Companion for Chapter 10
Food Security

SUMMARY

- Global food security is one of greatest challenges of sustainable development due to the continuous increase of world's population and the environmental changes. In order to address this issue, farm systems must become more productive and more resilient to environmental risks. Malthus warned in 1798 that humanity will be stuck at subsistence levels, because any temporary boost in food production that relieves food insecurity would cause a rise in population, which would lead back to food insecurity. As Malthus warned, population growth has been steady, and we are left to ponder whether our food system will be able to feed the 10 billion people that should exist by the end of the century.
- However, the problem of food insecurity is more complicated that Malthus could have imagined for four main reasons: 1) malnutrition; 2) continuous population growth; 3) climate and environmental changes threatening food production; 4) the food system itself contributing to climate and environmental changes.
- Malnutrition impacts 40% of the world's population through: 1) *undernourishment,* the insufficient intake of calories and proteins, affects about 900 million people either through chronic malnutrition that occurs over time and is reflected in childhood stunting, or through acute malnutrition that usually arises from episodes of wars, disasters, or droughts, and is reflected in childhood wasting; 2) *micronutrient malnutrition*, a.k.a hidden hunger, which is the inadequate intake of micronutrients such as iron, vitamin A, and zinc, and it affects about 1 billion people; 3) *obesity,* the result of an intake of too many calories, the wrong kinds of calories, and extreme physical inactivity, and it affects around 1 billion people and is spreading from high-income to middle-income countries.
- Nutritional science can provide guidance, as illustrated by the "healthy eating pyramid," which depicts types of food and amounts required for well-balance diets, including daily exercise at the base of the pyramid.
- Global food supply is being destabilized by climate shocks and by an increase in food demand as countries with rising income are consuming more meat, therefore amplifying the demand for grains (each kg of meat requires 10-15kg of feed grains to raise cattle). From 1970 to 2000, real food prices were falling, but since the early 2000s global food prices have been rising, threatening the wellbeing of the poor who often spend a large percent of their family income on food. The inverse relationship of total consumption per person and the share spent on food is known as Engel's Law.
- Agricultural land, used for cropland or grazing, constitutes about 40% of the world's total land area in form of arable land, farmland, meadows and pasturelands. Forests cover about 30% of Earth's land area and uninhabitable land (deserts and high mountains) cover about 30%. Urban areas constitute only about 3% percent of world's land. One of the great challenges in food security is the enormous diversity in farm systems around the world, which differ in what they

grow and how they grow it, depending on climate (temperature and rainfall), soil quality, water availability or feasibility of irrigation, topography, pests, biodiversity, and transport costs.

- Challenges in the food supply run in two directions: environmental changes threaten food production, and conversely, current agricultural practices threaten the environment.
- Some major threats to food production are the impacts of climate change and ocean acidification. At high temperatures, food productivity decreases, crops may not grow at all, seeds may become infertile, and soil's moisture diminishes. In addition, global precipitation pattern will change: tropics and subtropics may get driers, while places next to equator will get wetter. Climate change creates rising sea levels that threaten coastal lowlands, and increases in ocean acidification damages marine life. People living in regions subjected to the impacts of climate change are more likely to suffer from hunger and may be forced to migrate. Other important environmental factors that affect food systems are invasive species, the overuse and depletion of freshwater sources, and the use of pesticides and herbicides that can poison soils and threaten biodiversity vital for crop productivity.
- Current agricultural practices threaten the environment primarily because the agricultural sector is a major emitter of the major GHGs (carbon dioxide, methane and nitrous oxide) and because it has a major impact on the nitrogen cycle leading to excess reactive nitrogen in the environment. Agriculture is also a major threat to biodiversity because it is destructive to habitats for other species (deforestation) and because of the use of pesticides and herbicides in farm production. Finally it is responsible for the overuse of freshwater for crop irrigation.
- The Haber-Bosch process, developed around 1910, solved the scarcity problem of nitrogen nutrients needed to increase global food production: it enabled to chemical transformation of the atmospheric N2 molecules into reactive nitrogen. This was a great technological innovation which, along with the development of high-yield seed varieties of the Green Revolution, made it possible to produce enough food for billions of people. Unfortunately, the heavy use in nitrogen-based fertilizers results in water pollution (some nitrogen enters the water supply as nitrates, polluting rivers and the sea, which leads to algal blooms and nitrification of downstream estuaries), air pollution (some nitrogen enters the atmosphere as nitrogen oxide causing smog and local pollution), more GHGs released (some nitrogen enters the atmosphere as nitrous oxide), and soil acidification.
- The path to sustainable development should involve solutions specific to each geographic region. These should include: 1) increases in productivity (via plant breeding or advance genetic modification; e.g. drought-resistant varieties of crops); 2) more nutritious crops (e.g. golden rice); 3) "precision farming" that economize on use of water, nitrogen, and other inputs of production, and leverages of better soil testing, soil mapping, and localized chemistry; 4) improved water management and develop solar-power irrigation; 5)better harvesting, storage, and transport of crops to avoid losses.

EASY

REVIEW

Concepts and Definition

Can you define or explain the significance of these concepts?

Malthusian Crisis	Pastureland and cropland
Stunting	Ocean acidification
Wasting	Haber-Bosh process
Chronic vs. acute undernutrition	Nitrogen cycle
Hidden hunger	Eutrophication
Body Mass Index	Green Revolution
Willet's food pyramid	Golden rice
Engel's law	Precision farming

Check your facts

1) In what year did Malthus write "*An essay on the Principle of Population*"?
2) What percent of the world population is malnourished?
3) How many people in the world are malnourished?
4) What BMI (Body Mass Index) defines obesity?
5) How much land is devoted to agriculture in % of the world's total land area?
6) How much land is devoted to agriculture in square km?
7) What percent of total human use of fresh water goes to agriculture, industrial use, and households respectively?
8) For what share of total GHGs emissions is AFOLU (Agriculture, Forestry, and Other Land Use) responsible?
9) Approximately when was the Haber-Bosch process invented?
10) What share of total food production is estimated to be wasted?

Answers: 1) 1798; 2) greater than 30; 3) 40%; 4) about 3 billion; 5) 40% of the world's total land area; 6) around 50 million square km; 7) 70% for agriculture, 20% industrial use and 10% for household use; 8) 24%; 9) 1908-1912; 10) 30 - 40%

Review questions

What are the different types of malnutrition?
Where are the epicenters of malnutrition?
What countries have severe hidden hunger index?
What foods have a high glycemic index?
What are the trends in global food prices and what are the consequences?
What are the major farm systems in Africa?
Where are the world's forests?
Where pastureland and cropland located in the world?
What conditions location of cropland and forests?
What are the environmental threats to food production?
How do temperature increases interact with crop productivity?
How does climate change impact the ocean? What might happen with marine life?
What are the problems with the current agricultural practices around the world?

What are the societal threats resulting from excess reactive nitrogen?
Who made the Green Revolution possible and how we can apply the concepts to out present environmental challenge and food insecurity?
What can be done to move towards a Sustainable Development path in agriculture?
How and why we need to take responsibility for our personal health and the way we approach food as individuals?

DATA ACTIVITIES

EASY

A. Malnutrition

Go to Gapminder World (http://www.gapminder.org/world). Plot "Malnutrition, weight for age (% of children under 5)" against log "Income per person" and answers the questions that follow.

1) In 2005, which country appeared to have the highest percentage of malnourished children?
2) What is China's percentage of malnutrition in 1990, 2000, and in 2010?
   Now plot "Food supply (kilocalories /person /day)" against income per capita.
3) In 2006, which countries appeared to have the lowest food supply?
4) How high was the food supply in the US in 2006? How many times higher is that than the country with lowest food supply?
5) Approximately, how many times higher was the food supply in China in 2007 vs 1961?

Answer: 1) Burkina Faso 2) 2.6% in 1990, 1.1 in 2000 and 0.6% in 2010; 3) Congo (Dem Rep) and Eritrea; 4) 3748 kCal/person/day / 2.3 times higher; 5) about x 2

EASY

B. Global Forest Resourses Assesment

Look at the FAO map entitled "Annual change in forest area by country, 2005-2010." (http://www.fao.org/forestry/fra/62219/en/)?

1) Which country achieved the most net gain of forest area during 2005-2010?
2) Which countries have a net loss greater than 500,000 ha?

Answer: 1) China 2) Brazil, Indonesia, Australia

EASY

C. Agriculture

Use the World Bank indicator database (http://data.worldbank.org/indicator/all) to answer the questions that follow.

1) What are the top 3 countries with the greatest amount of arable land per capita (hectares per person) in 2012?
2) What are the top 3 countries with largest area of land under cereal production (hectares) in 2013?
   Use the graph tool on the World Bank website to plot cereal yield (kg per hectare) for China, United States, Japan, India, World and Sub-Saharan Africa (all income levels) for the period 2005-2013.
3) What was the cereal yield (in kilograms per hectare) in the US in 2013?
4) What was the cereal yield (in kilograms per hectare) for Sub-Saharan Africa in 2013?
5) By how much did the sub-Saharan Africa yield increase between 2005 and 2013?
6) Do you observe any patterns?

Answer: 1) Australia, Kazakhstan and Canada; 2) India, China and US; 3) 7,340 kg/ha; 4) 1,434 kg/ha; 5) 267 kg/ha

EASY

D. Crop Production

Using the FAO statistical services (http://faostat3.fao.org/), find data on world cereal production (tons) and answer the questions that follow.

1) What were the top 4 crops produced in the world in 2013?
2) What were the top 2 cereals produced in the world in 2013?
3) Approximately, what was the level of cereal production (in tons) in 2013?
4) What countries were the top 4 cereal producers in 2013?
5) What was the level of cereal production in the United States in 2013?
6) What were the top 3 most produced crops in the United States in 2013?

Answer: 1) sugar cane, maize, rice and wheat; 2) maize and rice; 3) 2.8 billion tons; 4) China, US, India, Brazil; 5) About 437 million tons 6) Maize, soybeans and wheat;

MEDIUM

Agricultural Water

Using the FAO website (http://data.fao.org/statistics), download data for agricultural water withdrawal for all countries for the last period available. Use the database called AQUASTAT.

1) What are the top 3 largest contributors to agricultural water withdrawal?
2) What is the US contribution to agricultural water withdrawal?
3) Construct a bar chart in excel showing the top 20 largest contributors to agricultural water withdrawal. Make the name of these 20 countries appear next to the y-axis. Use a log scale for the x-axis if you find it useful.

Answer: 1) India, China, US 2) 7% or 192.4 m^3/yr.

MEDIUM

D. Nutrition Indicators

The WHO has created a method for comparing nutrition indicators across populations. Standardized measures of physical development, whereby a child is compared to an international cohort of same-aged individuals, were created to determine their position in the distribution. Stunting is seen as a measure of chronic undernutrition over long periods, and wasting is seen as a more acute measure. Download the WDI table on nutrition and growth: http://wdi.worldbank.org/table/2.18

1) Investigate the first two columns, prevalence of undernourishment in 1990 and in 2013 to find out whether there are any clear trends. In particular, plot a graph with the prevalence in 1990 on the x-axis and the prevalence in 2013 on the y axis for all the countries. Plot a line y = x so that it is graphically easy to identify the countries where the prevalence has increased or decreased. In which countries the decrease has been most spectacular? How can you explain these spectacular decrease?
2) Using data on the prevalence of stunting, wasting and several wasting, investigate whether undernutrition is more likely to affect female than male or inversely. Display appropriate graphs to support your analysis. Suggest mechanisms (either social or biological) that could explain a gender difference.

HARD

E. The South Asian enigma

Levels of economic growth, agricultural production, infrastructure, and public services are higher in South Asia than in sub-Saharan Africa. However, South Asian has higher prevalence of underweight pre-school children than sub-Saharan Africa. This has been called the South Asian enigma.
Write a 3 to 5 page paper examining this so called South Asian enigma. Make sure you first analyze available data to verify the validity of the claim. Provide appropriate maps or graphs that you will

have constructed using data, for example from the World Bank. Second, review very briefly in the literature the arguments that have been put forward to explain this enigma. Finally, suggest appropriate policies that a South Asian government might want to implement to improve undernutrition.

DISCUSS AND DEBATE

1) Using the case study below, discuss what you think are the main causes and best strategies to overcome malnutrition in the world.

2) Using Figure 10.11 in the book, describe major farm systems in Africa. Discuss the implications for policy-making.

3) According to you, what is the main challenge to the adoption of sustainable water management?

4) Discuss plant breeding and the controversy about creation of genetically modified organisms (GMOs) or GMO crops as a solution to food insecurity.

5) Discuss how information technology can help solve global food insecurity?

6) Discuss how behavioral change can either aid or harm the trajectory towards sustainable agriculture and food security.

CASE STUDY

Unhealthy soils in the cradle of the Green Revolution

Irrigated rice and wheat are grown on 23.5 million hectares of land inhabited by more than 1 billion people in the Indo-Gangetic plains and other fertile valleys of Asia. Yields in this system, which rose dramatically during the Green Revolution, have now reached a plateau, largely because of declining soil health. Farmers apply too much nitrogen fertilizer and too little organic matter and other sources of essential nutrients, resulting in severe deficits of phosphorus and potassium and widespread micronutrient deficiencies. Too low a proportion of crop residues is incorporated back into the soil; animal dung is burned as domestic fuel; excessive tillage is practiced to control weeds; few or no green manures, cover crops, or agroforestry technologies are used; and rising water tables are leading to salinization. The degradation of soil and water resources severely affects human health. Many parts of South Asia that depend on the rice–wheat system are now hunger hotspots. In addition to calorie and protein undernutrition, iron and zinc deficiencies are pervasive, particularly among nursing mothers and infants. Agricultural productivity and human health in the region will only be improved and sustained if soil and water resources are restored and maintained. This can be done through the use of technologies such as conservation tillage and planting on raised beds, which are gradually spreading through parts of the region. Conservation tillage is now used on about 1.3 million hectares of irrigated wheat land, where the crop residues left as mulch have begun to rebuild soil organic matter.

UN Millennium Project Hunger Task Force. Halving Hunger: It Can Be Done (2005), Box 3

FURTHER READING

- **MDGs and SDGs**

This report provides an update on progress that countries are making towards the goal of halving world hunger by 2015.
UN Millennium Project Hunger Task Force. Halving Hunger: It Can Be Done (2005)

This report, issued as preparation for the post-2015 UN development agenda, discusses the various challenges related to agriculture.
Sustainable Development Solutions Network Thematic Group on Sustainable Agriculture and Food Systems. 2013. Solutions for Sustainable Agriculture and Food Systems: Technical Report for the Post-2015 Development Agenda. New York: Sustainable Development Solutions Network.

- **Sustainable farming**

This report discusses the many challenges facing global farming and food and make a strong case for governments, the private sector and civil society to continue to prioritize global food security and sustainable agricultural production.
Foresight. The Future of Food and Farming (2011) Executive Summary. The Government Office for Science, London

This article evaluates prospects for conserving natural resources and improving environmental quality while meeting increased food demand.
Cassman, K. G., Dobermann, A., Walters, D. T., & Yang, H. (2003). Meeting cereal demand while protecting natural resources and improving environmental quality. Annual Review of Environment and Resources, 28.

The author identifies eight steps that, taken together, could enable farming to feed 10 billion people and keep Earth habitable.
Clay, J. (2011). Freeze the footprint of food. Nature, 475.

Using new geospatial data and models, the authors evaluate how new approaches to agriculture could benefit both food production and environmental sustainability.
Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., Zaks, D. P. M. (2011). Solutions for a cultivated planet. Nature, 478.

This report explores how the management of land-based biomass production and consumption can be developed towards a higher degree of sustainability across different scales: from the sustainable management of soils on the field to the sustainable management of global land use as a whole.
United Nations Environment Programme. 2014. Assessing Global Land Use: Balancing Consumption with Sustainable Supply. A Report of the Working Group on Land and Soils of the International Resource Panel. Nairobi: United Nations Environment Programme.

In their annual letter, Bill and Melinda Gates make a bet that, in the next 15 years, 1) child deaths will go down by half, and more diseases will be eradicated than ever before; 2) Africa will be able to feed itself; 3) better software will revolutionize learning; and 4) mobile banking will help the poor

radically transform their lives.
Bill Gates 2015 Annual Letter http://annualletter.gatesfoundation.org

- **Human appropriation of biosphere**

This article examines human impact on the biosphere by calculating the fraction of net primary production (NPP) that humans have appropriated.
Vitousek, P. M., Ehrlich, P. R., Ehrlich, A. H., & Matson, P. A. (1989). Human appropriation of the products of photosynthesis. BioScience, 36 (6).

This paper introduces a new approach for mapping large intact forest landscapes (IFL), defined as an unbroken expanse of natural ecosystems within areas of current forest extent, without signs of significant human activity, and having an area of at least 500 km^2 .
Potapov P., A. Yaroshenko, S. Turubanova, M. Dubinin, L. Laestadius, C. Thies, D. Aksenov, A. Egorov, Y. Yesipova, I. Glushkov, M. Karpachevskiy, A. Kostikova, A. Manisha, E. Tsybikova, I. Zhuravleva. 2008. "Mapping the World's Intact Forest Landscapes by Remote Sensing." Ecology and Society, 13(2): 51. http://www.ecologyandsociety.org/vol13/iss2/art51/

- **Others**

In this study, researchers developed indices and maps of global hidden hunger to help prioritize program assistance, and to serve as an evidence-based global advocacy tool.
Muthayya, Sumithra, Jee Hyun Rah, Jonathan D. Sugimoto, Franz F. Roos, Klaus Kraemer, and Robert E. Black. 2013. "The Global Hidden Hunger Indices and Maps: An Advocacy Tool for Action." PLoS One 8(6):e67860. doi:10.1371/journal.pone.0067860.

This report is an assessment made by about 200 leading European experts from different disciplines and perspectives on the sources and effects of reactive nitrogen in the environment.
Sutton, Mark A., Clare M. Howard, Jan Willem Erisman, Gilles Billen, Albert Bleeker, Peringe Grennfelt, Hans van Grinsven et al., eds. 2011. The European Nitrogen Assessment: Sources, Effects and Policy Perspectives. Cambridge: Cambridge University Press.

This report examines the dynamics of the new global food economy by looking at what would happen to global food prices, trade, and food security under four alternative scenarios for the period between 2010 and 2050.
Rosegrant, Mark W., Simla Tokgoz, Prapti Bhandary, and Siwa Msangi. 2012. "Scenarios for the Future of Food." In 2012 Global Food Policy Report, 89–101. Washington, DC: International Food Policy Research Institute.