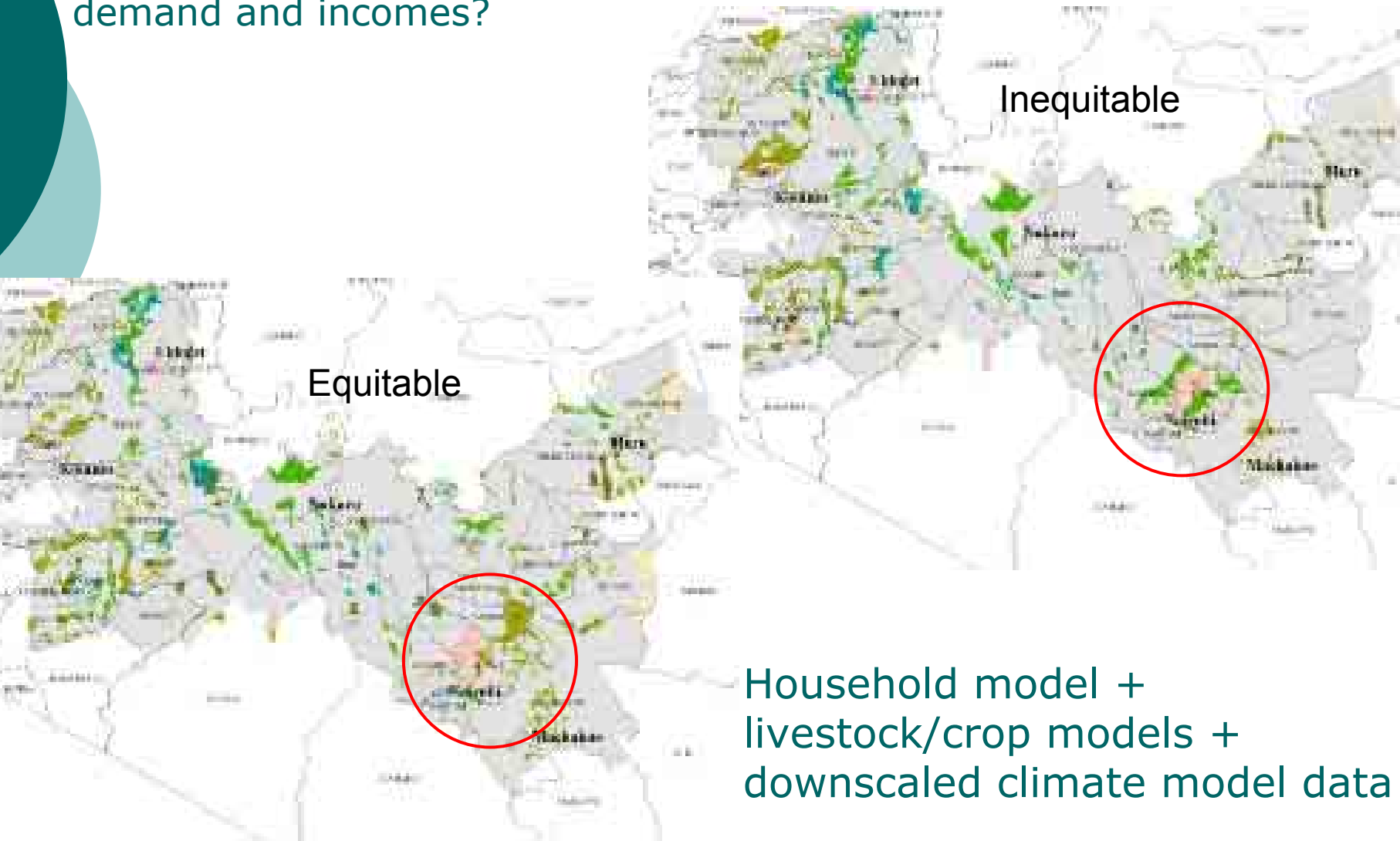
Equitable growth with
climate
change



Inequitable
growth

Land-use models (CLUE) + spatial econometrics

- how might farming systems change in relation to changing demand and incomes?



How might household production change in response?

Results of scenario analyses

- Subsistence farming is likely to decrease in Kenya under all scenarios: shifts to more intensive food crops and dairy production
- In all scenarios, shifts away from farming to non-agricultural households
- Increase in subsistence farming under the inequitable scenario in the less favoured areas
- Highlands of Kenya may not be significantly affected by climate change

An example at the global level

The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD)

- Global initiative to understand the future of world food production and other sectors
- Led by World Bank with a wide range of partners and donors
- How to reduce hunger and poverty, improve rural livelihoods, and facilitate equitable, environmentally, socially and economically sustainable development through access to, and use of agricultural knowledge, science and technology?



IAASTD Conceptual Framework

Human impacts on

- Incomes and employment
- Hunger
- Human health
- Resilience and vulnerability
- Social and gender equality
- Economic diversification
- Rural livelihoods
- Quality of natural environment
- Social stability

Indirect change drivers

- Economic
- Demographic (urbanisation, migration)
- Socio-political (policies and institutions)
- Cultural and ethical (values)
- Global KST

Direct change drivers

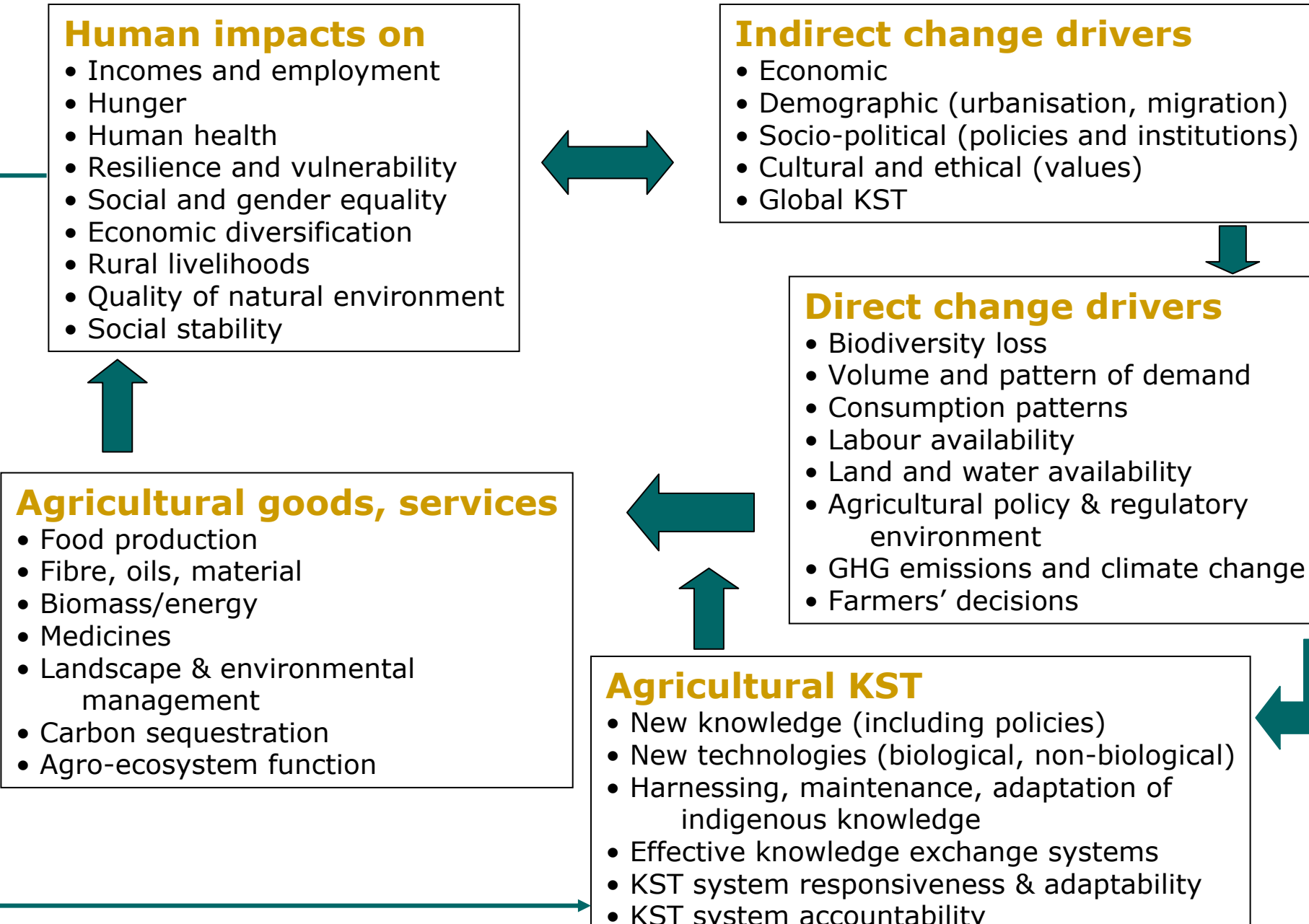
- Biodiversity loss
- Volume and pattern of demand
- Consumption patterns
- Labour availability
- Land and water availability
- Agricultural policy & regulatory environment
- GHG emissions and climate change
- Farmers' decisions

Agricultural KST

- New knowledge (including policies)
- New technologies (biological, non-biological)
- Harnessing, maintenance, adaptation of indigenous knowledge
- Effective knowledge exchange systems
- KST system responsiveness & adaptability
- KST system accountability

Agricultural goods, services

- Food production
- Fibre, oils, material
- Biomass/energy
- Medicines
- Landscape & environmental management
- Carbon sequestration
- Agro-ecosystem function



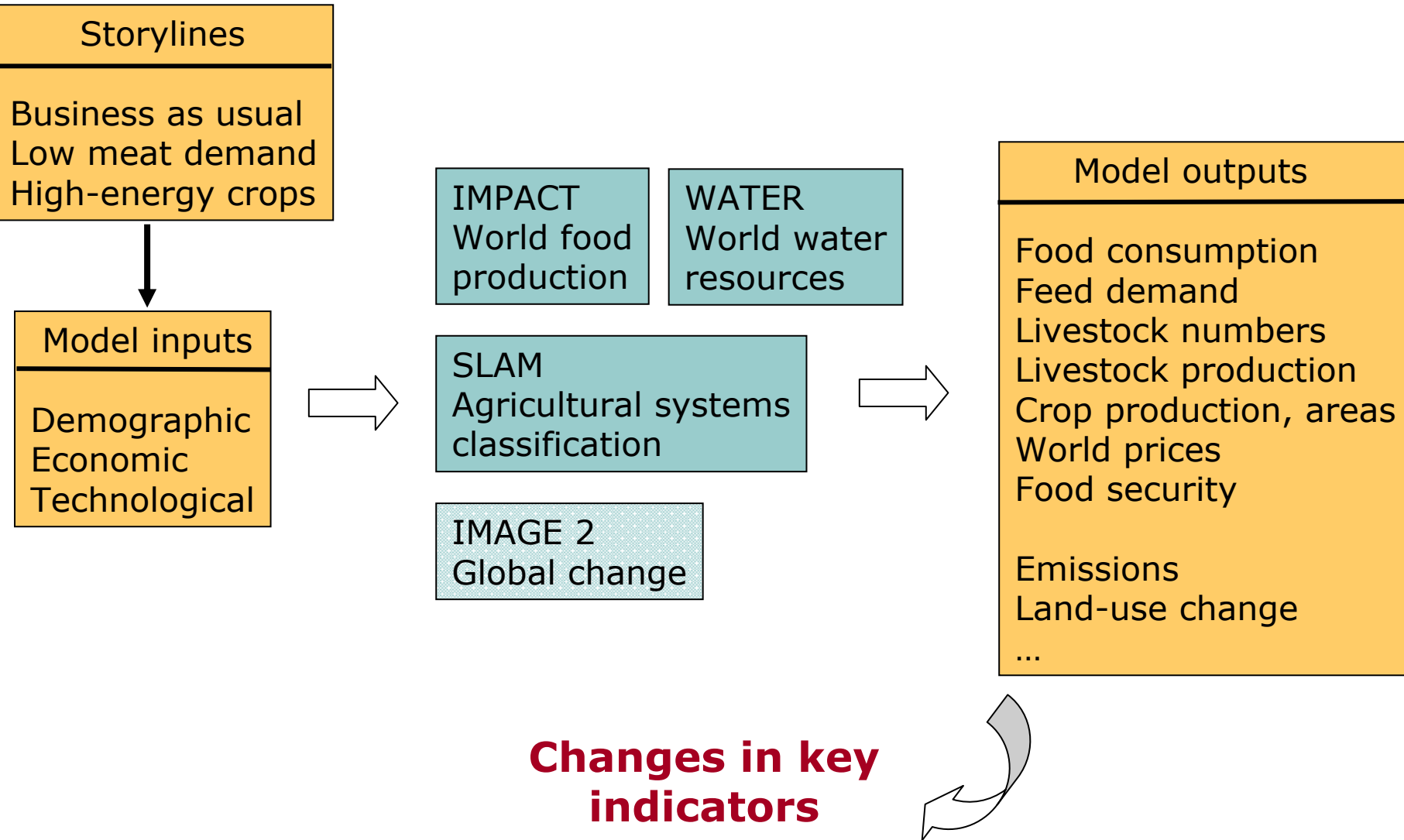
Scenario development framework

Two essential activities

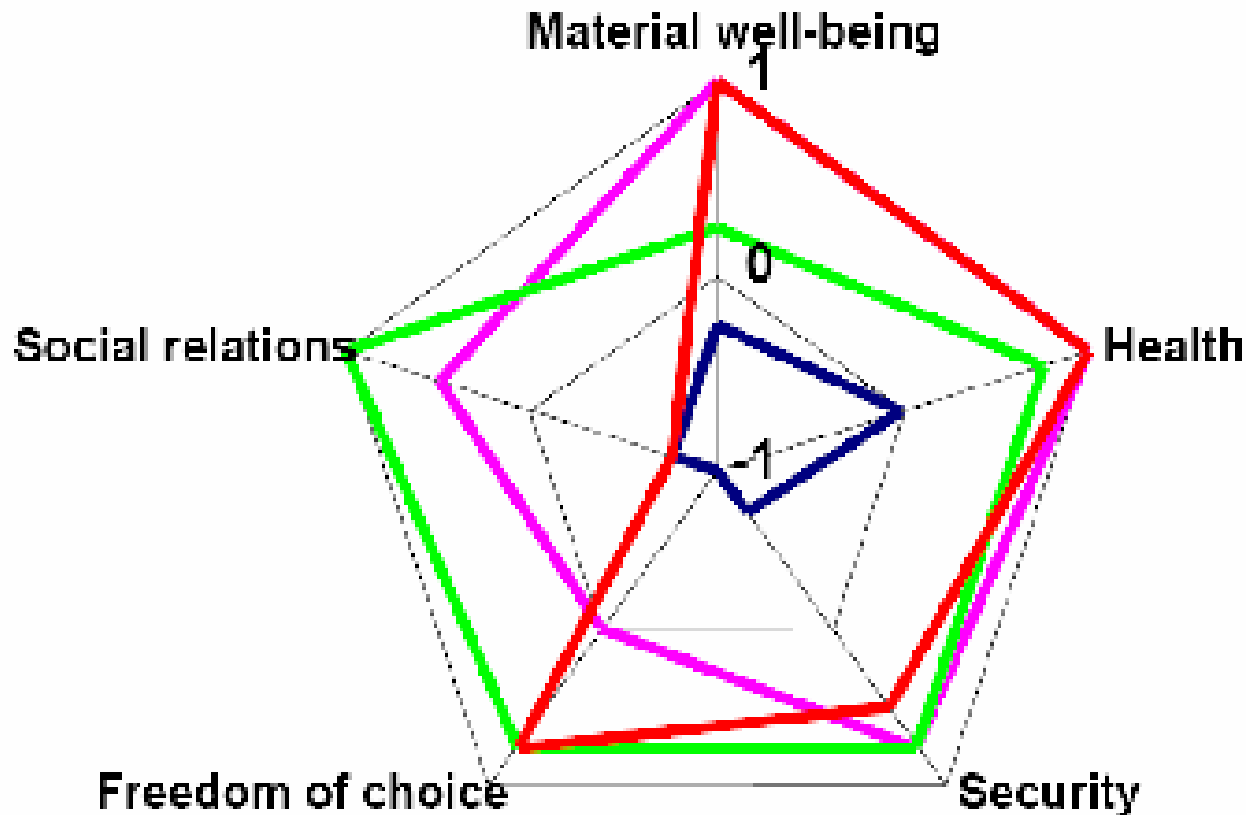
- Formulation of alternative scenario storylines
 - Facilitates internal consistency of different assumptions
 - Takes into account broad range of elements and feedback effects
- Quantification
 - Helps provide insights into those processes where sufficient knowledge exists to allow modelling
 - Takes into account interactions among various drivers and services

Modelling to quantify scenarios

(IAASTD, 2008)



Human Well-Being Across the Scenarios



Assessing trade-offs between different dimensions of well-being: are there win-win scenarios?

Grazing intensities in rangeland systems to 2030 and 2050 for the reference run, by region (TLU/ha)

	2000	2030	2050
Central & West Asia and North Africa	0.052	0.077	0.083
East & South Asia and the Pacific	0.044	0.067	0.067
Latin America & the Caribbean	0.188	0.293	0.318
North America & Europe	0.052	0.063	0.060
Sub-Saharan Africa	0.062	0.090	0.090
World	0.064	0.094	0.098

Implications

- Results suggest considerable intensification of livestock production in humid-subhumid grazing systems, particularly in LAC
- Structural changes are inevitable in the livestock sector, with impacts on
 - Social equity
 - Environment
 - Public health
- Will need sustained public policy action to ensure that livestock system development can play a role in poverty reduction

Outlook and challenges



Understanding impacts and responses

- Enormous spatial heterogeneity in impacts, responses: local-level effects, “recommendation domains” of limited size
- Impacts and responses often dynamic and non-linear
- Climate and other shocks will affect power, governance and equity relations that will disadvantage the vulnerable
- Many missing pieces in our understanding of how households and systems may respond:
 - Objectives, attitudes, constraints
 - Critical biophysical impacts, interactions of crops and livestock enterprises, etc

Challenges

- Considerable advances in integrated assessment of livestock systems over the last 20 years, but ...
- Given the dynamism of the livestock sector, need to build on scenarios of systems evolution and alternative development pathways – we have to think ahead
- New sustainability and socio-cultural issues to address: e.g. water and energy use by the livestock sector, shifts in dietary preferences
- More work required to be able to assess trade-offs at different levels and to identify not only what is desirable but also what is feasible

