Modeling the land and GHG effects of land sparing interventions

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(with Maria Bowman UC Berkeley & NRDC)
CESM Societal Dimensions
2/19/13

Who I am…

- NCAR postdoctoral fellow
- Host- Brian O'Neill Lead, Integrated Assessment Modeling Group
- Funded by the NCAR Integrated Science Program
- Ph.D. in Environmental Policy from UC Berkeley in August 2012
  - On reducing agricultural causes of deforestation in Brazil

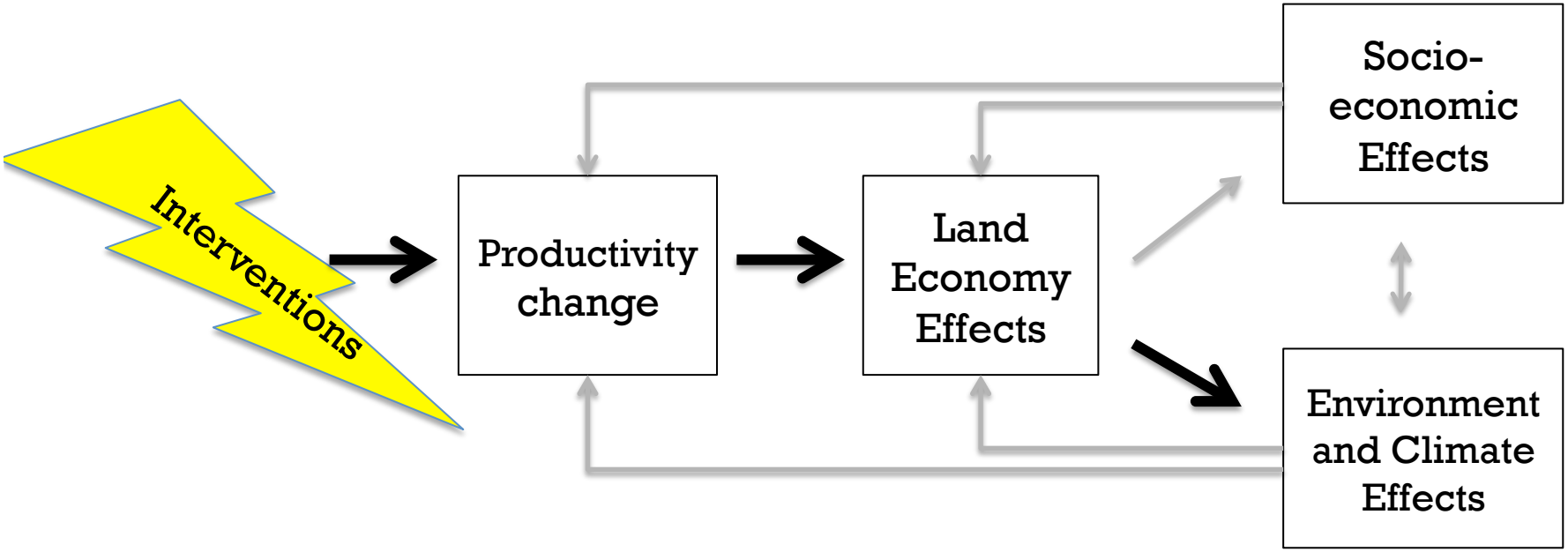
Take Away Themes

- changes in agricultural productivity have important implications for the climate and earth system
- the reverse is also true
- the relationship between agricultural productivity and land use outcomes is complex and multifaceted
- IA model approaches vary greatly
- crop vs. livestock quite different w/i a model experiment
- IA model approaches could benefit from systematic comparison of land sparing dyanamics with closer coupling with climate models.

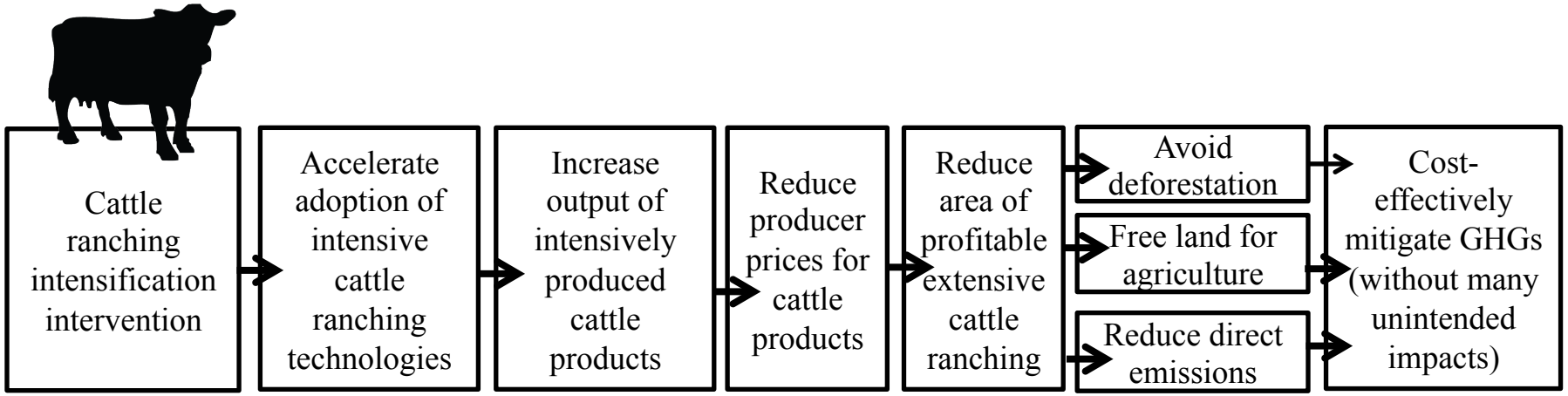
Land Sparing Interventions?

- What they are:
  - Technologies, management practices and laws to boost outputs from agricultural lands with the aim of "freeing" land for forests and other productive uses
- Why this matters to CESM
  - Agriculture systems are a major cause of land use and land cover change (LULUC)
  - LULUC causes radiative forcing.
  - Interventions to change agricultural production can vastly alter radiative forcing
- Why CESM matters for land sparing research
  - Climate affects both productivity and land cover, thereby shaping the land sparing outcomes

Basic Land Sparing Framework



One mechanism for a land sparing interventions in cattle systems to affect the climate



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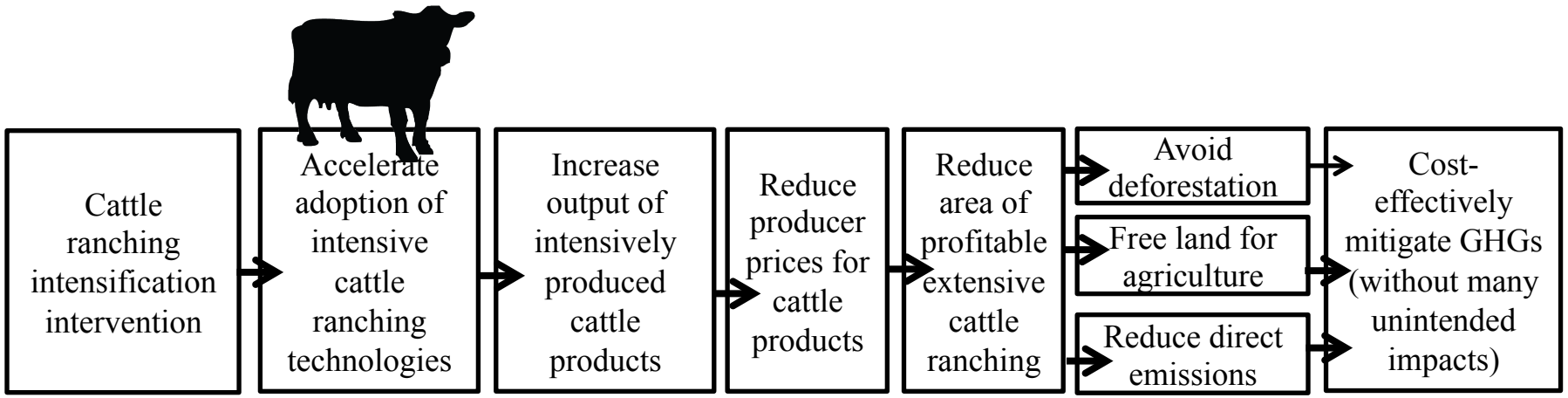

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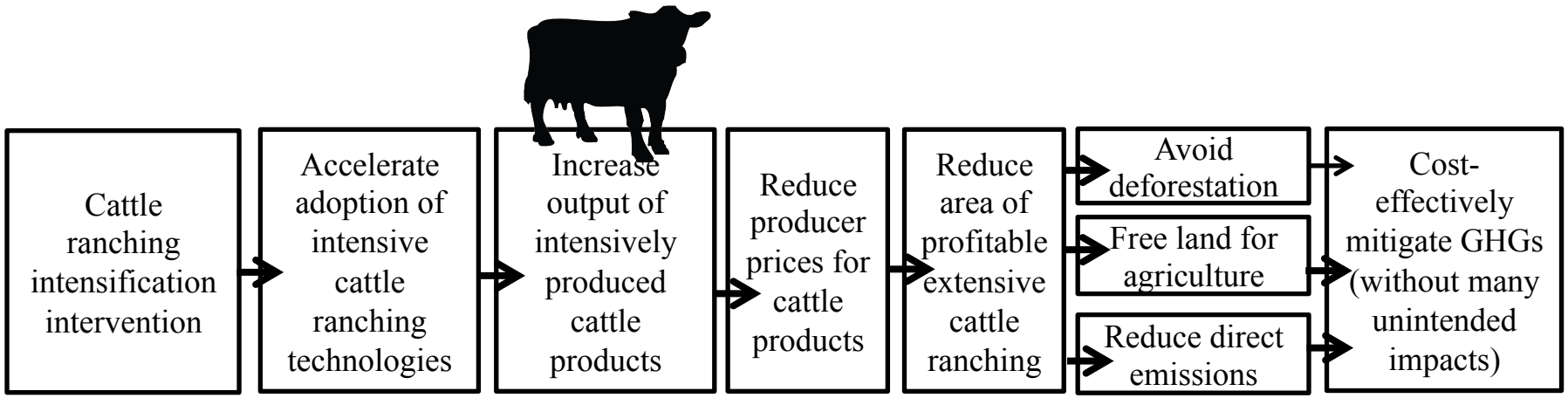

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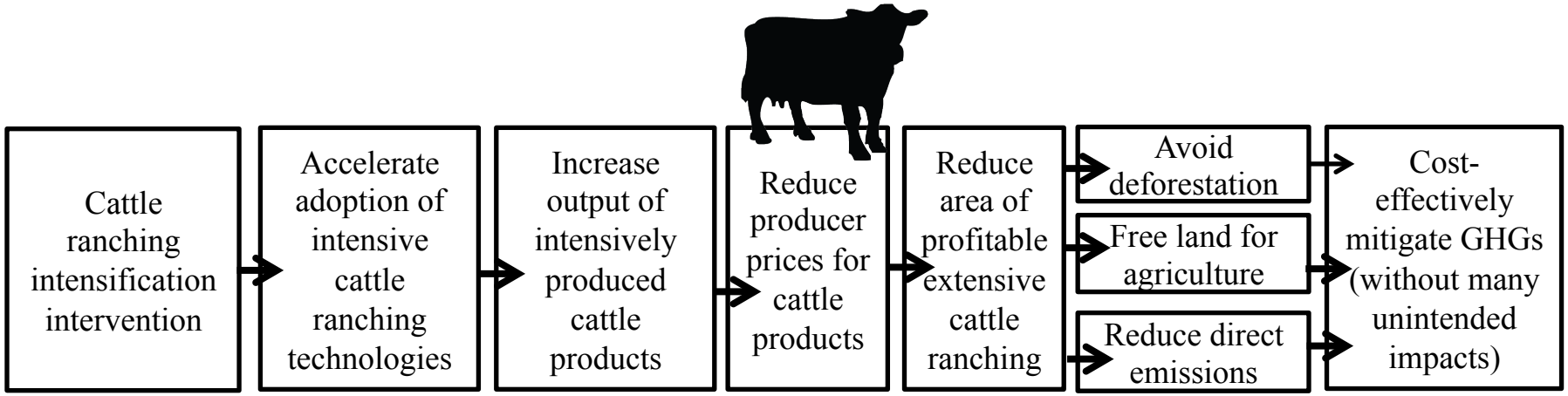

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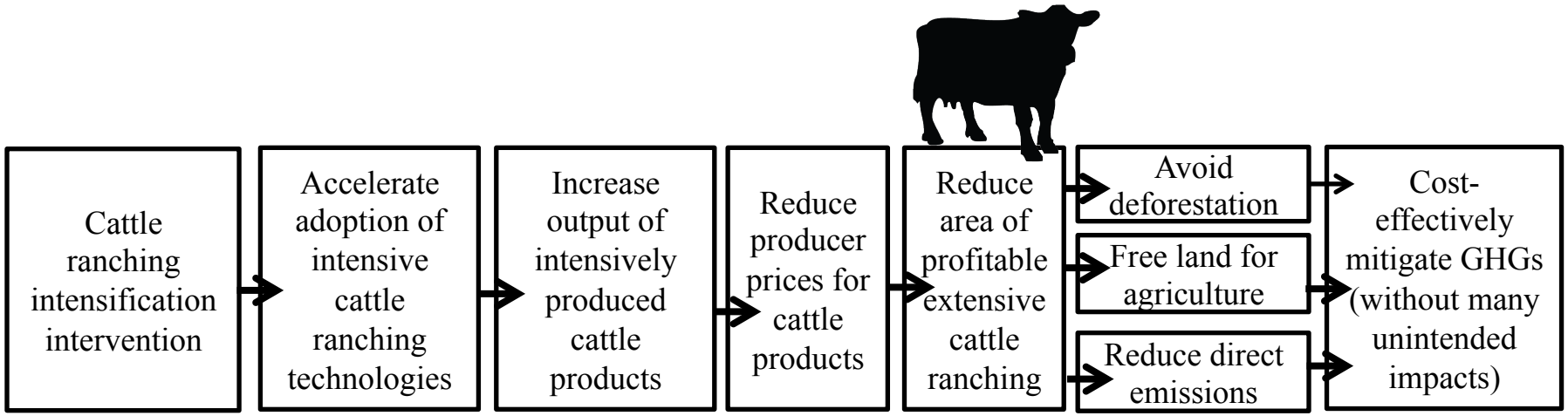

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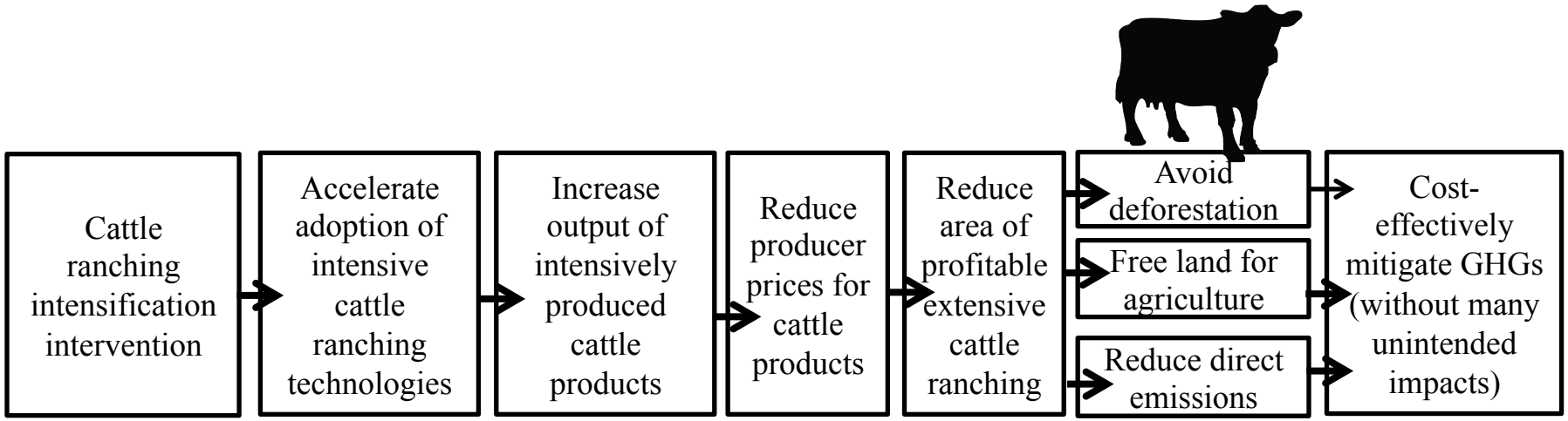

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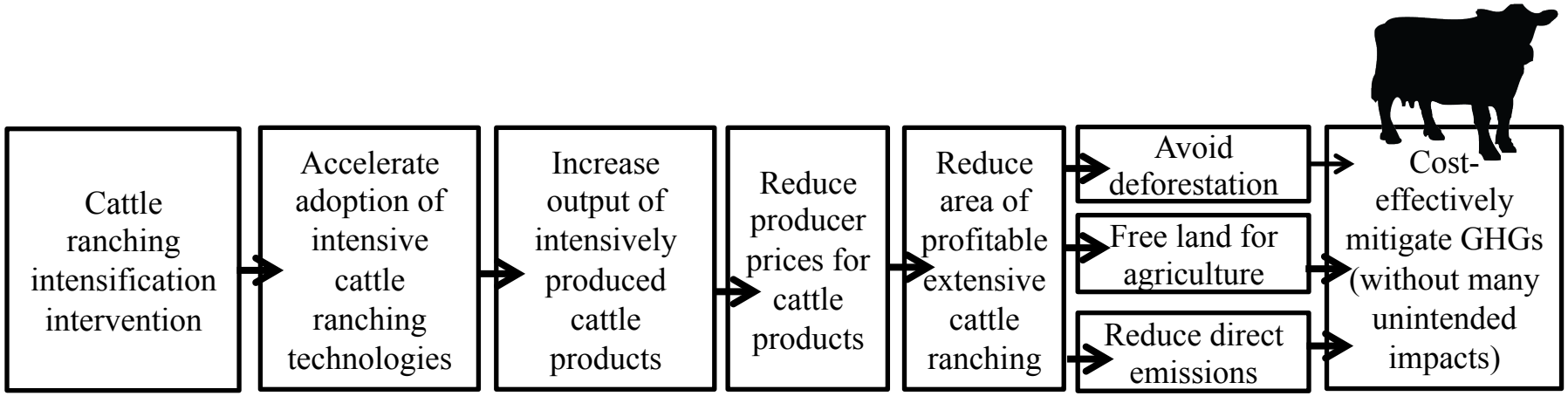

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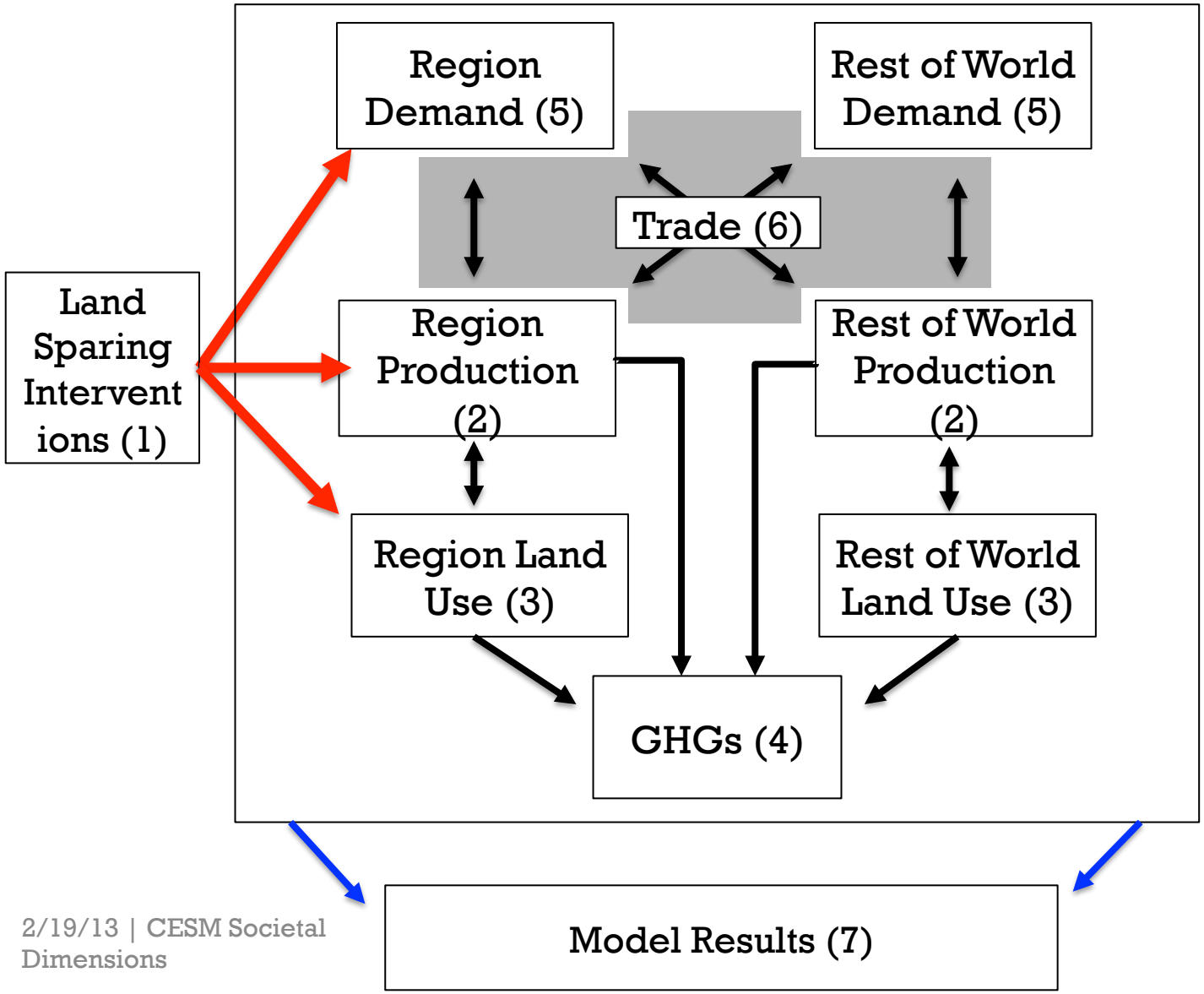
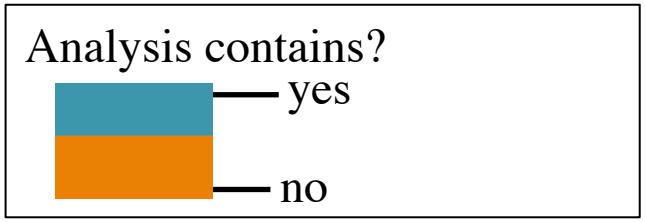
Land Sparing Model Comparison: Conceptual Framework



(1) Representation of interventions
(2) Agricultural Production Function
(3) Land Access and Competition
(4) Agricultural Greenhouse Gases and mitigation
(5) Consumer Demand
(6) Trade and Regions
(7) Model Results Comparison

Models We Compared



	Brazil?	Cattle	Land Use Change	Int'l Trade	Partial Equillibrium	General Equillibrium	Intervention
Cohn et al., under review							
Zacks et al., 2009							
Cattaneo, 2005							
Gouvello et al., 2010							
Lapola et al., 2010							
Martha et al., 2012							
Cederberg et al., 2011							
Bustamante et al., 2012							
Golub et al., 2012							
Strassburg, 2013							

(1) Representation of interventions

- Model constraint
- Land-based price instrument
- Carbon tax
- None of the above

CESM connection: Carbon and land taxes would be altered by impacts of changing climate on agriculture

(2) Agricultural Production Function

- Components
  - Land, labor, capital, materials, energy
    - Credit constrained producers will behave differently than others (see Assunção et al. 2013, Angelsen & Kaimowitz, 2001)
- Functional form
- Substitutability
  - Energy vs. labor vs. land
- Enumeration
  - Prices vs. quantities

CESM connection: Land productivity is climate dependent

(3) Land Access and Competition

- Expert judgment to predict crop and livestock expansion, statistical approach to locate (Wassenaar)
- Deforestation modeled using projection based on historical trends. Economic model used to simulate cropland expansion. Difference is pasture extent (Gouvello)

CESM connection: Historical patterns used for allocation depend on climate

(4) Agricultural Greenhouse Gases and mitigation

- Most models use Saatchi et al. (2007) for biomass carbon
- Variation in time profile of emissions and whether these differ across transition matrix permutations
- Differences in supply curve of LUC under agricultural expansion
  - Spatially explicit approaches
  - Regional approaches
  - Historical approaches
  - Bottom up vs. top down a good summary (see Creutzig et al. 2012)

CESM connection: Changing biomass and soil carbon

(6) Trade and Regions

- Regions
  - Vary across models
  - May vary across model components
- Trade
  - Spatial equilibrium
    - Logistics costs + tariffs
  - Historically-based trade patterns (Armington elasticities approach)
  - Can have big effects of GHG mitigation (see Bohringer et al. 2012)
- Upshot
  - Supply response matters!
  - For more see Cohn et al (on how land sparing in Brazil depends on supply response)
  - And Hertel 2012 (for a conceptual framework on supply response under unilateral change in productivity)

(7) Model Results Comparison

	Golub&	Gouvello#	Cohn@	Strassburg	Lapola
Adoption rate	n.a.	~50%	10 to 66%	100%	100%
Increase in cattle density (AU/ha)	0 to 0.3	0.5	0.2 to 0.9	1 to 1.5	0.13
Avoided Deforestation in Brazil (millions of hectares)	-.09 to 1.8	10	2 to 25	23	12
GHG mitigation in Brazil (Gt)	3+	6.3	1 to 7	14	9
Leakage	16 to 56%*	n.a.	-20 to 22 %	n.a.	n.a.

& over the period 2001 to 2021
# over the period 2006 to 2030
@ over the period 2010 to 2030
~over the period 2003 to 2020
*livestock products
^GHG mitigation
+ all of Latin America

CESM connection(s)?

Concluding Thoughts

- Perturbations in agricultural productivity are a socio-economic phenomenon with substantial climate effects
- Agricultural productivity has multiple linkages and dependencies with the earth and climate system
- Substantial heterogeneity in socioeconomic modeling approaches
- Opportunities to do coupled economic-climate model comparison of land sparing and other agricultural productivity change
  - Including on "adaptation as mitigation"
    - See Lobell et al. (2013)

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(5) Consumer Demand

- Often represented as linearly rising with time and decline in price
  - But slope varies too
- More complex in reality
  - See Carlson Kanyama & Gonzalez, 2009 on non-linear price response
  - See Pradhan et al., 2012 on for a typology of food transitions
  - Hertel 2012 and Chrakravorty et al. 2009 on the role of bioenergy in making demand elastic

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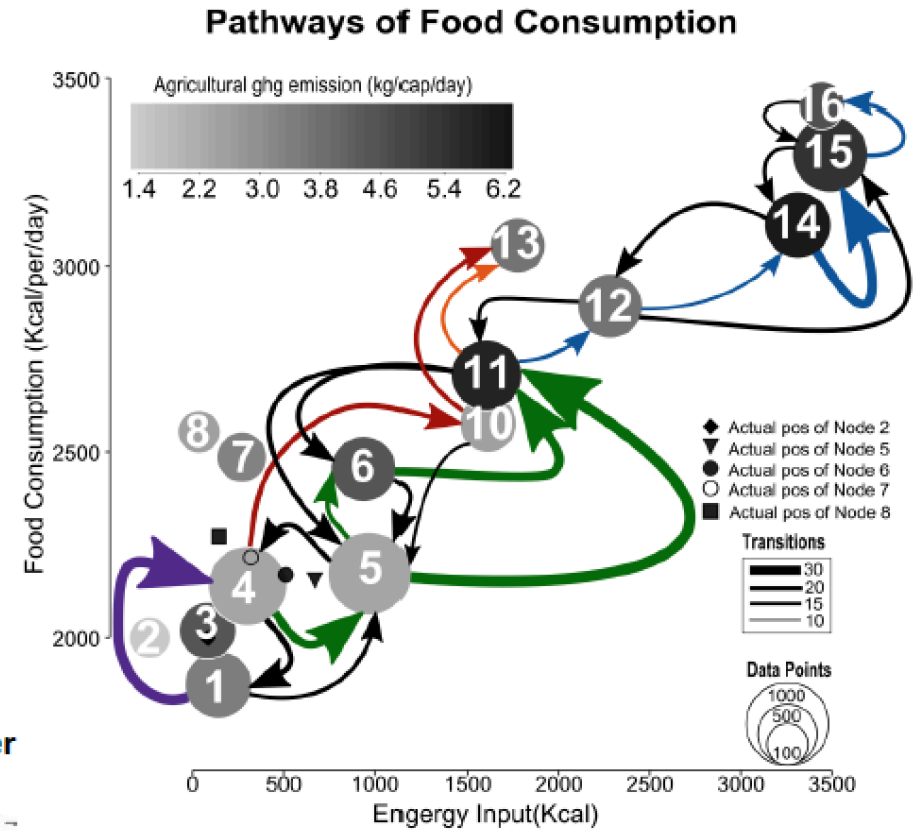
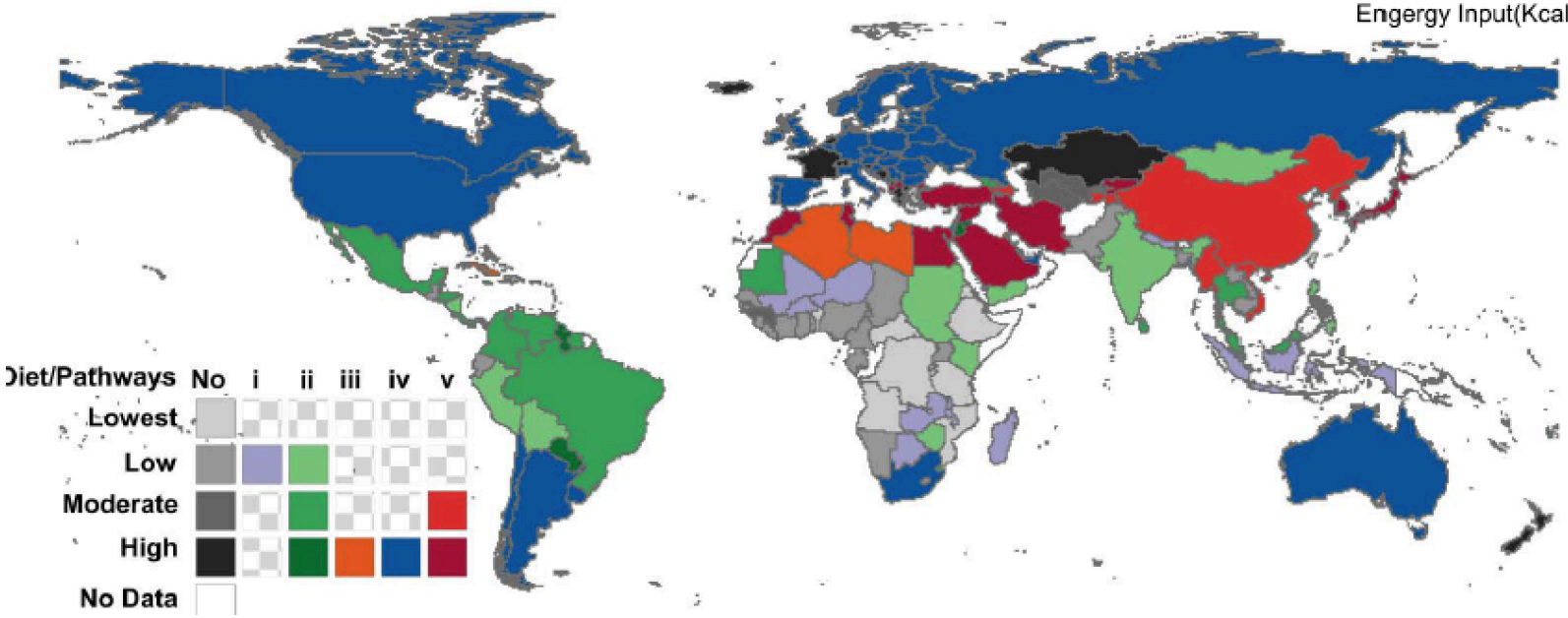
Food transition pathways

- dietary transition <- change in dietary pattern of a country
- directed graph with a line width proportional to the count (> 10 transitions)

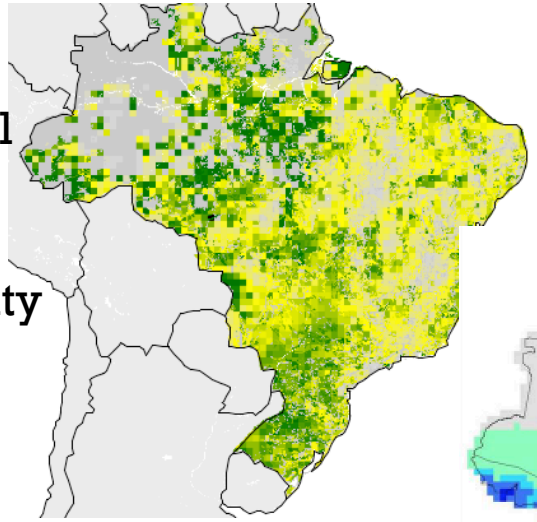


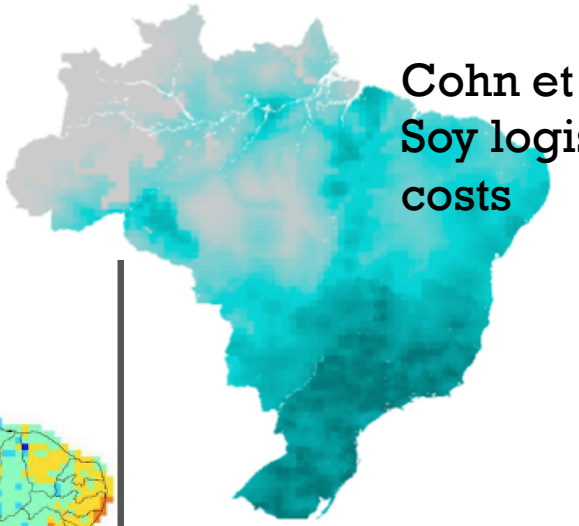
Followed food transition pathways and achieved dietary patter



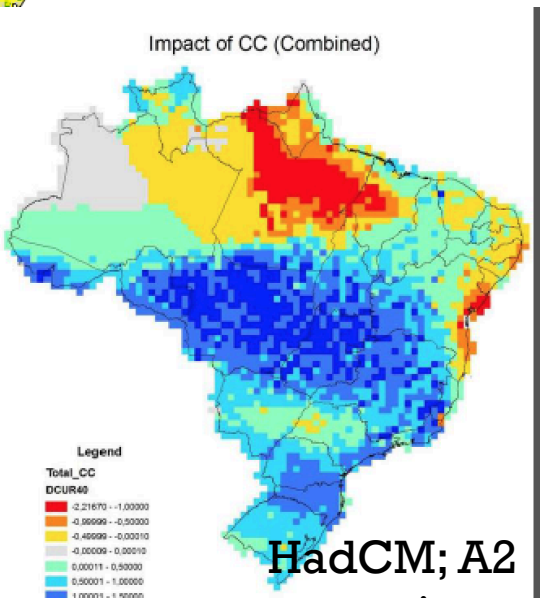
Pradhan, 2012

Cohn et. al Cattle Ranching Productivity

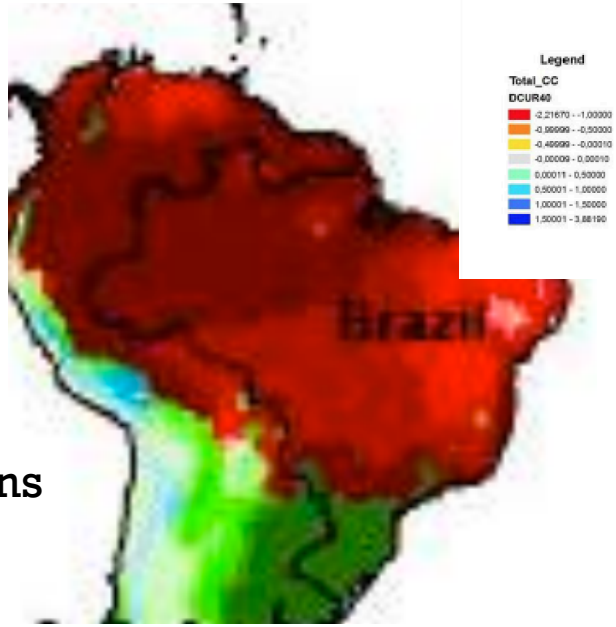




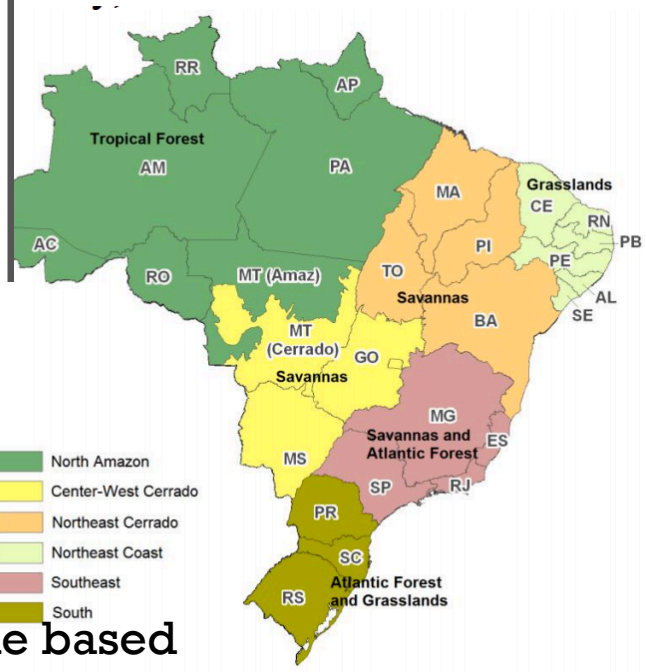
Cohn et al. Soy logistics costs



HadCM; A2 scenario



GTAP Regions + AEZ



Gouvello biome based model regions