Global scale agricultural systems: the role of diet and food waste

Peter Alexander
University of Edinburgh
23rd May 2016

Introduction

Food demand
(Agricultural production)

Food system losses and waste

Method

1. Allocate areas for each primary crop
e.g. Soybeans

2. Allocate areas for processed commodities, by economic value

3. Allocate areas for animal products

HALF

Food Security

References

Introduction

**Food demand** (+ non-food uses) vs. **Production**

- **Population**
- **Consumption**
- **Yield/Intensity**
- **Agricultural area**

Focus here will be on land use impacts from diet and consumer waste
Method

Assumptions

- Constant global production practices
  - Production efficiency from global average in 2011
  - Agricultural production practices do not adapt
- Mix and rates of livestock feeds fixed
- Monogastrics, i.e. pigs and poultry, nutritional requirements exclusively from feed
- Ruminants, e.g. cattle, consume feed and all pasture
- Diets adopted by the global population

Data and coverage

- Use FAO country-level panel data, 1961-2011
  - production areas
  - uses of commodities (‘commodity balance’), and
  - food supply, caloric and protein contents
- 90 commodities
  - 50 primary crops, 32 processed and 8 animal products
  - 99.4% of food calories consumed
- Links needed between
  - Primary and processed commodities
  - Feed (and pasture) and livestock products

1. Allocate areas for each primary crop

   e.g. Soyabean

   Food (10Mt)  Feed (13Mt)  Processing (224Mt)  Non-food use (1Mt)  Stock variation (2Mt)  Waste (4Mt)  Seed (7Mt)

   Uses over which production area allocated

2. Allocate areas for processed commodities, by economic value

   - Soyabean oil
     42Mt from 51 Mha
   - Soyabean meal/cake
     175 Mt from 51 Mha

   Then allocated by use as for primary commodities

   - Food (25 Mt)  Non-food (17Mt)
   - Feed (172Mt)

3. Allocate areas for animal products

   a) Feed requirements (DM) from feed conversion ratios per edible weight
   b) Monogastrics just from feed
   c) Ruminants remainder of feed (23%) and all of pasture

Survey of 134 countries found ruminants consumed 26% of feed (Alltech, 2013)
Assumptions

- Constant global production practices
  - Production efficiency from global average in 2011
  - Agricultural production practices do not adapt
- Mix and rates of livestock feeds fixed
  - Monogastrics, i.e. pigs and poultry, nutritional requirements exclusively from feed
  - Ruminants, e.g. cattle, consume feed and all pasture
- Diets adopted by the global population
Method

Assumptions

- Constant global production practices
- Production efficiency from global average in 2011
- Agricultural production practices do not adapt
- Mix and rates of livestock feeds fixed
- Monogastrics, i.e. pigs and poultry, nutritional requirements exclusively from feed
- Ruminants, e.g. cattle, consume feed and all pasture
- Diets adopted by the global population

Data and coverage

- Use FAO country-level panel data, 1961-2011
- Production areas
- Uses of commodities ('commodity balance'), and food supply, calorific and protein contents
- 90 commodities
- 50 primary crops, 32 processed and 8 animal products
- 99.4% of food calories consumed
- Links needed between primary and processed commodities
- Feed (and pasture) and livestock products

1. Allocate areas for each primary crop
e.g. Soyabean

2. Allocate areas for processed commodities, by economic value

3. Allocate areas for animal products

a) Feed requirements (DM) from feed conversion ratios per edible weight
b) Monogastrics just from feed
c) Ruminants remainder of feed (23%) and all of pasture

Survey of 134 countries found ruminants consumed 26% of feed (Alltech, 2013)
Human Appropriation of Land for Food Index
- Agricultural area to need to supply a diet (including consumer waste)
- with constant 2011 production systems
- expressed as percentage of the world land surface for global population

By country

Over time

Consumption patterns

Dietary scenarios

- 14-fold range across diets by country
- Agricultural land compared to current diets:
  - India -55%
  - USA +178%
- Food types consumed has greater impact than quantity
- Area for average USA consumer waste (including over-consumption) sufficient to produce two average Indian diets
- Nutritional requirements of 52 g/person/day protein, and 9.8 MJ (2342 kcal)/person/day
By country

Map of HALF index by country in 2011. Countries where the index could not be calculated due to no commodity consumption data being available, e.g. Libya, Somalia and Greenland, are shown in light grey.
Over time

HALF index from 1961 to 2011, globally and for selected counties. Solid lines show variable diets, but constant population and agricultural production systems (at 2011 values). Dashed lines show variable diet, population and agricultural production systems over time.
Consumption patterns

Mean energy per capita, a), and percentage energy derived from animal products, b), in foods consumed from 1961 to 2011 globally, and for selected countries, using global average nutritional values.

Per capita daily rates of bovine, pig and poultry meat consumption from 1961 to 2011
Dietary scenarios

Cropland and pasture to produce food under alternative dietary scenarios, expressed as required percentage of world land, or HALF index, using global 2011 population and production systems. Results provide at least required amounts of both energy and protein.
Human Appropriation of Land for Food Index

- Agricultural area to need to supply a diet (including consumer waste)
- with constant 2011 production systems
- expressed as percentage of the world land surface for global population

By country

Over time

Consumption patterns

Dietary scenarios

- 14-fold range across diets by country
- Agricultural land compared to current diets:
  - India -55%
  - USA +178%
- Food types consumed has greater impact than quantity
- Area for average USA consumer waste (including over-consumption) sufficient to produce two average Indian diets
  - Nutritional requirements of 52 g/person/day protein, and 9.8 MJ (2342 kcal)/person/day
Food system losses and waste

Background

- Leading study on food waste Gustavsson et al. (2011)
  - 1.3 billion tonnes per year of food lost or wasted
  - ~3% of food produced
  - Uses loss rates
    - Per region (7), food system stage (3), and commodity type (7)
    - But, not clear how these rates were determined
- Our aim was to:
  - Use empirical (e.g. FAO) data as much as possible to calculate losses
  - Extend system scope, e.g. to include:
    - over-consumption, and
    - losses in livestock production
  - Compare losses occurring at different stages in food system

Loss categories

- 6% global agricultural dry biomass consumed as food
- 48.5% of harvested crops (DM) lost, including over-consumption
- Substantial losses from livestock
- Over-eating at least as large as losses as consumer food waste
- Aggregating food losses as wet mass can be misleading
Background

- Leading study on food waste Gustavsson et al. (2011)
  - 1.3 billions tonnes per year of food lost or wasted
  - ~1/3 of food produced
  - Uses loss rates
    - Per region (7), food system stage (5), and commodity type (7)
    - But, not clear how these rates were determined
  - Our aim was to:
    - Use empirical (e.g. FAO) data as much as possible to calculate losses
    - Extend system scope, e.g. to include:
      - over-consumption, and
      - losses in livestock production
    - Compare losses occurring at different stages in food system
Loss categories

- **Agricultural residues & unharvested crops**
  - Difference between NPPs and harvested crops and grassland

- **Storage and transport losses**
  - Losses in each country and during international trade calculated from FAOstat (2015a)

- **Processing losses**
  - Difference between input commodities and commodities produced from processing

- **Food wasted by consumers**
  - Food reaching consumers multiplied by rates of consumer waste from Gustavsson et al., (2011)

- **Over-consumption**
  - Difference between food consumed and nutritional requirements

**Cropland NPP**
- Ito & Ohkawa (2004)
  - FAO crop production (FAOSTAT, 2015c)

**Grassland NPP**
- Ito & Ohkawa (2004)
  - Difference between livestock inputs required and total feed provided from cropland.

- **Harvested crops**
  - Processed commodities
    - FAO crop commodity balance (FAOSTAT, 2015a)

- **Harvested grass**
  - Livestock inputs
    - Requirements to produce animal products (FAOSTAT, 2015b) with feed conversion ratios (Alexander et al., 2016)

- **Livestock production losses**
  - Difference between livestock inputs and animal products produced

- **Animal products**
  - Animal product distribution losses
    - Losses in the storage and transport of animal products (FAOSTAT, 2015b)

- **Food reaching the consumer**
  - FAO crop and livestock food supply (FAOSTAT, 2015d-e)

- **Food consumed**
  - Food reaching consumers less consumer waste

- **Nutritional requirements**
  - Food in-take required for human health (SACN, 2011)
Food system Sankeys

a) Dry Matter

b) Energy

c) Protein

d) Wet Mass

Dry weight flow scale legend:
- 20 Gt/yr
- 5 Gt/yr
- 2 Gt/yr
- 0.5 Gt/yr
- 0.2 Gt/yr

Flow type legend:
- Cropland production
- Grassland production
- Primary crops
- Livestock products
- Food commodities
- Waste and losses
Harvested crop losses
Food system losses and waste

**Background**

- Leading study on food waste Gustavsson et al. (2011)
  - 1.3 billion tonnes per year of food lost or wasted
  - 1/3 of food produced
  - Uses loss rates
    - Per region (7), food system stage (3), and commodity type (7)
    - But, not clear how these rates were determined
  - Our aim was to:
    - Use empirical (e.g. FAO) data as much as possible to calculate losses
    - Extend system scope, e.g. to include:
      - Over-consumption, and
      - Losses in livestock production
    - Compare losses occurring at different stages in food system

**Loss categories**

- 6% global agricultural dry biomass consumed as food
- 48.5% of harvested crops (DM) lost, including over-consumption
- Substantial losses from livestock
- Over-eating at least as large a losses as consumer food waste
- Aggregating food losses as wet mass can be misleading
Ongoing modelling

Potential for some social behaviour of consumers, e.g. cultural consumption differences, migration, civil unrest or even wars.

Governmental behaviours, e.g. responses to food shortages, imposing trade barriers

Only represents agricultural sector, and without social behaviour or heterogeneity of land managers within countries.
Global scale agricultural systems: the role of diet and food waste

Peter Alexander
University of Edinburgh
23rd May 2016

HALF
Human Appropriation of Land for Food Index
- Agricultural area to need to supply a diet (including consumer waste)
- With constant 2031 production systems
- Expressed as percentage of the world land surface for global population

Food system losses and waste

- Food system Sankeys
  - Food system Sankeys
  - Harvested crop losses
  - Food system Sankeys
- Food system losses are a fraction of global food requirements
- Food system losses are a fraction of global food requirements

Ongoing modelling

Potential for some social behaviour of consumers, e.g. cultural consumption differences, marketing, and arrest an even waste.

References