The changing face of agriculture and food systems into the 21st Century

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The challenges before us

Increasing food production by ~60% by 2050 given:

- population growth
- per capita consumption growth (in some nations), waste
- adapting to climate changes
- emission-reduction needs
- increasing input constraints (fuel, N, P, water)
- degradation status of terrestrial/marine resources
- biodiversity status and threatening processes, growing recognition of environmental services
- lower R&D expenditure
- increased volatility incl. through a range of governance issues etc
Food, climate and environment

- Food security
- Human health
- Energy
- Natural resources and environment
- Climate change mitigation and adaptation
The pace of change - 2017

- CO$_2$ emissions highest on record
- Atmospheric CO$_2$ concentration highest on record
- Atmospheric methane concentration highest on record
- Global average temperature 2$^{nd}$ highest on record
- Southern hemisphere temperature highest on record
- Sea level highest on record
- Global sea ice extent lowest on record
- Insurance losses highest on record
- etc
CO₂ emission rising again: record levels

Data: CDIAC/GCP/BP/USGS

Projection 2017
36.8 Gt CO₂
△ 2.0% (0.8%–3.0%)

2016: 36.2 Gt CO₂

1990–99
+1.1%/yr

2000–09
+3.3%/yr


CO₂ emissions (Gt CO₂/yr)
Racing towards the Paris 1.5°C target
Global population growth

PROJECTED WORLD POPULATION

Global population growth to 2050

The World Health Organization estimates that one third of the world is well-fed, one third is under-fed and one third is starving. By 2050 that number could be significantly larger when the world’s population is expected to reach a whopping 9 billion. The world’s driest regions in Northern Africa and the Middle East are also the fastest growing, putting them at an especially high risk of furthering the food crisis.
Food consumption per capita increasing

![Graph showing food consumption per capita increasing over time for different regions worldwide.](image-url)
Globally, climate change already affecting crop yields

Porter et al. 2014
... and in Australia too

Hughes et al. 2017
Impacts: more negative and less positive over time

Porter et al. 2014
Yield variability likely to increase
Incremental adaptations: crop management

- Reduced tillage, stubble retention, direct drill
- Early sowing (including dry sowing can halve soil evaporative losses)
- Efficient and effective fertilisation (and lime)
- Weed control and crop cover management
- High intensity rotations, dual purpose and break crops
- Rapid root growth (+50% yield)
- Precision agriculture (putting effort in the right places)
- Decision-support to manage climate variability (e.g. Yield Prophet)
• Improved establishment and early vigour
  – big seeds, thin leaves
• Balance water use before and after flowering
• Higher transpiration efficiency of leaves
• Coping with high temperatures in critical periods
• Storage of stem sugars for use in grain fill
• Response to elevated CO$_2$
• Focus on existing systems only may result in maladaptation – and in missed opportunities
• Need to consider more systemic and transformational adaptations – increasingly so as changes continue

Comprehensiveness: more than incremental

Howden et al. (2010), Park et al. (2012), Rickards and Howden (2012)
Adaptation along value chains

- Less predictable farming conditions
- Increased energy costs
- Road closures and disruptions
- Sudden demand for alternative product stream

New varieties; variation in quality
Non-viable farming regions
Worker heat stress
Increased fuel costs
Increased pressures for low-carbon
Increased demand for low-carbon products

FUTURE IMPACTS?

Lim Camacho et al. 2014
Food quality impacts as well

- Protein content
- Micro-nutrient content
- Food hygiene: key organisms (*Salmonella* and *Campylobacter*) increase risk with temperature, rotavirus decrease
  - gastroenteritis (2.5% increase for each degree rise in temperature)
- Wastage and loss
- Appearance
- Wine flavour and alcohol level
Options for mitigation

Crops
- Reduced nitrous oxide emissions and embodied emissions
- Improve soil C

Livestock
- Reduced enteric methane
  - animal and pasture management
  - vaccines and additives
- Reduce manure-related emissions
- Improve soil and vegetation C

Reduce value chain emissions
Emission reductions to keep within 2°C
Land-based negative emissions

- Almost 90% of scenarios in the IPCC 5th Assessment that stay within 2°C have large scale negative emissions (mostly BECCS)
- Re-afforestation, deforestation, forest management
- BECCS (bio-energy carbon capture and storage)
  - water
  - food
  - resource base
  - biodiversity
- Enhanced weathering
Changes needed, trade-offs and options

- Current trends in yield improvement will not meet food demand in 2050
- Further expansion?
  - GHG emissions and biodiversity
- Intensification to close yield gaps?
  - GHGs, impacts on soils, water, input dependencies, risk
- Even if yield gaps closed, demand will drive further expansion
- What are additional options?
Agriculture and LUC emissions: 2050

- Increased crop area
- Increased crop area + waste reduction
- Increased crop area + waste reduction + diet change
- Yield gap closure
- Yield gap closure + waste reduction
- Yield gap closure + waste reduction + diet change

Gt CO$_2$e/year

2009

Total 2050 all sectors

Bjazelj et al. 2014
May not be easy: yield vs area trajectories

Index of cereal area (baseline 1961)

Index of cereal yield (baseline 1961)

Data: FAO 2017, following Keating and Carberry 2011
The role of agriculture in society has changed.
People love their food: protein and calories

Tilman and Clark 2014
Obesity a major problem
Alternative products: rapidly improving

• Impossible Burger – premium meat alternative
• Perfect Day yeast-based, lactose tolerant ‘milk’
  – 65% less energy, 84% less GHG, 91% less land, 98% less water
R&D expenditure is lagging behind

(a) Graph showing the annual public investment (US$ billion) for Developed and Developing countries from 1981 to 2007.
Future global food security depends on at least a 50% increase (but preferably more) of R&D investment in developing countries

Fischer et al. 2014
R&D, trust and scientific curiosity

- An element of declining trust in the research community
  - post-modernism
  - perception that researchers increasingly operating out of self-interest rather than the common good
  - lower levels of science literacy in critical decision-making bodies
  - ideology and polarisation (incl. social media-assisted ‘bubbles’)
- More transactional relationships
- Shorter term projects
- Developing scientific curiosity/interest at age 12 to 14 years old seems to be critical
Summary

• Powerful drivers – will change the face of agriculture
• Strong interaction between different aspects
• A range of practical, logical options but a range of constraints
• Positive, strategic and timely choices in a fast-changing world