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The Effect of Future Diet on Bioenergy Availability

Jay S. Gregg Katherine Calvin Anna Hvid

Technical University of Denmark Climate Center, Risø National Laboratory for Sustainable Energy

Overview

- Question:
  - What is the effect of diet on land use and bioenergy potential?
- Part I. Bioenergy Potential
- Part II. Historical Trends
  - 1. Total Caloric Intake
  - 2. Percentage of Animal Products in the Diet
  - 3. The Developed vs. Developing World
- Part III. Future Scenarios
  - 1. GCAM
  - 2. Scenario Development
  - 3. Results

Part I.
Bioenergy Potential

Bioenergy Potential

- Technical (Theoretical) Potential – total amount that can theoretically produced
- Supply Potential – often used interchangeably with technical, but could also vary if one considers sustainability constraints
- Demand Potential – amount of biomass demanded by the global market at a given price or under a given policy scenario, in consideration of other energy options

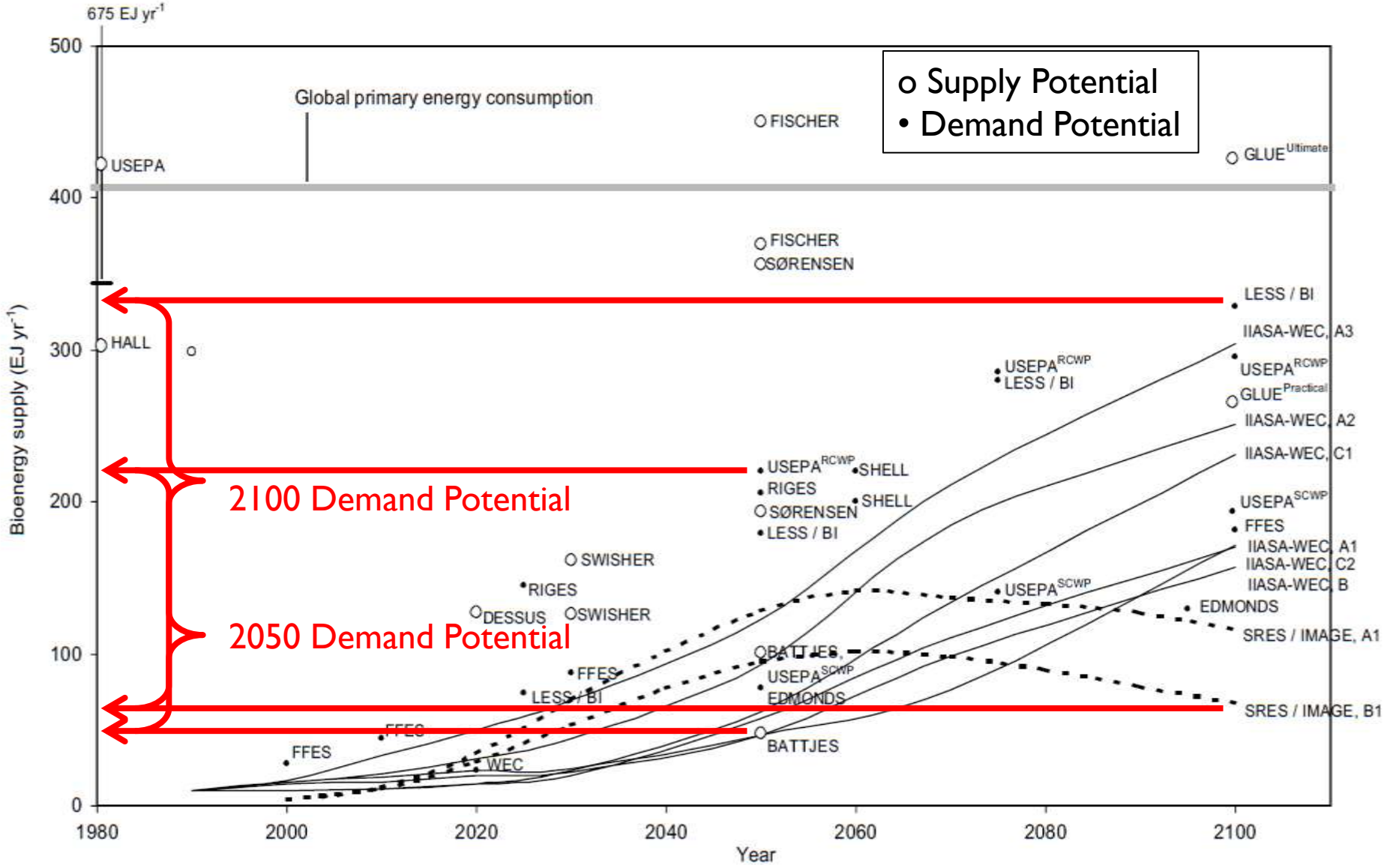


Fig. 2. Potential biomass supply for energy over time. Resource-focused studies are represented by hollow circles and demand-driven studies are represented by filled circles. USEPA and HALL, who do not refer to any specific time, are placed at the left side of the diagram. IIASA-WEC and SRES/IMAGE are represented by solid and dashed lines respectively, with scenario variant names given without brackets at the right end of each line. The present approximate global primary energy consumption is included for comparison. (The global consumption of oil, natural gas, coal, nuclear energy and hydro electricity 1999–2000 was about 365 EJ yr^{-1} [43]. Global biomass consumption for energy is estimated at 35–55 EJ yr^{-1} [44–46].)

Berndes et al. 2003

Issues Affecting Bioenergy Potential

*Table ES.2 Overview of uncertainties and their impact on biomass resource potentials**

Issue/effect	Importance	Impact on biomass potentials compared to	
Supply potential of biomass		*supply as estimated in recent studies*	*OECD baseline scenario in IMAGE*
Improvement agricultural management	***	↑↓	↑ 40-65%
Choice of crops	***	↓	↓ 5-60%
Food demands and human diet	***	↑↓	n/a
Use of degraded land	***	↑↓	↑ ca. 30-45%
Competition for water	***	↓	↓ 15-25%
Use of agricultural/forestry by-products	**	↑↓	n/a
Proceted area expansion	**	↓	↓10-25%
Water use efficiency	**	↑	n/a
Climate change	**	↑↓	n/a
Alternative protein chains	**	↑	n/a
Demand for biomaterials	*	↑↓	n/a
GHG balances of biomass chains	*	↑↓	n/a
Demand potential of biomass		*demand as estimated in recent studies*	*biomass supply as estimated in TIMER*
Bio-energy demand versus supply	**	↑↓	↓ 80-85%
Cost of biomass supply	**	↑↓	n/a
Learning in energy conversion	**	↑↓	n/a
Market mechanism food-feed-fuel	**	↑↓	n/a

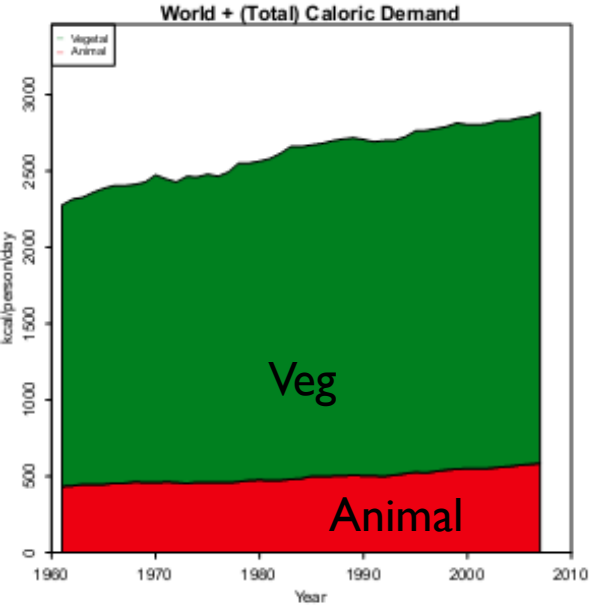
Importance of the issues on the range of estimated biomass potentials: ***- large, ** - medium, * – small
Impact on biomass potentials: potentials as estimated in recent studies would: ↑ - increase, ↓ - decrease, ↑↓ increase or decrease – if this aspect would be taken into account.
N/a: no quantitative analysis has been carried out in this study
* See Section 4.2 for a more detailed description of underlying results of this Table

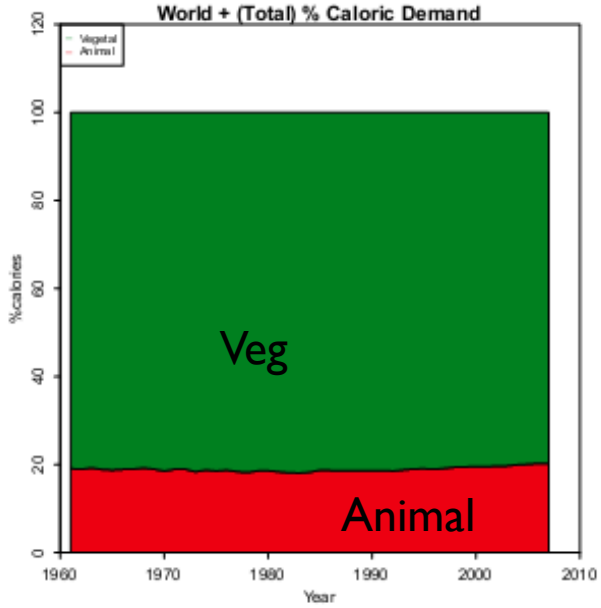
Dornburg et al. 2008

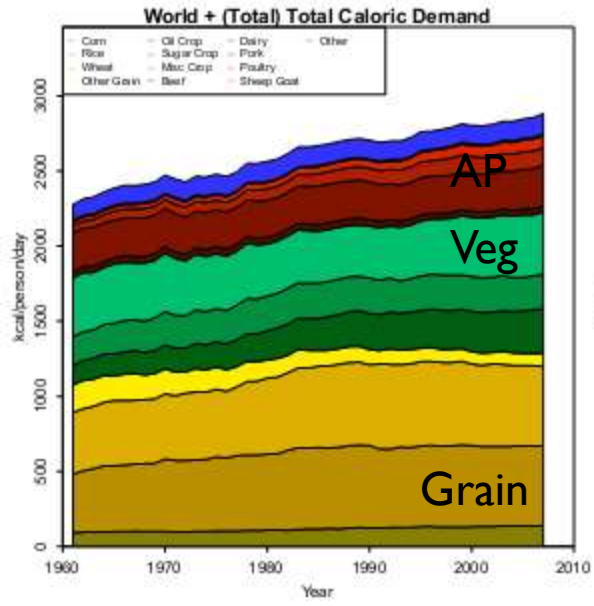
Method

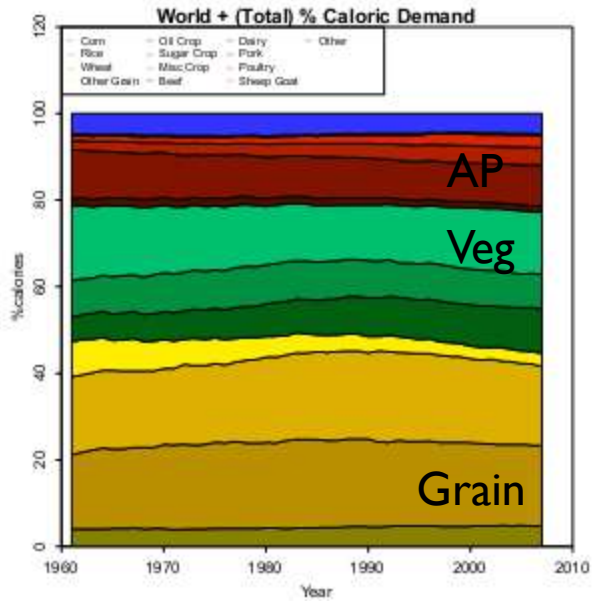
- 1. Analyze FAOSTAT Food Supply for all countries 1961-2007
- 2. Aggregate FAOSTAT data into GCAM regions and categories
- 3. Develop Scenarios
- 4. Calibrate GCAM to match historic FAO data
  - adjust animal efficiencies and non-food demand of vegetal products
- 5. Change income elasticities for each GCAM food category to achieve desired scenario by 2095 (linear approach)

Part II.
Historical Trends in Food Consumption







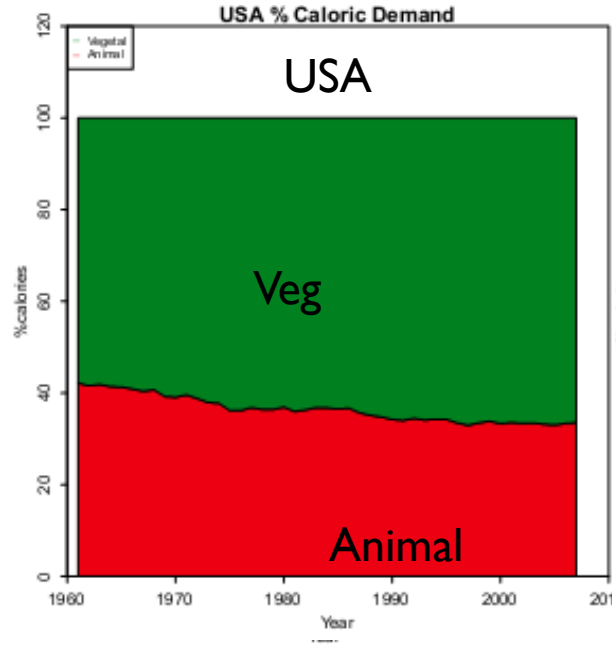


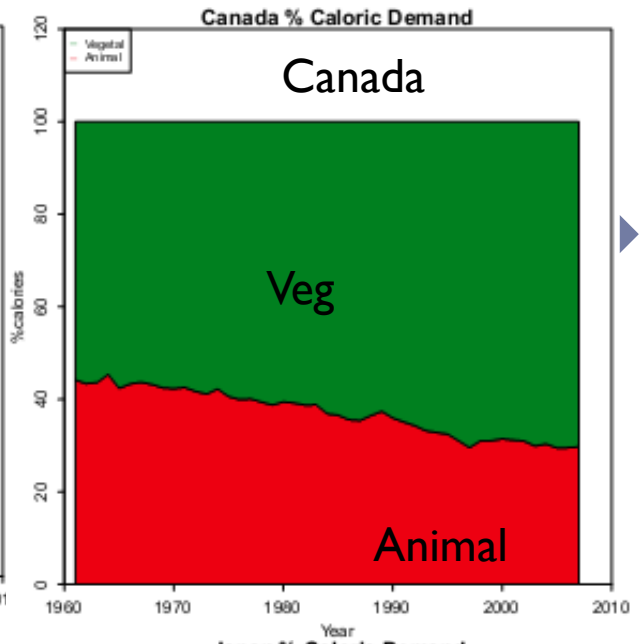
Global Trends

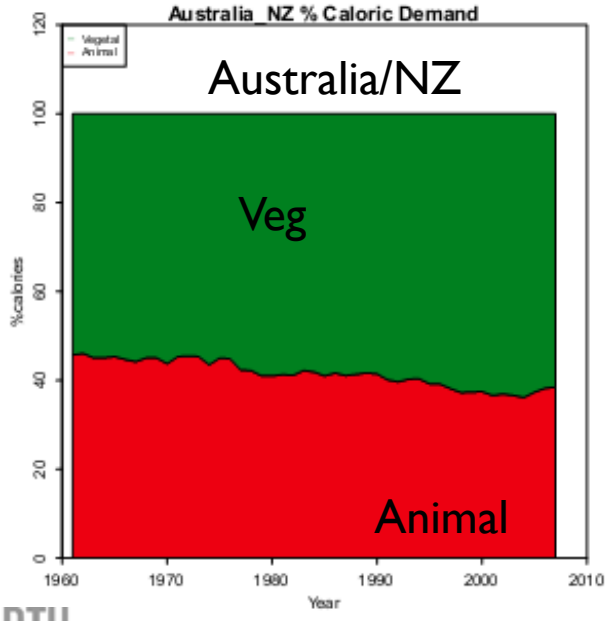
- Have not changed much in the last 50 years
- Overall food demand has increased
- Animal product demand has remained relatively constant

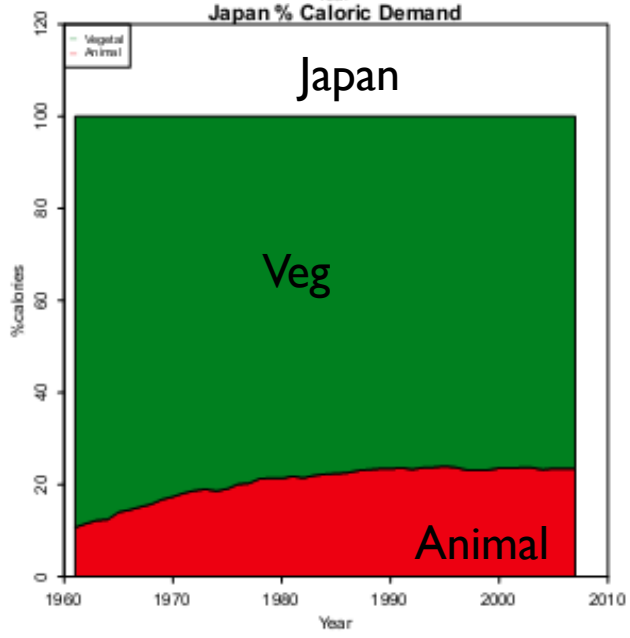
raw data source: FAOSTAT

Developed Regions





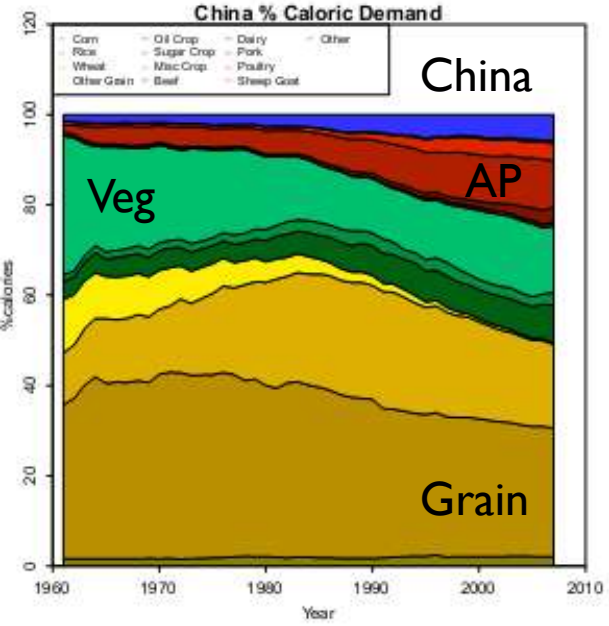


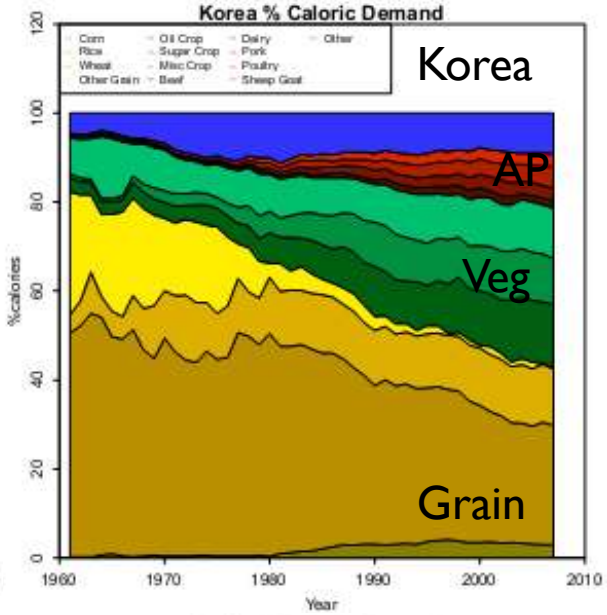


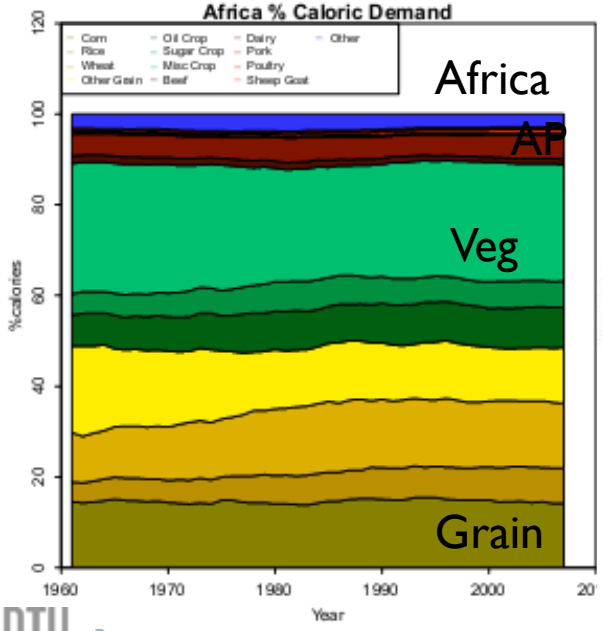
- Animal product demand tends to decrease as a proportion of diet

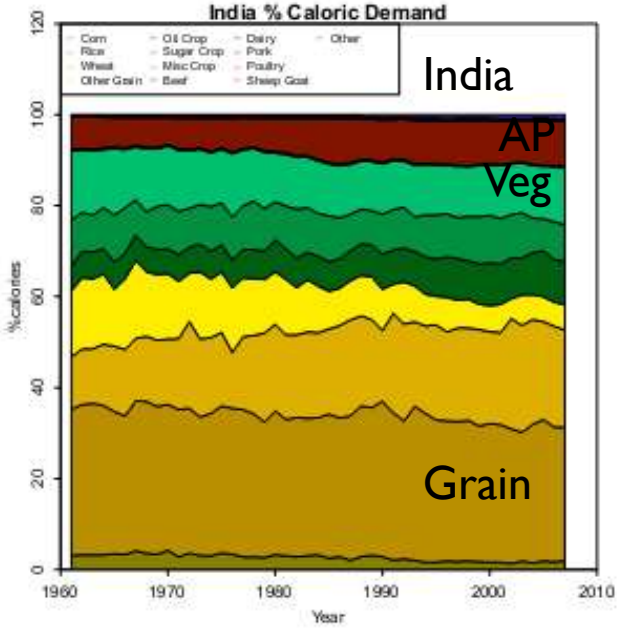
raw data source: FAOSTAT

Developing Regions



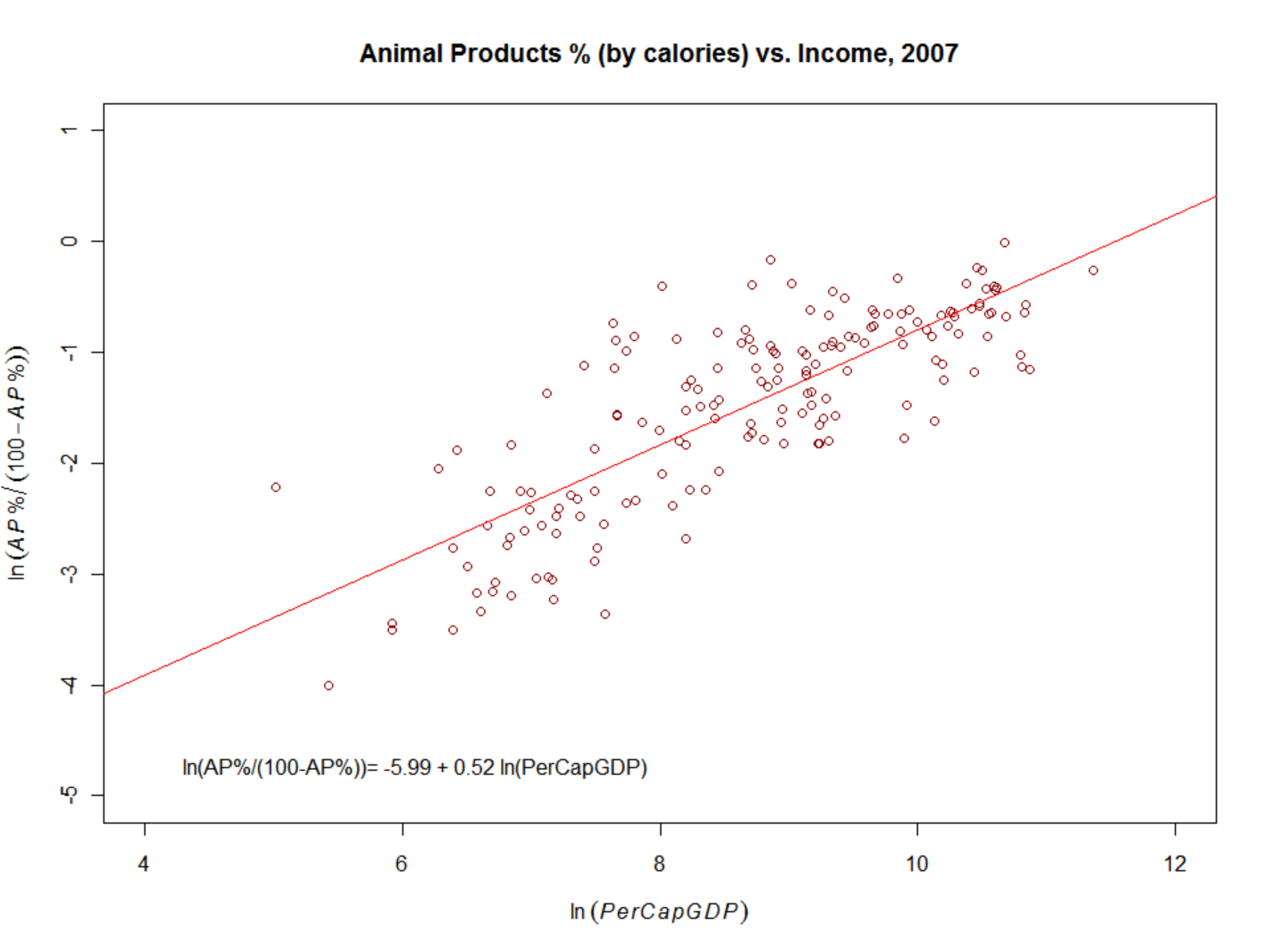


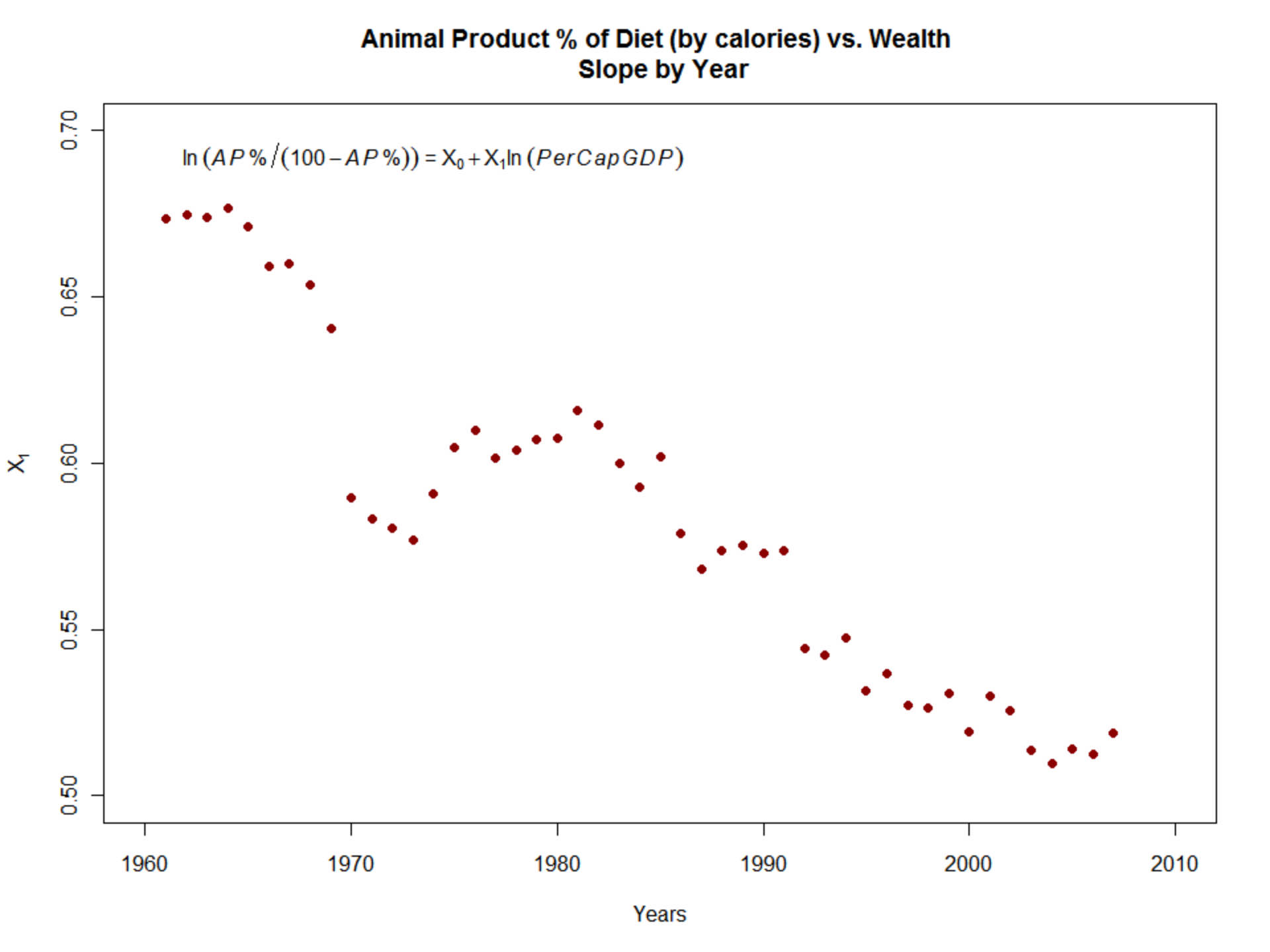


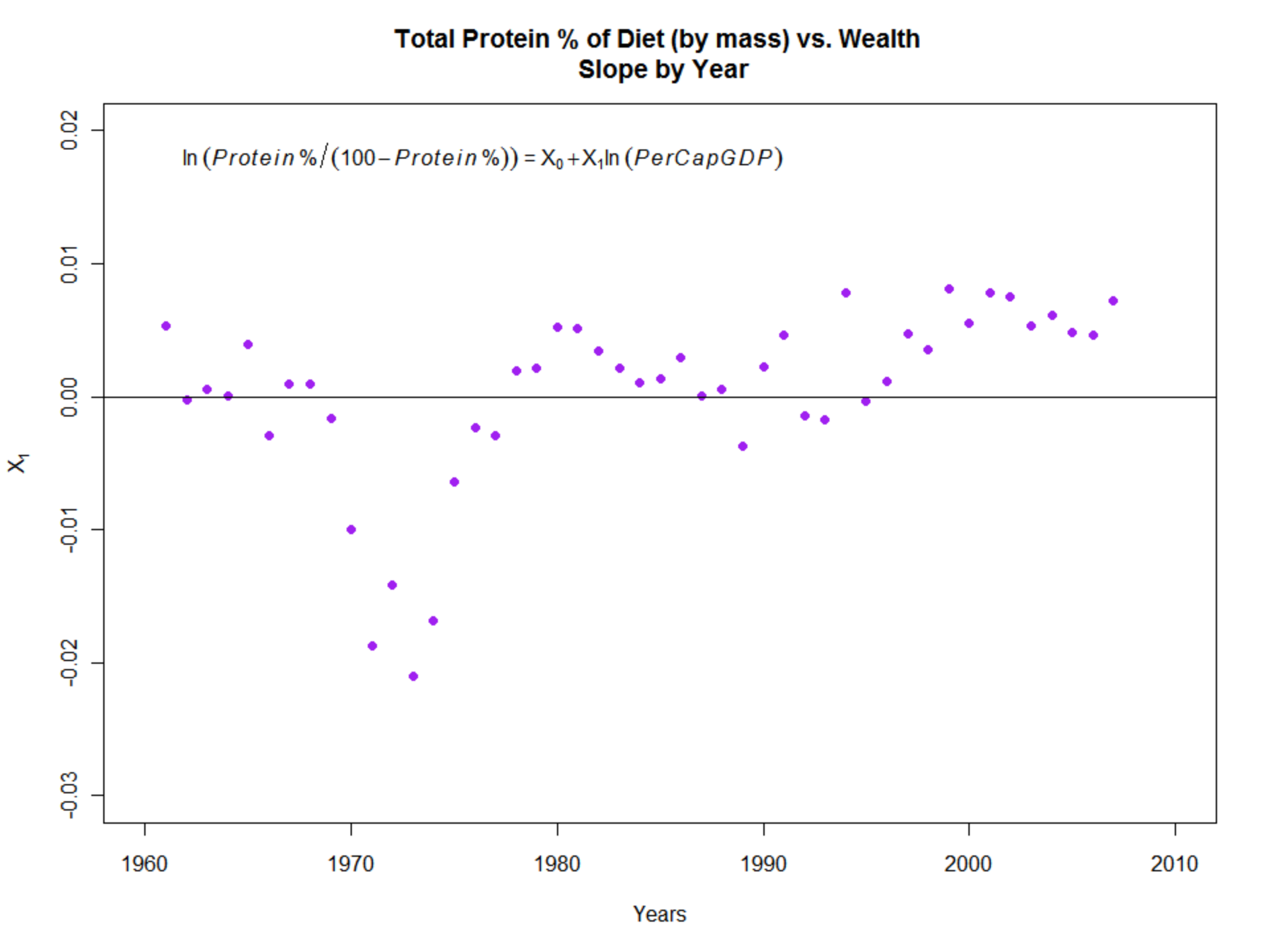


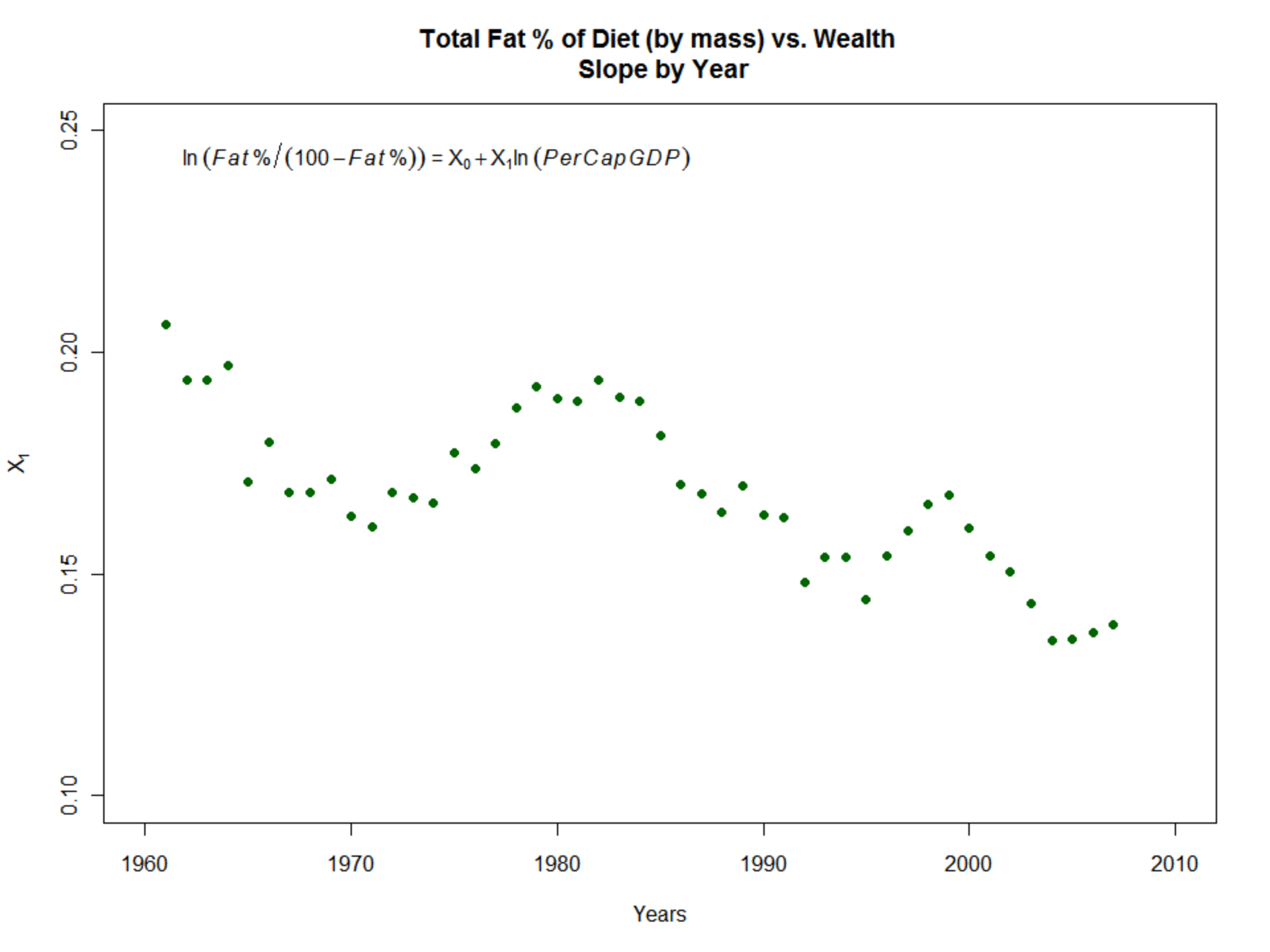
- Animal product demand tends to increase as a proportion of diet; but not always (e.g., Africa, India)
- Vegetable demand also increases

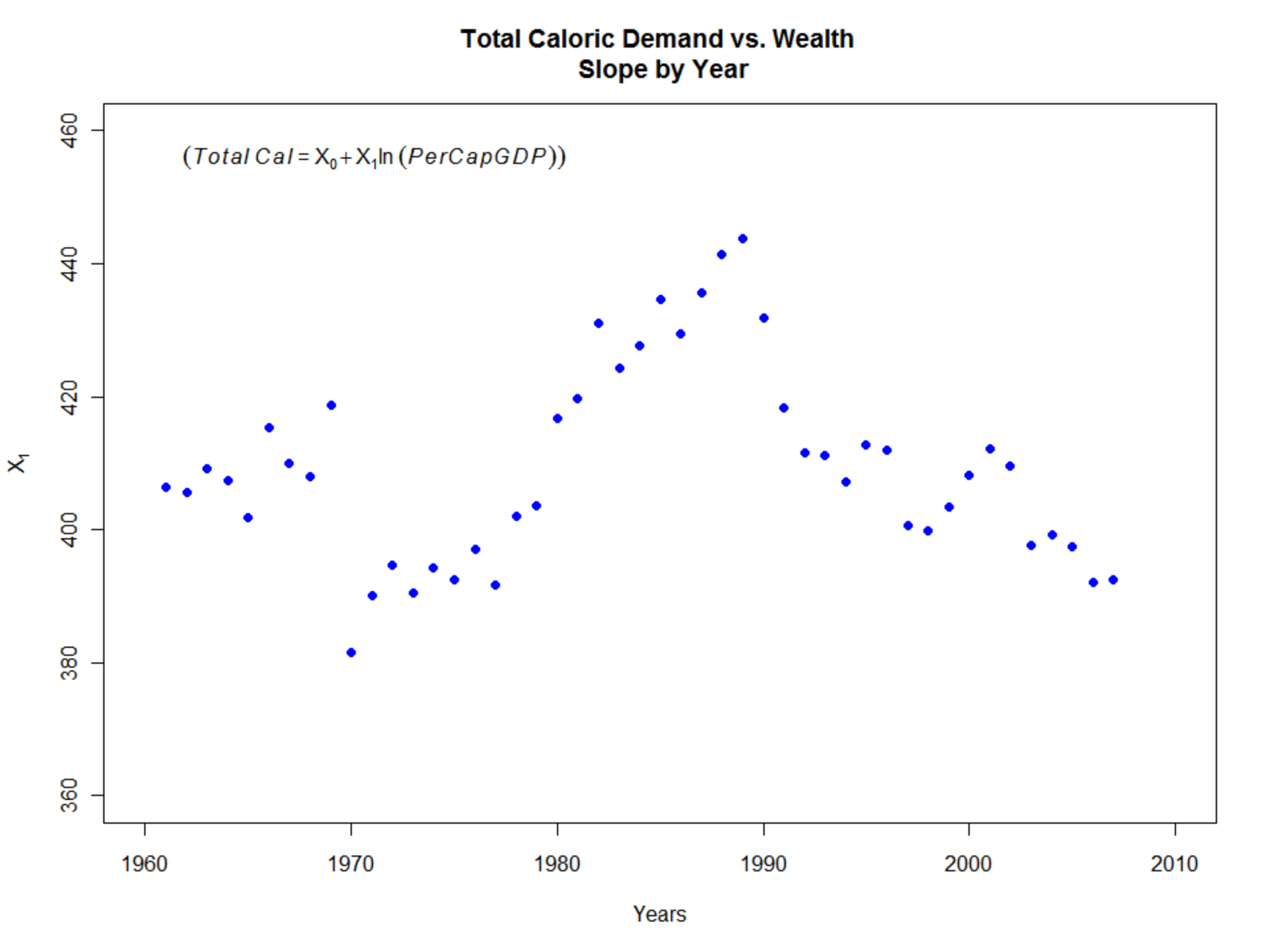
raw data source: FAOSTAT


Animal Products % (by calories) vs. Income, 2007
ln(AP%/(100-AP%))
ln(PerCapGDP)
ln(AP%/(100-AP%))= -5.99 + 0.52 ln(PerCapGDP)
1
0
-1
-2
-3
-4
-5
4
6
8
10
12


Animal Product % of Diet (by calories) vs. Wealth
Slope by Year
$\ln(AP\%/(100-AP\%)) = X_0 + X_1 \ln(PerCapGDP)$
X_1
0.70
0.65
0.60
0.55
0.50
1960
1970
1980
1990
2000
2010
Years


Total Protein % of Diet (by mass) vs. Wealth
Slope by Year
$\ln(Protein\%/(100-Protein\%)) = X_0 + X_1 \ln(PerCapGDP)$
0.02
0.01
0.00
-0.01
-0.02
-0.03
X_1
1960
1970
1980
1990
2000
2010
Years

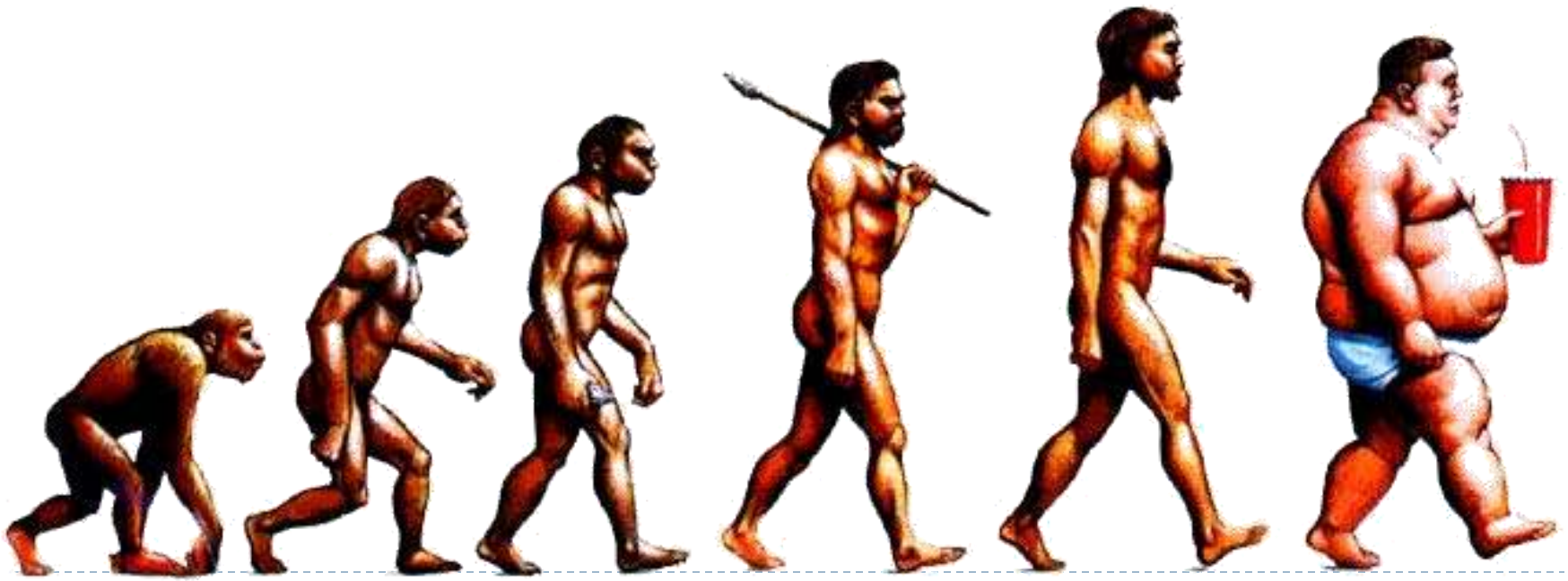

Total Fat % of Diet (by mass) vs. Wealth
Slope by Year
$\ln(Fat\%/(100-Fat\%)) = X_0 + X_1 \ln(PerCapGDP)$
X_1
0.25
0.20
0.15
0.10
1960
1970
1980
1990
2000
2010
Years


Total Caloric Demand vs. Wealth
Slope by Year
$(Total\ Cal = X_0 + X_1 \ln(PerCapGDP))$
X_1
460
440
420
400
380
360
1960
1970
1980
1990
2000
2010
Years

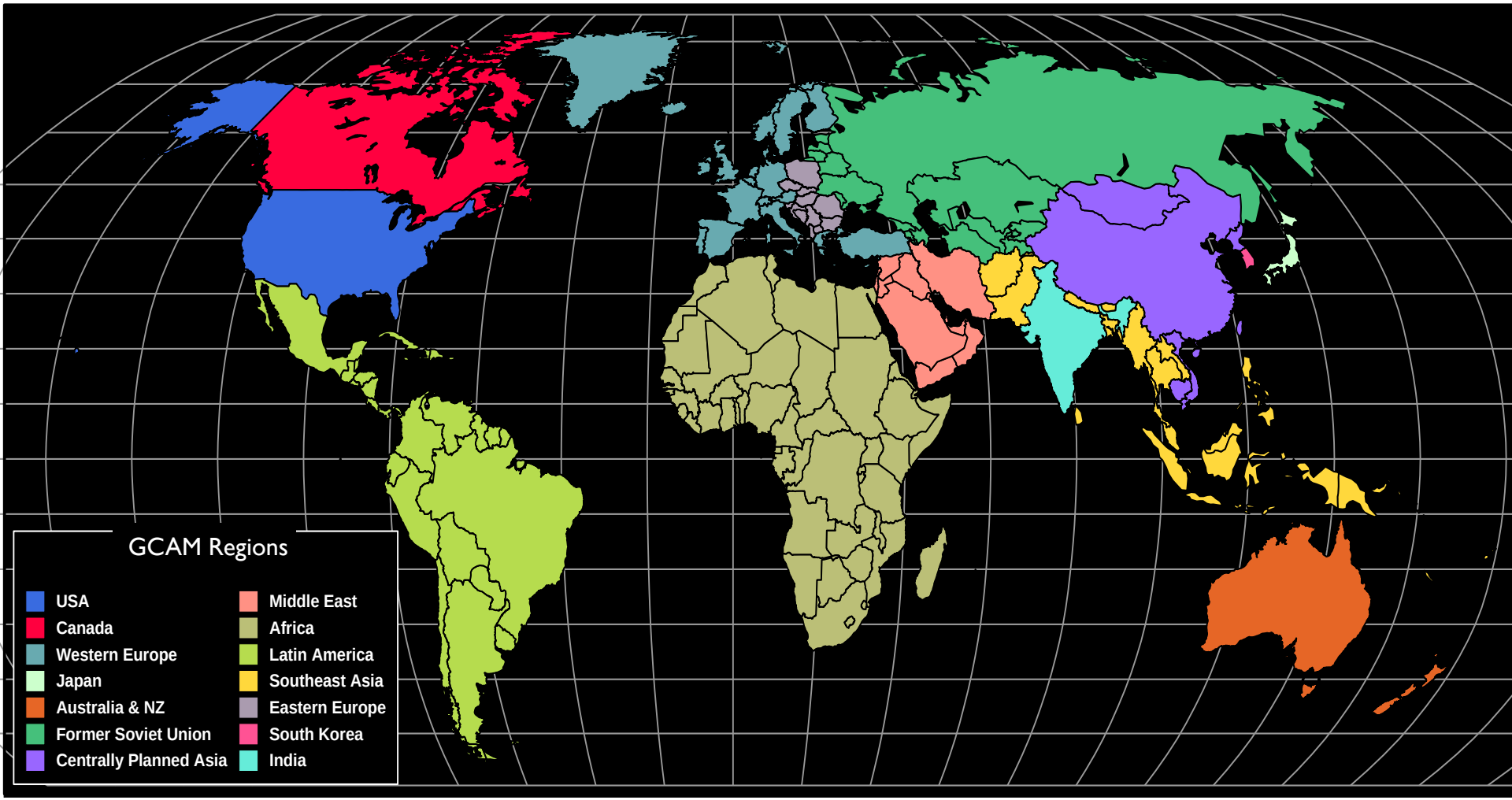
Summary of Historic Trends

- Developed countries are reducing or plateau-ing their animal consumption
- Developing countries are increasing animal consumption, but also vegetable consumption
- Percent of Animal Products increases with increasing wealth; but not as much as it used to
- Protein demand as % of calories has no relationship to wealth.
- Fat demand increases with increasing wealth; this relationship changes slightly over time... not as much as it used to be
- Total calorie demand increases with wealth; this relationship changes over time, but no apparent trend. We can assume that there is a maximum number of calories that can be demanded.

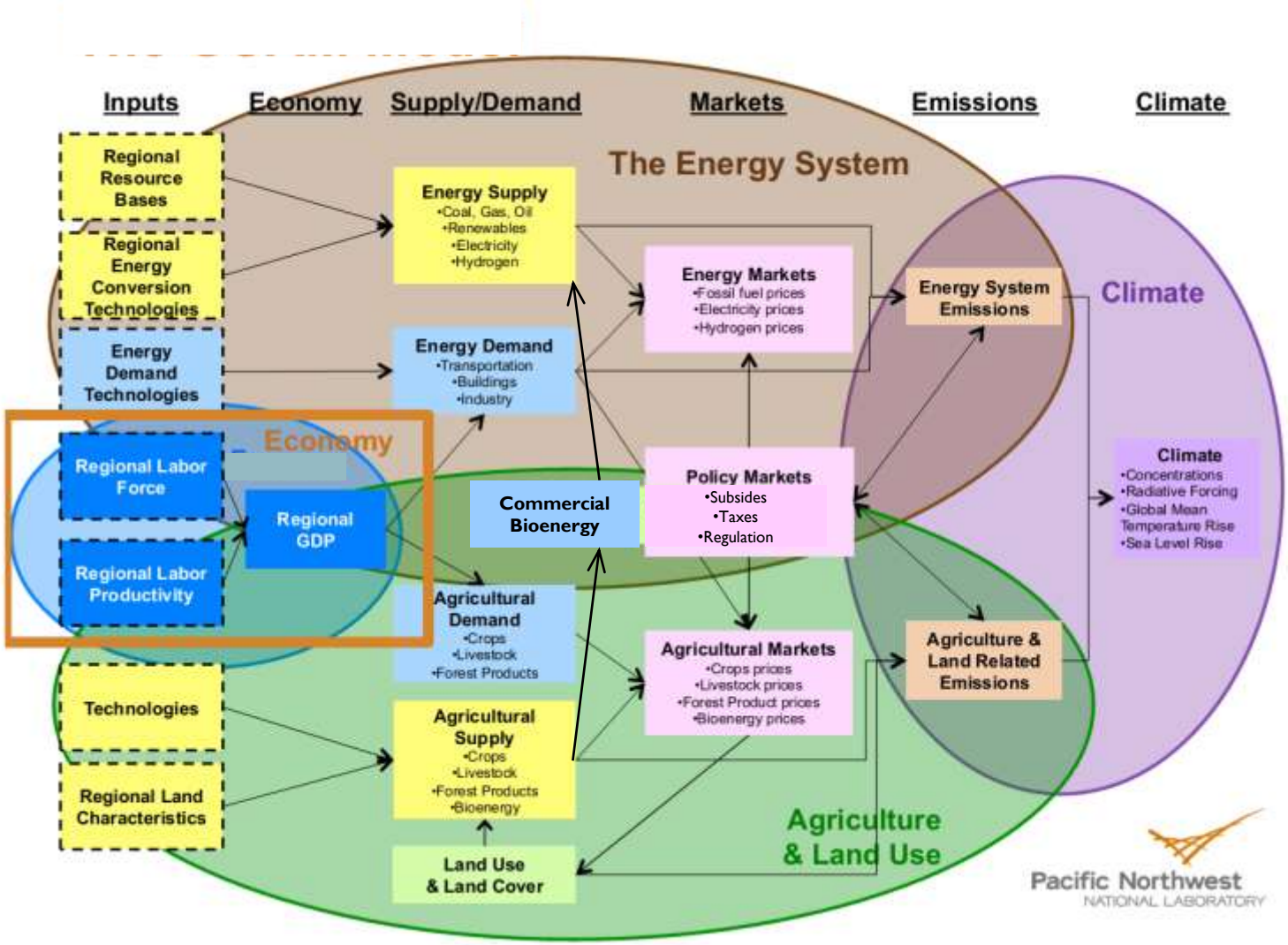
Part III.
Modeling Diets of the Future



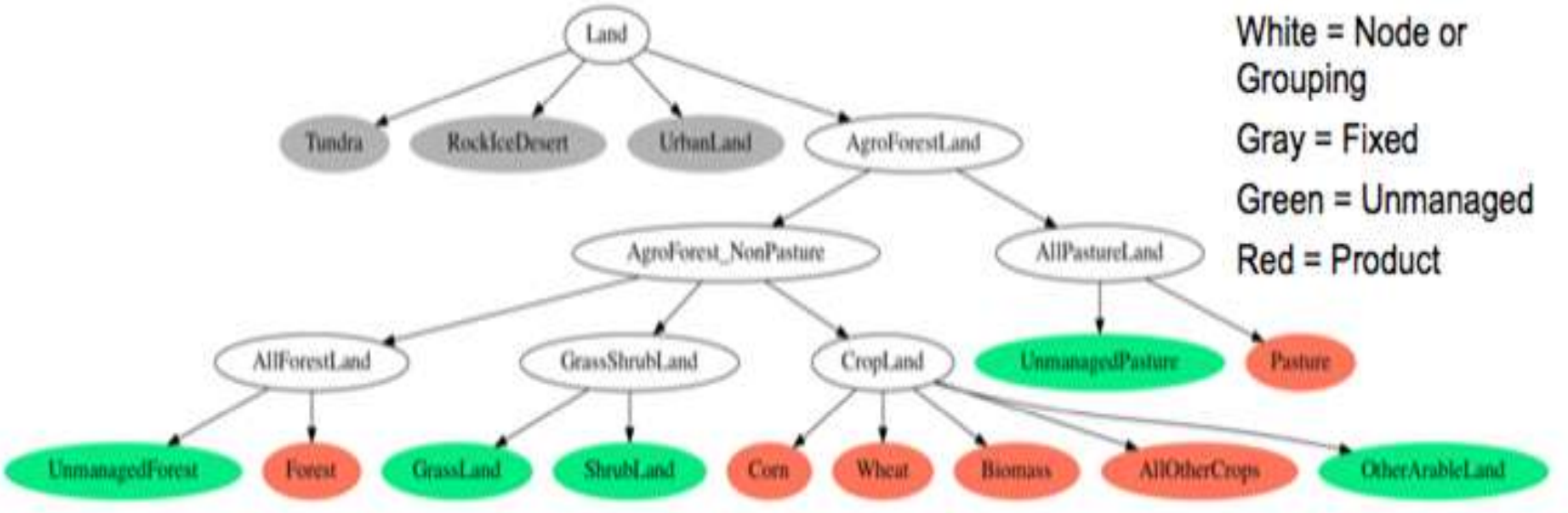
GCAM: Global Change Assessment Model



GCAM Structure



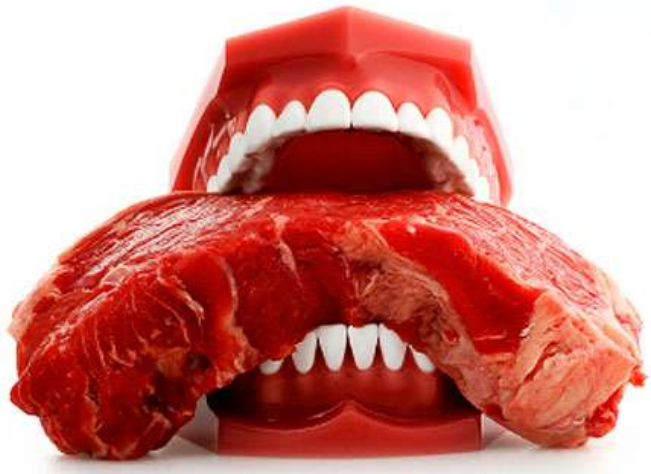
GCAM Land Category Nesting



Scenarios Explored for Future Diet

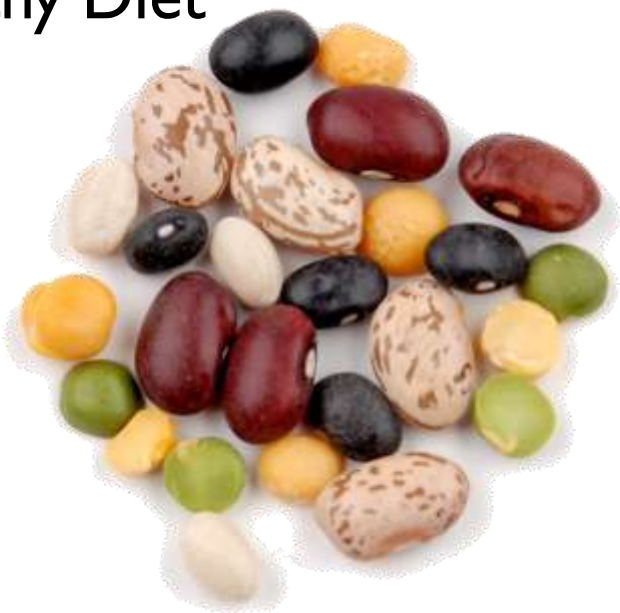
- 1. High Animal Products
  - Evolve to a American/Western European Diet
  - ~3500-4000 kcal/cap/day
  - ~35-40% animal products
  - small price elasticity to allow model to solve
- 2. Low Animal Products
  - Evolve to a Indian Diet
  - ~2500 kcal/cap/day
  - 10% animal products
- 3. "Healthy" diet
  - Defined by Harvard/ WHO
  - ~2800 kcal/cap/day
  - specific dietary consumption recommendations (high fruit and vegetable)
  - fat and protein targets
- 4. Extrapolated trend
  - Extrapolation of regional trends with relatively higher meat consumption
  - Per capita vegetal consumption unchanged

High Animal Products

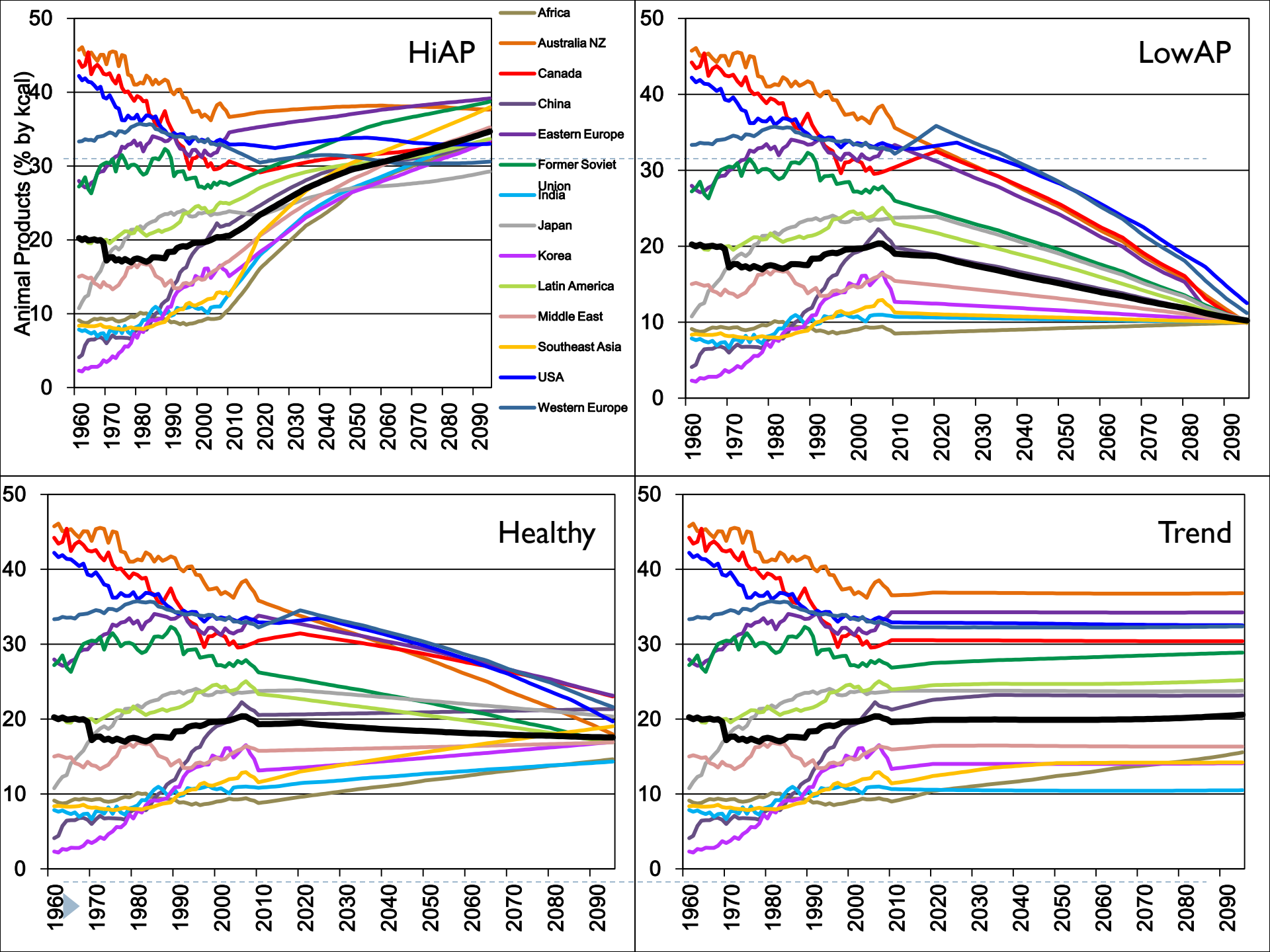


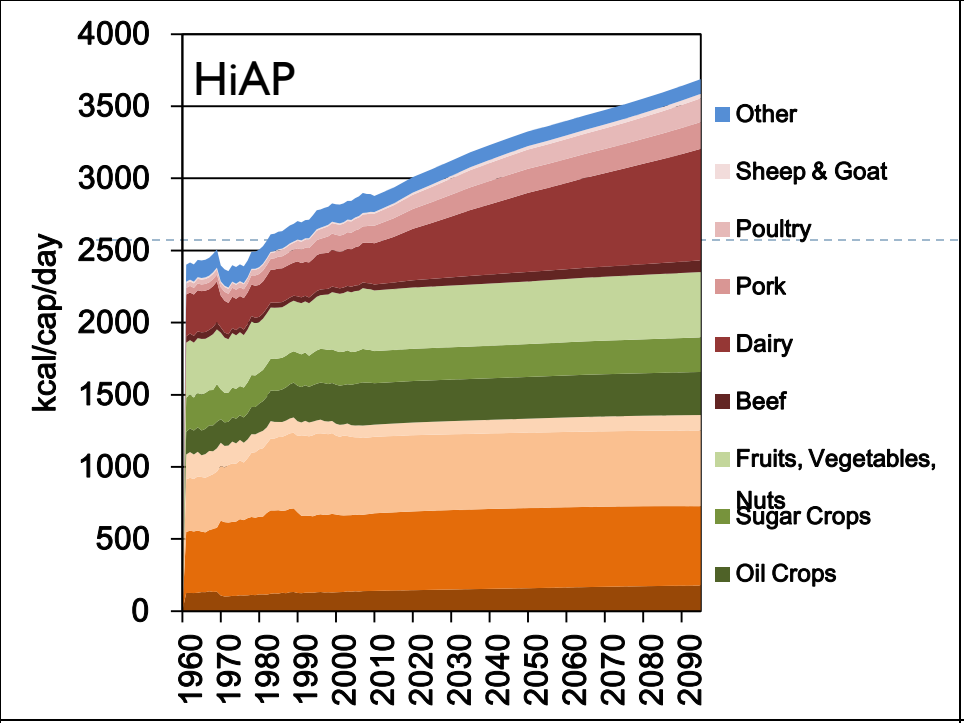
Low Animal Products

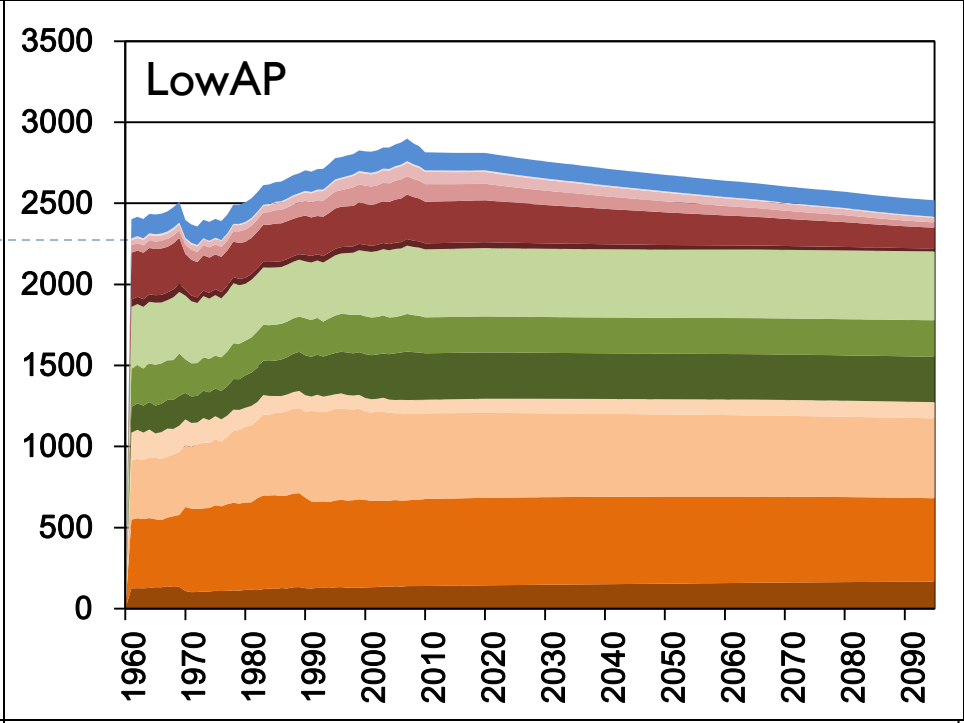
Healthy Diet

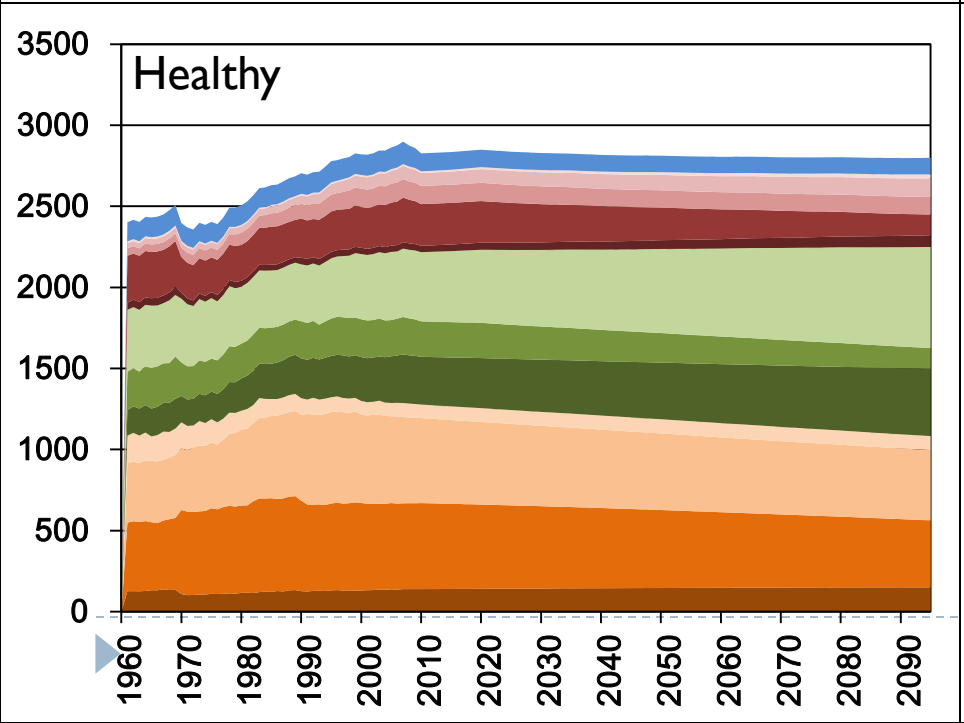


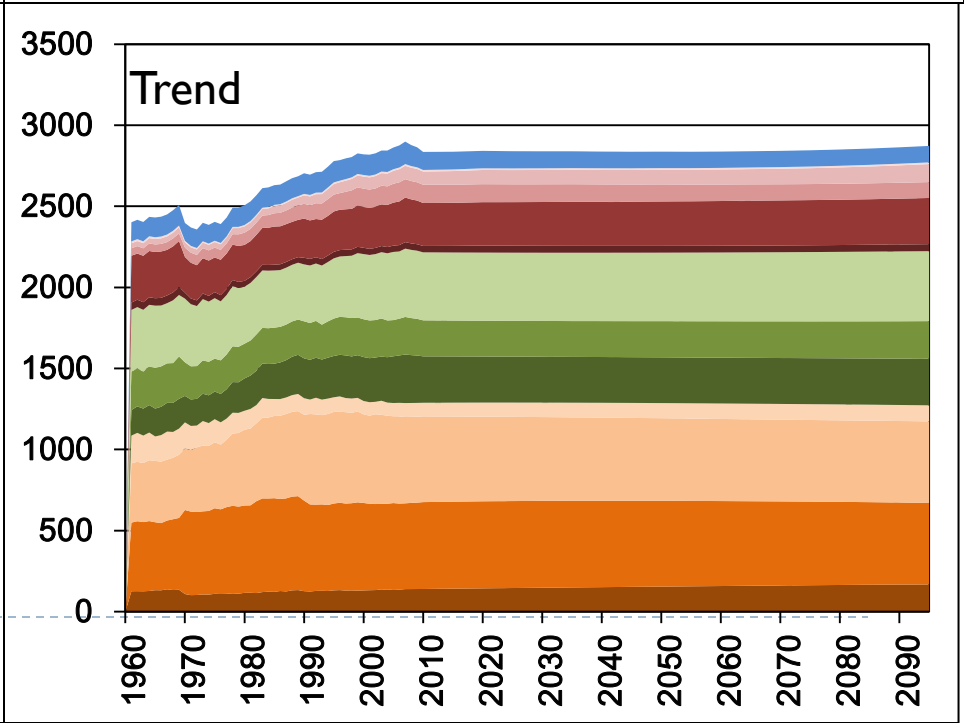
Extrapolated Trend

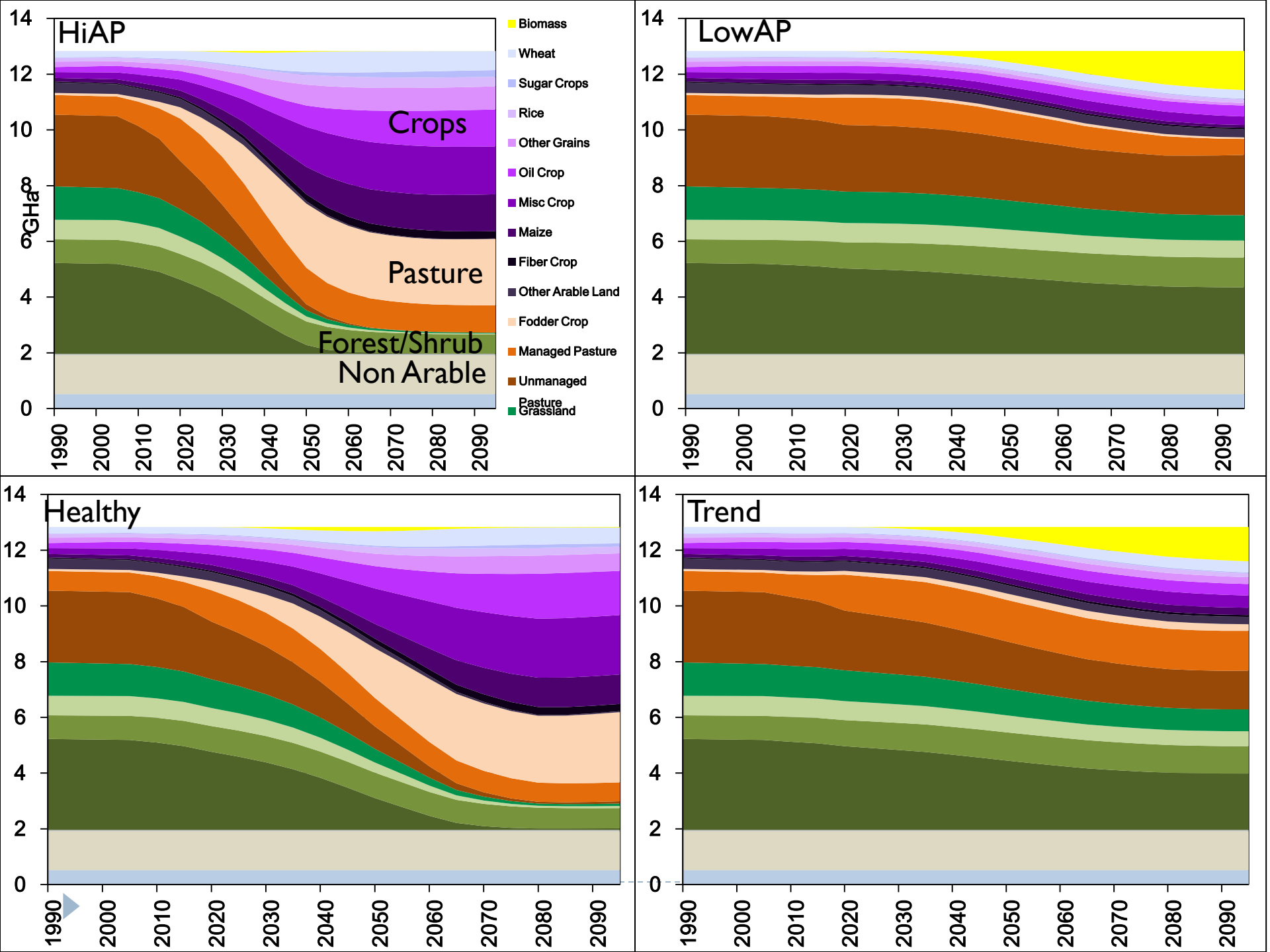

HiAP
LowAP
Healthy
Trend
Animal Products (% by kcal)
0
10
20
30
40
50
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
Africa
Australia NZ
Canada
China
Eastern Europe
Former Soviet Union
India
Japan
Korea
Latin America
Middle East
Southeast Asia
USA
Western Europe

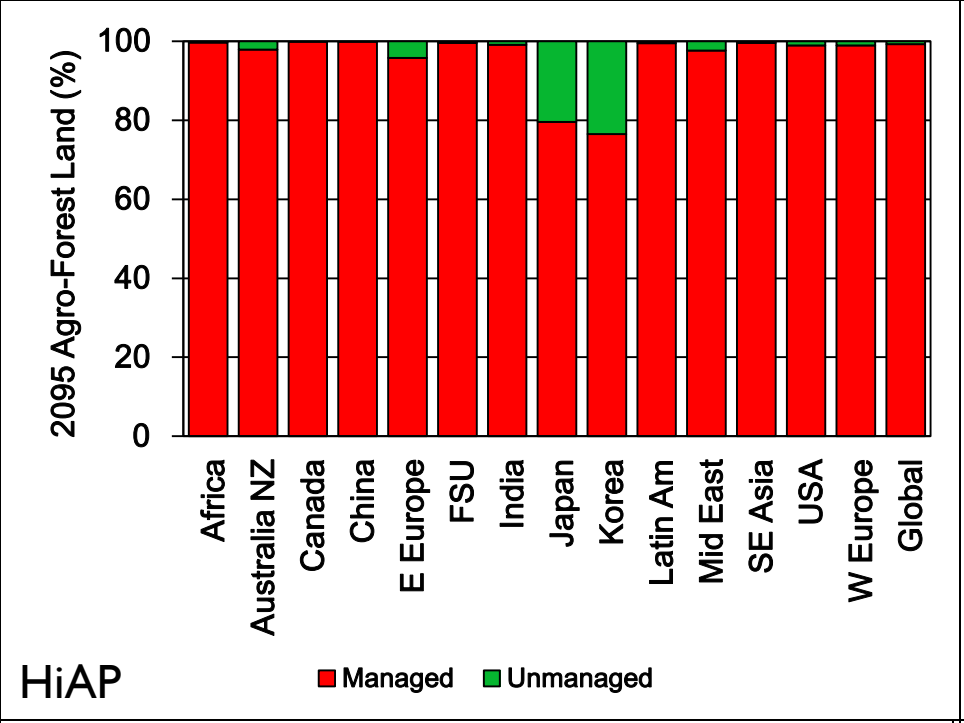

HiAP
kcal/cap/day
4000
3500
3000
2500
2000
1500
1000
500
0
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
Other
Sheep & Goat
Poultry
Pork
Dairy
Beef
Fruits, Vegetables, Nuts
Sugar Crops
Oil Crops

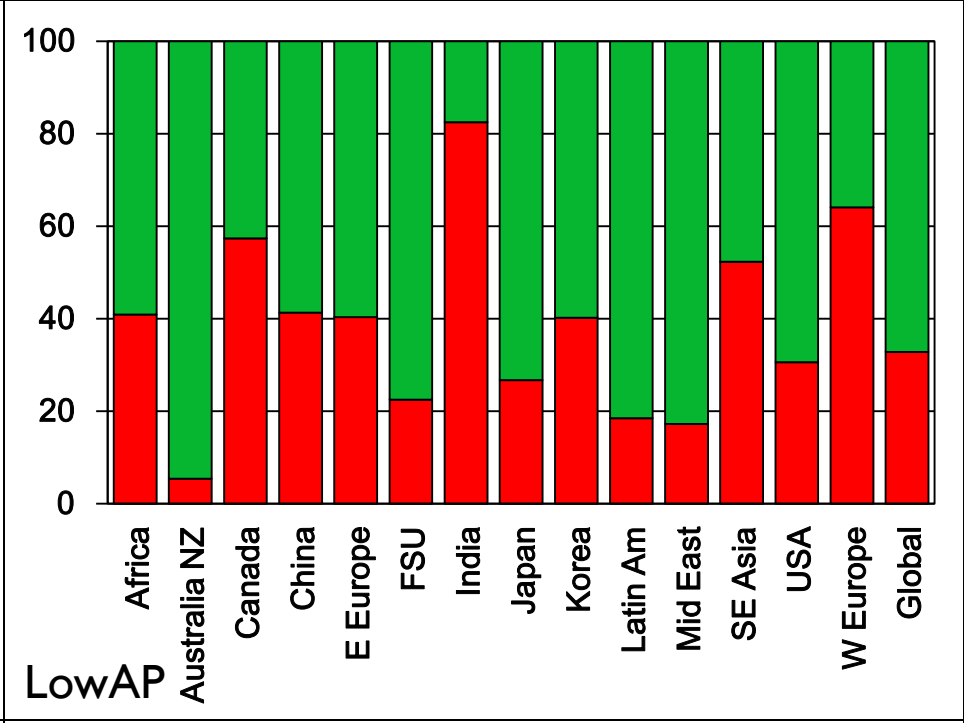

LowAP
3500
3000
2500
2000
1500
1000
500
0
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090

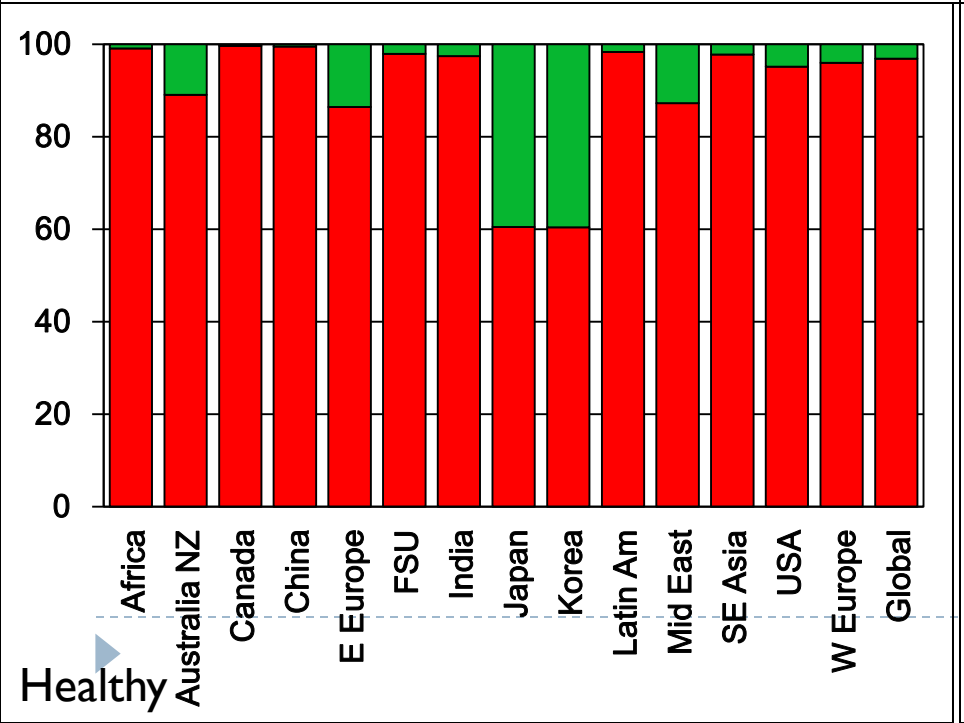

Healthy
3500
3000
2500
2000
1500
1000
500
0
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090

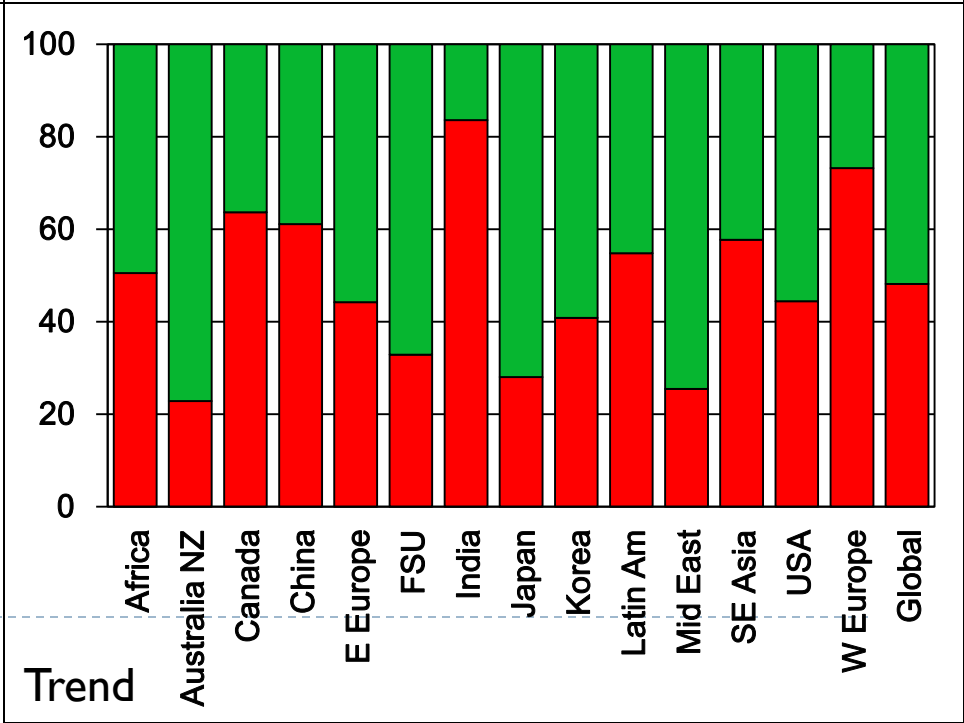

Trend
3500
3000
2500
2000
1500
1000
500
0
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090

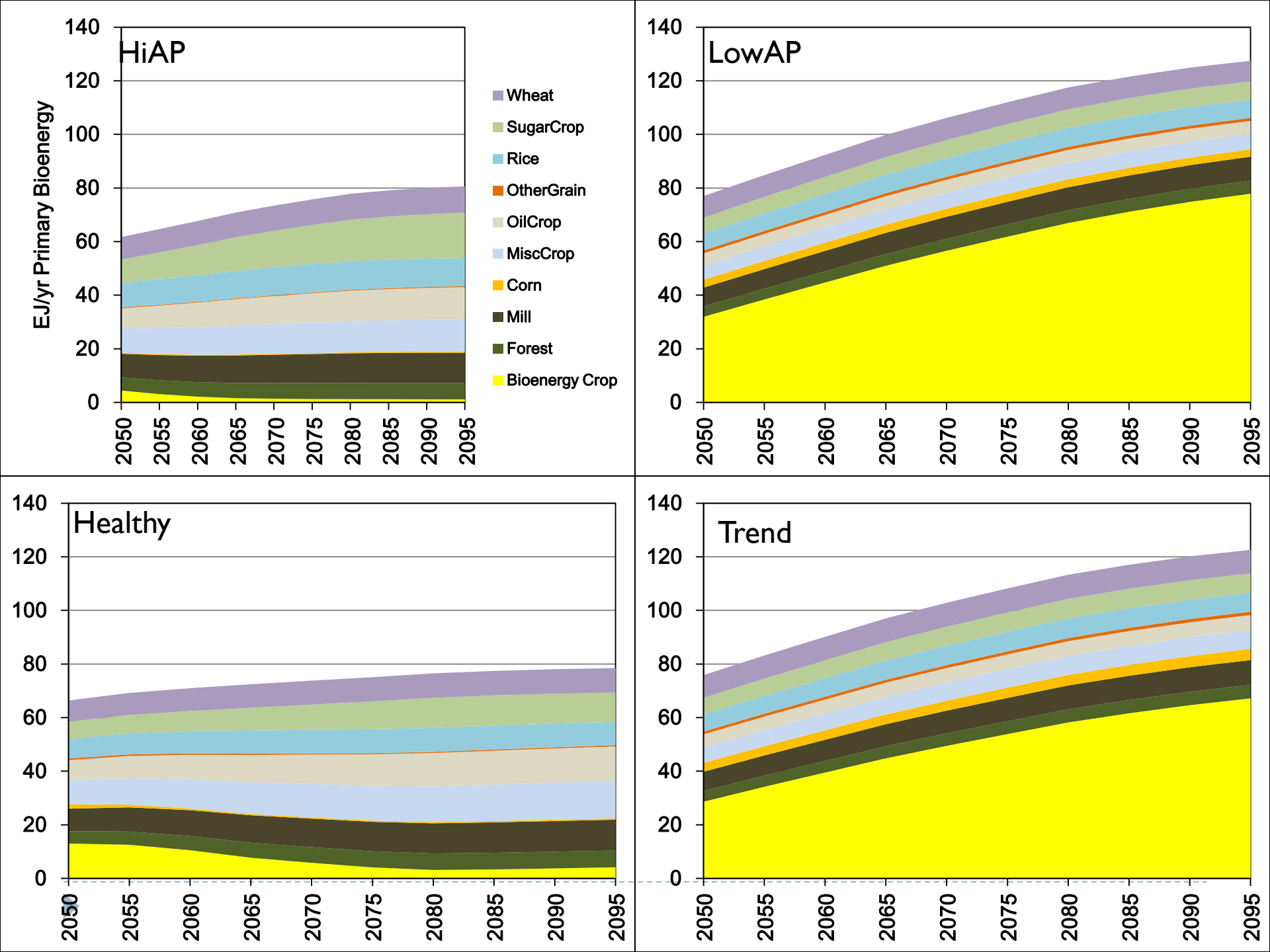

HiAP
LowAP
Healthy
Trend
GHa
Crops
Pasture
Forest/Shrub
Non Arable
Biomass
Wheat
Sugar Crops
Rice
Other Grains
Oil Crop
Misc Crop
Maize
Fiber Crop
Other Arable Land
Fodder Crop
Managed Pasture
Unmanaged Pasture Grassland
0
2
4
6
8
10
12
14
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090

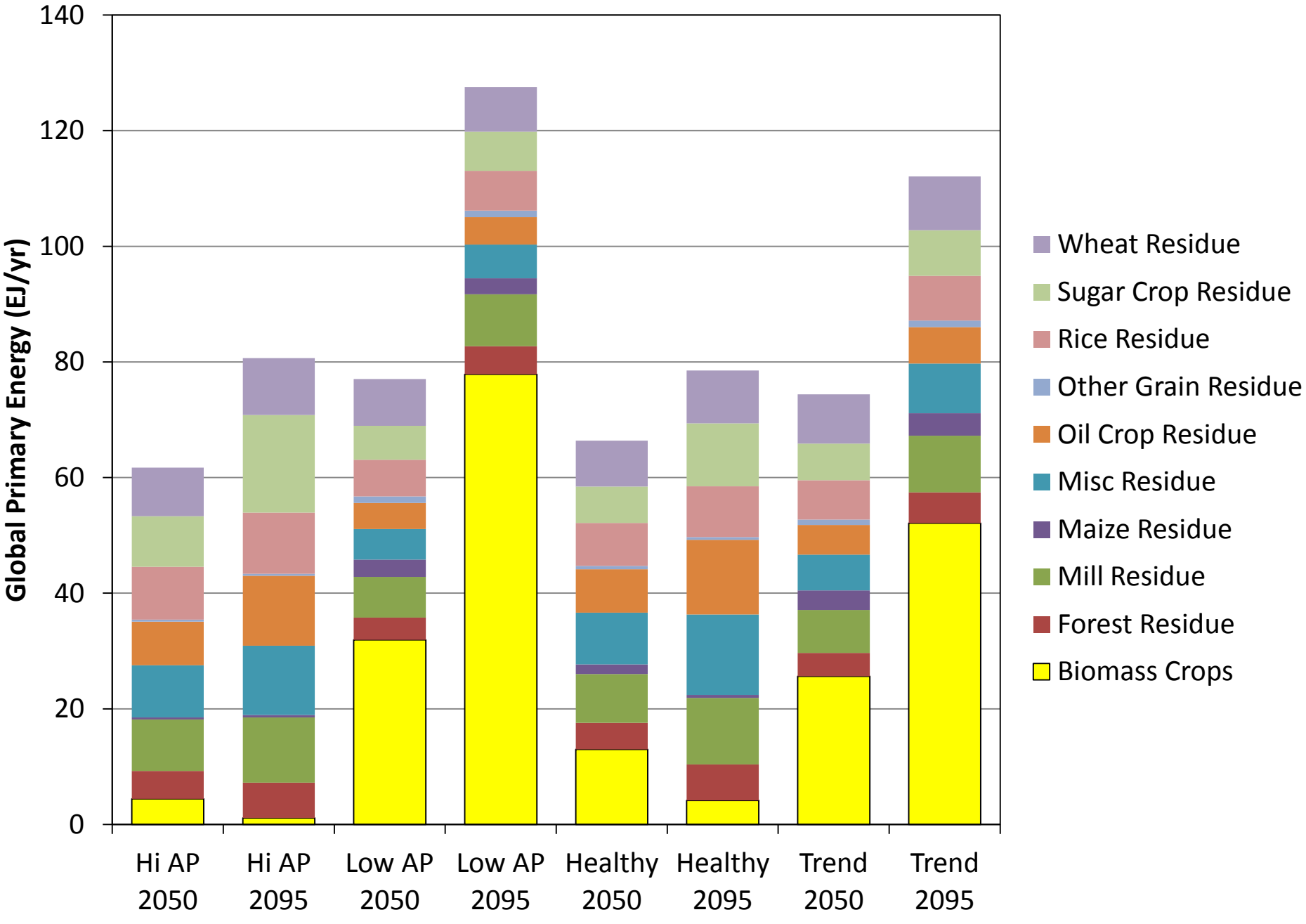

2095 Agro-Forest Land (%)
100
80
60
40
20
0
Africa
Australia NZ
Canada
China
E Europe
FSU
India
Japan
Korea
Latin Am
Mid East
SE Asia
USA
W Europe
Global
HiAP
Managed
Unmanaged

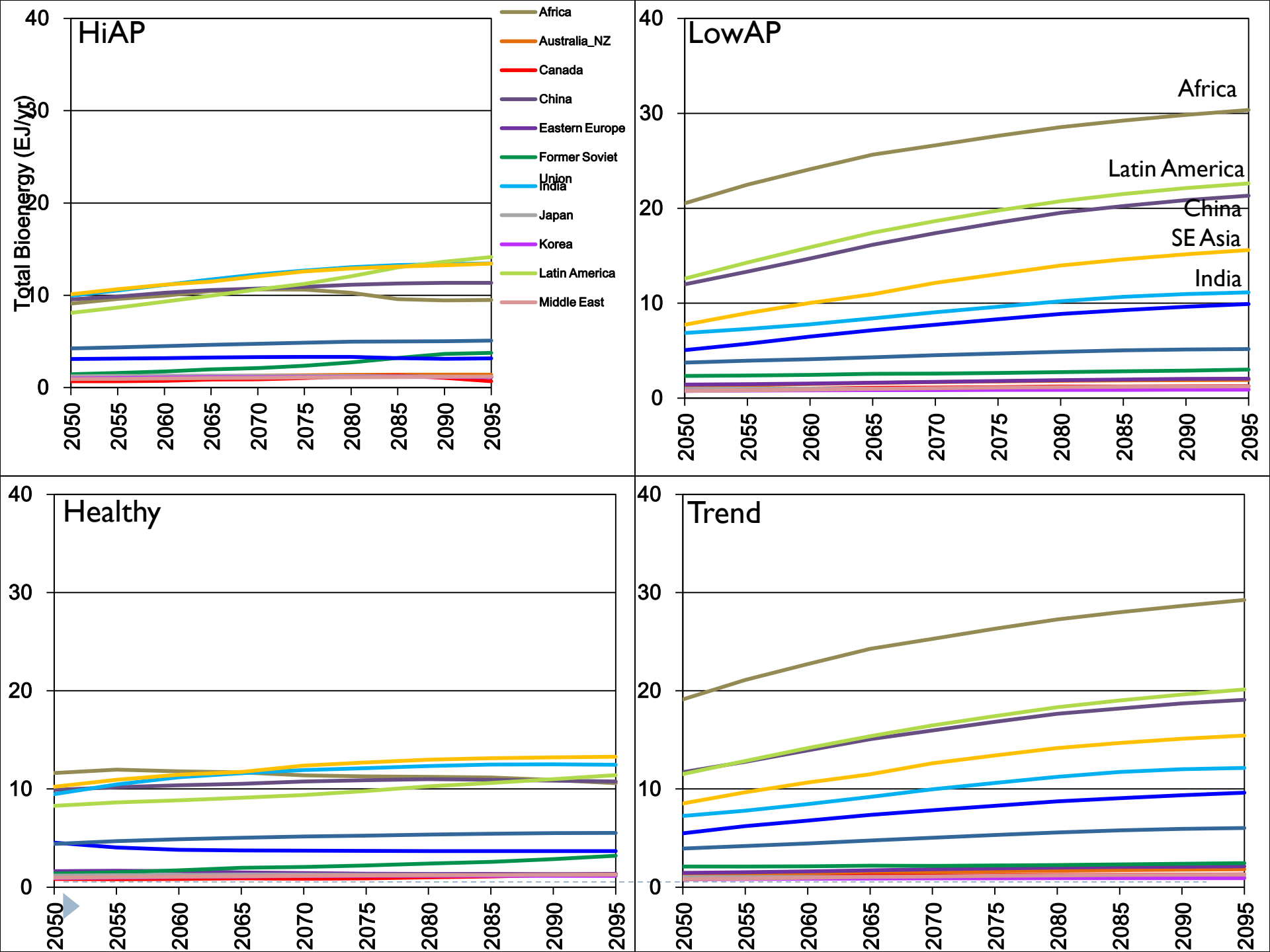

100
80
60
40
20
0
Africa
Australia NZ
Canada
China
E Europe
FSU
India
Japan
Korea
Latin Am
Mid East
SE Asia
USA
W Europe
Global
LowAP


100
80
60
40
20
0
Africa
Australia NZ
Canada
China
E Europe
FSU
India
Japan
Korea
Latin Am
Mid East
SE Asia
USA
W Europe
Global
Healthy


100
80
60
40
20
0
Africa
Australia NZ
Canada
China
E Europe
FSU
India
Japan
Korea
Latin Am
Mid East
SE Asia
USA
W Europe
Global
Trend

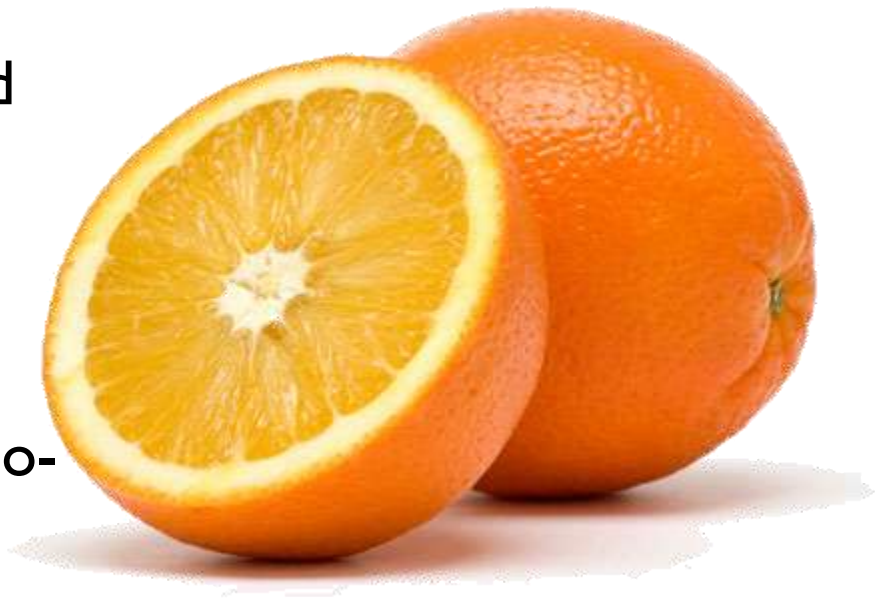

HiAP
LowAP
Healthy
Trend
EJ/yr Primary Bioenergy
0
20
40
60
80
100
120
140
2050
2055
2060
2065
2070
2075
2080
2085
2090
2095
Wheat
SugarCrop
Rice
OtherGrain
OilCrop
MiscCrop
Corn
Mill
Forest
Bioenergy Crop


Global Primary Energy (EJ/yr)
140
120
100
80
60
40
20
0
Hi AP 2050
Hi AP 2095
Low AP 2050
Low AP 2095
Healthy 2050
Healthy 2095
Trend 2050
Trend 2095
Wheat Residue
Sugar Crop Residue
Rice Residue
Other Grain Residue
Oil Crop Residue
Misc Residue
Maize Residue
Mill Residue
Forest Residue
Biomass Crops


HiAP
LowAP
Healthy
Trend
Total Bioenergy (EJ/yr)
Africa
Australia_NZ
Canada
China
Eastern Europe
Former Soviet Union
India
Japan
Korea
Latin America
Middle East
Latin America
China
SE Asia
India
0
10
20
30
40
2050
2055
2060
2065
2070
2075
2080
2085
2090
2095

Conclusions

- Assumptions about how diets around the world will develop have a large effect on global land use and biomass availability.
- Increased animal consumption requires more land and bioenergy potential is reduced.
- It is possible that a healthy diet may also require a lot of land and could reduce bioenergy potential.
- A global vegetarian diet can leaves a lot of land to produce bio-energy and leave natural areas.



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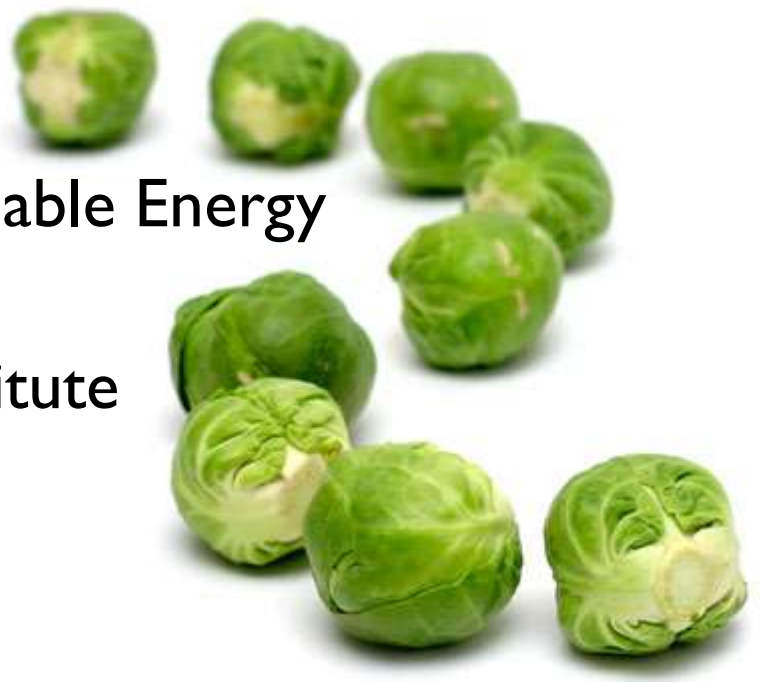

Thank you!