FAO’s long-term projections on the future of food and agriculture: from scenario to modelling

Dominik Wisser, Marc Müller, Aikaterini Kavallari, Lorenzo Giovanni Bellú, FAO Global Perspectives Studies Team (GPS)

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FAO’s long-term projections

- Since the early 60s
- Indicative World Plan for Agricultural Development (1970)
- Series of publications “World Agriculture towards 20xx”
Food + Nutrition Security

**Dimensions**
- Availability
- Access
- Stability
- Utilization

**Components**
- Agricultural and food production, inputs, stock levels, trade
- Levels and distribution of incomes and assets, expenditure, markets, prices
- Climatic conditions, resilient and sustainable production systems, economic factors
- Sufficient energy and nutrient intake by individuals, food preparation and storage

**Qualitative and quantitative analyses and projections**
AT 20XX: Approach

• Based on detailed accountancy system of FAOSTAT Food and Commodity Balance Sheets

• Informed ideas about future evolution of variables of interest (productivity, inputs, etc.)

• Real prices were assumed to stay constant over time -> no price path projections; base year prices used as weights to aggregate over commodities

• Single scenario projections of food and commodity balances, often supplemented by further calculations (like food security indicators, investment)
FOFA 2050: Approach

Different methodology:

• Three scenarios (GDP, climate change, policies)
• Time-varying impact of climate change on yields, water and land
• Quantitate models for the agriculture sector (FAO GAPS) and the entire economy (ENVISAGE)
• Impacts: Land use, water use, greenhouse gas emissions
• Food security indicators
Shared Socioeconomic Pathways

Source: O’Neil et al. 2013
FOFA SAP Scenarios

- **TSS**: Towards sustainability
- **BAU**: Business as usual
- **SSS**: Stratified societies

Axes:
- Challenges for food access and utilization
- Income-food distribution, poverty, opportunities, ...
- Climate change, technological progress, trade ...
- ... strategies and policies
- Challenges for food availability and stability
Scenarios and policies

- Scenario pathway WoP
- Scenario pathway WiP
- Scenario snapshot 2050 (WoP)
- Scenario snapshot 2050 (WiP)

Challenges for food security and nutrition

- Base period

Years: 2010, 2020, 2030, 2040, 2050
Towards Sustainability (TSS)

- The world increasingly develops following a sustainable path
- A fairly generalized equity in terms of access to basic services, universal and sustainable access to sufficient, safe and nutritious food
- No extreme poverty, reduced income inequality within and across countries
- Sustainable use of natural resources and substantial climate change mitigation
- Economic growth is moderate, but social welfare is increasing (social cohesion, inclusiveness, empowerment, security, etc.)
- In the first decades, demand and production are investment-led
- Yields show moderate but convergent increases across countries, increased agricultural productivity for smallholders
- Widespread access to natural resources and distributed capital ownership
- Fiscal systems work properly so social protection schemes ensure acceptable welfare levels of those permanently or temporarily unable to actively participate in production processes
- **Low challenges both for equity and sustainable production occur**
Business as Usual (BAU)

Future develops according to socio-economic, technological and environmental trends similar to historical patterns; the world continues to do things as “usual”:

- Economic growth is medium and somehow uneven
- Long-term cross-country convergence is doubtful
- Diverse economic transformation, role of fiscal systems and social protection mechanisms
- Technological progress in agriculture should take place but cross-country yield gap will still remain
- Role of institutions (national, international) limited to solve conflicts and protracted crisis
- Moderate to high challenges to food availability/stability and access/utilization
Stratified Societies (SSS)

Future develops in a way that historical patterns on inequality become more marked and pronounced:

• Unequal investment in human capital, know-how, physical and financial assets; disparities in savings potential
• High inequalities both between and within countries regarding income availability
• Widening gap between well-educated/internationally connected that concentrate power and low-income/unskilled population
• High growth of the low-income population; low growth of the high-income population
• Agriculture follows diverse paths; coexistence of subsistence agriculture, low quality commercial agriculture for bulk of low-income population and production of high quality niche food
• **High challenges to food availability/stability and access/utilization**
### Scenario Assumptions I

<table>
<thead>
<tr>
<th></th>
<th>BAU</th>
<th>TSS</th>
<th>SSS</th>
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<tbody>
<tr>
<td><strong>Economic growth</strong></td>
<td>Moderate (SSP3).</td>
<td>Same total gross world Product as in BAU, but more distributed across countries as in SSP1.</td>
<td>High (SSP4), but “immizerising growth” mechanisms are at work.</td>
</tr>
<tr>
<td><strong>Income inequality within countries</strong></td>
<td>Current trends of modest convergence are maintained. SDG10 is barely achieved through fiscal policies and public spending.</td>
<td>Inequality reduction achievements exceed SDG10 targets.</td>
<td>SDG10 targets are not achieved, as within-country income distribution follows diverging patterns.</td>
</tr>
<tr>
<td><strong>Income inequality across countries</strong></td>
<td>Current trends of modest convergence (based on SSP3).</td>
<td>Inequality reduction achievements exceed SDG10 targets (proportions of per capita income as in SSP1).</td>
<td>Higher than BAU from 2050 onward (based on SSP4). SDG10 targets are not achieved, even by 2080.</td>
</tr>
<tr>
<td><strong>Public investment</strong></td>
<td>Modest, along current trends.</td>
<td>Focused on R&amp;D that stimulates technical progress on sustainable and pro-poor practices.</td>
<td>Limited, flowing rather on non-sustainable practices, like fossil fuels and favouring elites.</td>
</tr>
<tr>
<td><strong>International trade</strong></td>
<td>More bilateral trade agreements in place; tariff barriers are modest; non-tariff barriers gain some importance.</td>
<td>Both tariff and non-tariff barriers are lower than in BAU.</td>
<td>Both tariff and non-tariff barriers are higher than in BAU, creating more fragmentation.</td>
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### Scenario Assumptions II

<table>
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<tbody>
<tr>
<td><strong>Water</strong></td>
<td>Water efficiency improves but no major technical changes occur. More water-stressed countries emerge.</td>
<td>Water efficiency significantly improves thanks to investment. Limited CC reduces extreme droughts.</td>
<td>Water is unsustainably used. Little investment in water efficiency. CC exacerbates constraints.</td>
</tr>
<tr>
<td><strong>Forests</strong></td>
<td>Deforestation continues at current rates.</td>
<td>No additional deforestation. Investment in reforestation.</td>
<td>Further deforestation.</td>
</tr>
<tr>
<td><strong>Biodiversity</strong></td>
<td>Current loss rates prevail, also in the future.</td>
<td>Conservation practices (e.g. eco-agriculture, agroforestry) reduce the loss of biodiversity.</td>
<td>Current loss rates prevail, also in the future.</td>
</tr>
<tr>
<td><strong>Foreign investment</strong></td>
<td>Medium and along the north-south axis.</td>
<td>Higher than BAU in low-income countries, with positive impacts on local incomes.</td>
<td>Higher than BAU in low-income countries with little impact on local incomes.</td>
</tr>
<tr>
<td><strong>Evolution of diets</strong></td>
<td>Current trends of moderate convergence towards the consumption of more nutritious food maintained.</td>
<td>Balanced, healthy and environmentally sustainable diets are mostly universally adopted.</td>
<td>Diets worsen for most people due to lower purchasing power and lessened consumer awareness. Elites consume high-quality luxury foods.</td>
</tr>
</tbody>
</table>
### Scenario Assumptions III

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<tr>
<td><strong>Pests and diseases</strong></td>
<td>Continuation of current trends of increasing spread and AMR resistance. Average long-term yields are negatively affected by occurrence.</td>
<td>R&amp;D to focus on fighting against them.</td>
<td>Boosted by climate change, international trade and AMR. Increased use of drugs, particularly against them, and so more pests and diseases that threaten yields.</td>
</tr>
<tr>
<td><strong>Prevailing production systems</strong></td>
<td>Mixed. High value-added small farms and processors for high-quality food co-exist with large scale, high-input agriculture. Irrigation and intensive livestock increase to the extent possible.</td>
<td>Low-input precision agriculture, agroforestry intercropping, conservation, climate-smart ecological agriculture fit in “circular” economies. Animal welfare and biodiversity is promoted.</td>
<td>Segmented agriculture and food systems: a) many marginal producers for subsistence in LICs; b) big corporations for mass, low-quality food; c) small-medium farms both in HICs and LICs for luxury food for elites.</td>
</tr>
<tr>
<td><strong>Land intensity</strong></td>
<td>Along current trends: The quantity of land per unit of output decreases as long as crop and animal yields increase.</td>
<td>The quantity of land per unit of output is stable at base-year levels to preserve soil quality and restore degraded/eroded land.</td>
<td>The quantity of land per unit of output decreases for commercial agriculture and remains stable for smallholder/marginal farmers.</td>
</tr>
</tbody>
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RCPs

Scenario categories:
- >1000 ppm CO₂eq
- 720–1000 ppm
- 580–720 ppm
- 480–580 ppm
- 430–480 ppm

Data: CDIAC/GCP/IPCC/Fuss et al 2014

- **RCP8.5**
  - 3.2–5.4°C relative to 1850–1900

- **RCP6**
  - 2.0–3.7°C

- **RCP4.5**
  - 1.7–3.2°C

- **RCP2.6**
  - 0.9–2.3°C

Emissions from fossil fuels and cement (GtCO₂/yr)

**2016 Estimate**

**Historical emissions**

**net-negative global emissions**

Global Carbon Project
FOFA 2050 Data

- **Soil Agronomy**
  - Climate Data
    - 5 GCM
    - 4 RCP
    - 2006-2010

- **GAEZ 4.0**
  - Raster data (10km):
    - Yield
    - Suitable Areas
    - Water Demand

- **Population, GDP**
  - 3 SSPs
  - 2006–2100

- **GAPS PE-Model**

- **ENVISAGE CGE**
  - Post-process: Food security
    - GHG emissions, emission intensity

- **FAOSTAT (Baseline)**
- **GLEAM AQUASTAT**

- **110 regions (global coverage)**
- **41 activities (crops & livestock)**
- **32 commodities**
  - Yield, area, trade, prices
FAO GAPS

- 36 crop activities in 2 production systems (irrigated and rainfed)
- 1 activity for fish (2 production systems)
- 13 processing activities (oil milling, sugar extraction, paddy milling, cotton...)
- GAPS represents the supply and demand of 68 agro-food commodities out of which 21 processed) in 182 countries (out of 233 countries covered in UN DESA 2015 population projection) and of 194 countries of FAOSTAT’s commodity balance sheets.
- GAPS is calibrated for 2012 FAOSTAT data
The modelling framework

**FAO GAPS**
GLOBAL AGRICULTURE PERSPECTIVES SYSTEM
PARTIAL EQUILIBRIUM MODEL

**MODEL ASSUMPTIONS**
- FAOSTAT data for calibration (2011-2013)
- Behavioural parameters for demand and supply
- Gross domestic product to determine food demand price and income elasticities
- Population for calculating food demand
- Data on agricultural technologies and productivity from: FAO AQUASTAT, FAO Global Livestock Environmental Assessment Model, FAO-IIASA Global Agro-Ecological Zones database

**MODEL FEATURES**
- Supply based on price responsive yield and harvested area/herd size functions
- Food/feed/land demand functions
- Price/income-sensitive functions
- Quantities in physical units
- Commodity balances

**MODEL RESULTS**
- Agricultural equilibrium quantities and prices
- Crop yields
- Land/feed/pasture requirements
- Net trade by country and good
- Food security indicators, agricultural greenhouse gas emissions

**ENVISAGE**
ENVIRONMENTAL IMPACT AND SUSTAINABILITY
APPLIED GENERAL EQUILIBRIUM MODEL

**MODEL ASSUMPTIONS**
- Global Trade Analysis Project data for calibration
- Price/input substitution elasticities
- Labour productivity based on gross domestic product
- Population for labour dynamics
- Parameters on agricultural productivity based on GAPS results

**MODEL FEATURES**
- Sectoral nested production functions
- Food/feed/land demand functions
- Price/income-sensitive functions
- Virtual physical units
- Commodity and macro balances

**MODEL RESULTS**
- Economy-wide equilibrium quantities and prices
- Labour/land/capital requirements and remunerations
- Imports/exports by country and good
- Economy-wide greenhouse gas emissions indicators

**CONSISTENCY CHECKS ON RESULTS AND FEEDBACK ON MODEL ASSUMPTIONS**
Livestock in GAPS

6 animal species in 6 production:
- Cattle, buffalo, goats, sheep, pigs, poultry, others

9 production systems:
- Dairy herd grassland based
- Dairy herd mixed farming systems
- Dairy herd feedlots
- Meat herd grassland based
- Meat herd mixed farming systems
- Meat herd feedlots
- Monogastrics backyard
- Monogastrics intermediate or layers
- Monogastrics industrial or broilers

Production systems for monogastrics shift as function of income
FOFA SAP workflow

Analysis of trends and identification of challenges

- Preparation of scenarios' narratives
- Identification of scenario drivers
- Quantification of scenario drivers

Consistency checks and adjustments
- Running quantitative models
- Setting the quantitative models

Interpretation of models' results
- Qualitative assessments
- Scenario comparisons

Identification of strategic and policy options
FAO GAPS food demand

1. Allocation of income to food bundle
2. Allocation of calories to food items within the bundle

**Food bundles:**
- Cereals
- Domestically consumed cereals
- Starchy crops
- Protein crops
- Fruit und vegetables
- Other crops
- Vegetable oils
- Meat and fish
- Dairy and eggs
- Other food

**Assumptions:**
- the share of expenditure on food consumption declines as income increases
- an income increase stimulates substitution away from carbohydrates (e.g. staple foods) towards higher value items such as vegetables and animal-based proteins
Diet trends and income

Source: Tilman and Cark, 2014
Population growth rates

Source: UN World Population Prospects 2015, medium variant
Population projections

Source: UN World Population Prospects 2015, medium variant
Drivers of demand

Source: UN World Population Prospects 2015, medium variant, SSP3 GDP Data
Population projections

Source: UN World Population Prospects 2015, medium variant
Population projections

Source: UN World Population Prospects 2015, medium variant
Food demand (AT 2050)

Per person calorie intake 1961–2050

Dietary convergence

Per capita protein intake in low- and middle-income countries compared to high-income countries

Dietary convergence

Per capita calorie intake in low- and middle-income countries compared to high-income countries

Hist. livestock growth rates

Cattle

Goats

Pigs

Sheep

Mean annual growth rate (2000/2015)

Animal heads 2012 (million)
Land use competition

Source: FAO Global Perspectives Studies Team, based on Hurtt et al.
Dietary convergence

Per person calorie intake 1961–2050

Dietary convergence

Per person protein intake 1961–2050

Potential scenarios

Tier 1: Three FOFA 2050 scenarios

Tier 2: FOFA 2050 scenarios with adjustments on feed and land

Tier 3: Simulated changes for specific scenarios, e.g.:

- Changes in productivity (yield per head) by production system
- Changes in crop productivity
- Shifts in production systems (herd composition)
- Changes in demand for food (and meat mix) items
- Change in herd
- Selected changes in feed mix (only for traded feed items)
- Selected macro-economic shocks (per capita GDP, labour productivity in the livestock sector...)
- Changes in trade
- Constraints on water resources
- Further shocks (e.g. non-traded feed) after model adjustments
Thank you

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