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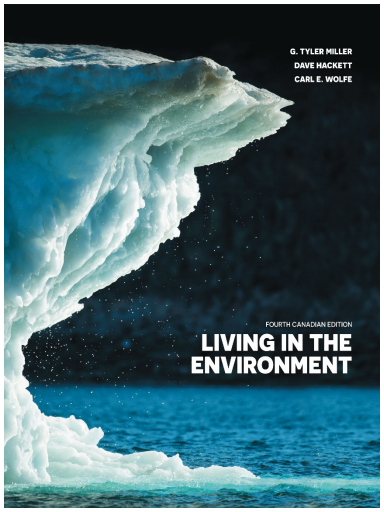

prepared by

Ian Dawe

Chapter 14

Food and Soil Resources

Key Concepts

Food production

– Methods, quantities, and issues

Soil degradation and conservation

Sustainability and eradicating hunger

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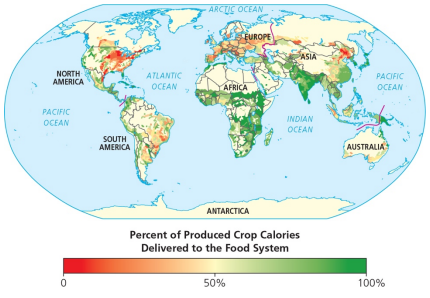
Feeding the Future

Feeding the world pulls 70% of the water we use, 40% of the earth's mass, and creates 30% of greenhouse gasses.

This is unsustainable.

Much of the food we grow doesn't feed humans but rather goes to livestock or biofuels.



Source: Data provided by the Global Landscapes Initiative, Institute on the Environment, University of Minnesota. Cassidy et al. 2013.

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Strategies for Sustainable Food, "Terraculture"

1. Stop expanding agriculture.
2. Close yield gaps; make the land already used as productive as it can be.
3. Increase agricultural resource efficiency.
4. Change diets (reduce meat, reduce distance transported, and reduce waste).

What Systems Provide Us With Food?

Croplands 77%

– Grains (primarily)

– Wheat, corn, rice > 50% of all food calories

– Annual crops

Rangelands 16%

– Meat, mostly from grazing livestock

Ocean fisheries 7%

How Is Food Produced?

How do natural ecosystems compare with agroecosystems?

- Soil stabilization
- Slowly evolving adaptations
- Solar energy
- Succession
- Structural + biological diversity

Croplands Provide Economic and Ecological Services

FIGURE 14-2 NATURAL CAPITAL

Croplands

Ecological and economic services provided by croplands

Ecological Services

- Help to maintain water flow and soil infiltration
- Providing partial erosion protection
- Building soil organic matter
- Storing atmospheric carbon
- Providing wildlife habitat for some species

Economic Services

- Food crops
- Fibre crops
- Crop genetic resources
- Jobs

(Left): © Tom Reichner/Shutterstock; (Right): © Orientaly/Shutterstoc

What Are the Major Types of Food Production?

Industrialized Agriculture (80%)

– High input, high-throughput

– *For example,* plantation agriculture (cash crops)

Traditional Agriculture

– Low-throughput agriculture

– Subsistence agriculture

– Traditional intensive agriculture

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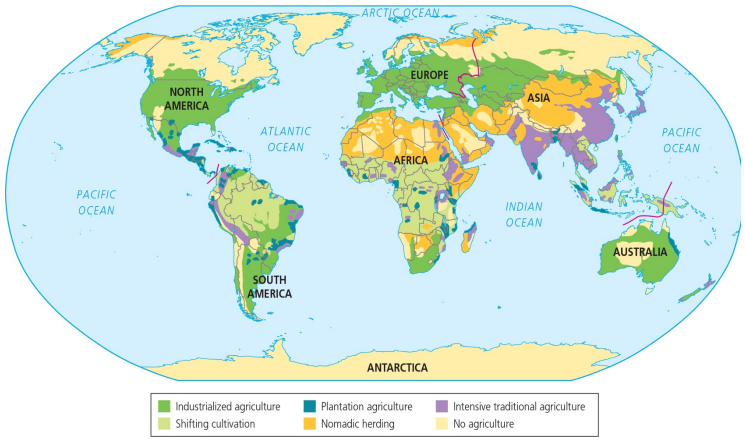
Where and How Food Is Produced



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Producing Food by Green Revolution

Three steps to increase yield per unit of cropland:

1. **Monocultures**
   - Selectively-bred/engineered for high yield
2. **Increased fertilizer, pesticides, water**
3. **Multiple cropping**

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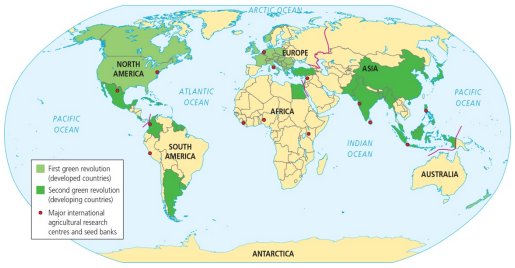
Worldwide Green Revolutions



- 1st green revolution
  - Developed nations
  - 1950–1970
  - High-input
- 2nd green revolution
  - Developing nations
  - Post-1967
  - Fast-growing rice, wheat

Major agricultural research centre

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The State of Agriculture in Canada

$104 billion industry (6.7% of GNP in 2012)

Employs 1.8% of workforce directly

- 12% in food-related industries

$44 billion in surplus and exports

68 million ha. farmland (limited availability)

– Number of farms decreasing

– Average size of farms increasing

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Canada: Agricultural Soil

Source: Modified from Canada and the World - An Atlas Resource, G.J. Matthews and R. Morrow, 1995, Prentice Hall Canada Inc.

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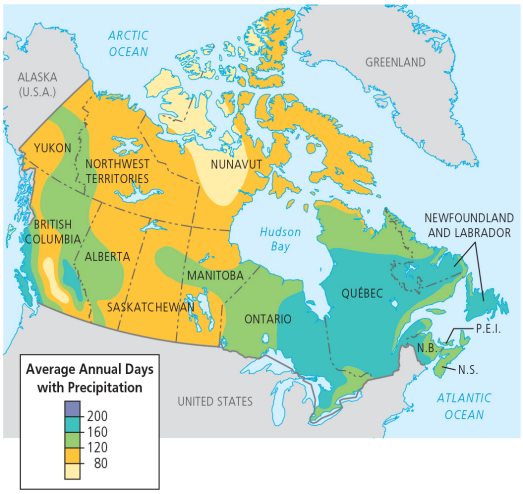
Canada: Precipitation for Agriculture



Source: Modified from Canada and the World - An Atlas Resource, G.J. Matthews and R. Morrow, 1995, Prentice Hall Canada Inc.

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Canada: Net Agricultural Land

83% Prairies

13% ON/QC

Source: Modified from Canada and the World—An Atlas Resource, G.J. Matthews and R. Morrow, 1995, Prentice Hall Canada Inc.

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Growing Techniques in Traditional Agriculture

Interplanting

– Simultaneous growth of different crops on one plot to reduce risk
  - Polyvarietal cultivation: Varieties of same crop
  - Intercropping: Different types of crops
  - Agroforestry (alley cropping)
  - Polyculture: Different maturation periods

Soil Erosion and Cropland Degradation

Cropland Degradation

Decreased future ability to support crops, livestock, or wild species

Soil Erosion

Migration of soil components, especially surface litter and topsoil

- Loss of fertility
- Sediment in water

Desertification

Loss of productive potential of arid land due to prolonged drought and human activities that reduce or degrade topsoil

Salinization & Waterlogging

Soil degradation due to irrigation

What Causes Soil Erosion?

Wind

Worst in Prairies (36% of cultivated land)

Water

High risk to 50-80% of cultivated land in Maritimes, B.C., ON

People

Considerable loss due to urban development

- 12,000 km^2 post-1970
- 18% of ON farmland

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Desertification

Causes

Overgrazing
Deforestation
Erosion
Salinization
Soil compaction
Natural climate change

Consequences

- Worsening drought
- Famine
- Economic losses
- Lower living standards
- Environmental refugees

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Desertification (2007)

Causes
- Overgrazing
- Deforestation
- Erosion
- Salinization
- Soil compaction
- Natural climate change

Consequences
- Worsening drought
- Famine
- Economic losses
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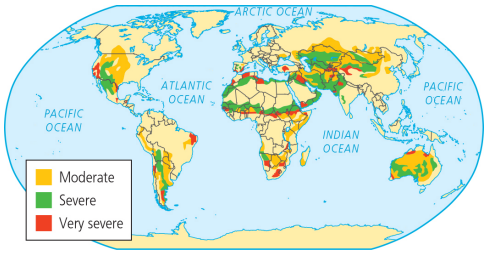

Source: Data from UN Environment Programme and Harold E. Drengue

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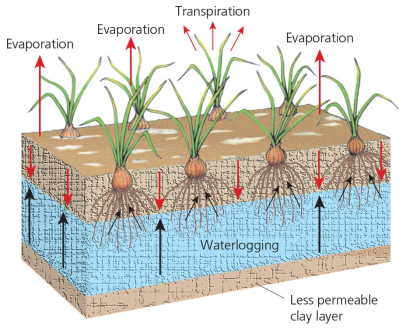
Salinization and Waterlogging



Salinization
1. Irrigation water contains small amounts of dissolved salts.
2. Evaporation and transpiration leave salts behind.
3. Salt builds up in soil.

Waterlogging
1. Precipitation and irrigation water percolate downward.
2. Water table rises.

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Soil Salinization: Solutions

Prevention

- Reduce irrigation
- Switch to salt- tolerant crops

Cleanup

- Flush soil (expensive and wastes water)
- Stop growing crops for 2-5 years
- Install underground drainage systems (expensive)

Inorganic Fertilizers: Trade-offs

FIGURE 14-11 TRADE-OFFS

Inorganic Commercial Fertilizer

Advantages and disadvantages of using inorganic commercial fertilizer to enhance or restore soil fertility. Pick the single advantage and disadvantage that you think are the most important.

Advantages

- Easy to transport
- Easy to store
- Easy to apply
- Inexpensive to produce
- Helps feed one of every three people in the world
- Without commercial inorganic fertilizers, world food output could drop by 40%.

Disadvantages

- Does not add humus to soil
- Reduces organic matter in soil
- Reduces ability of soils to hold water
- Lowers oxygen content of soil
- Supplies only two or three of 20 or so nutrients needed by plants
- Requires large amounts of energy to produce, transport, and apply
- Releases the greenhouse gas nitrous oxide (N_2O)
- Runoff can overfertilize nearby lakes and kill fish.

(Left): © EcoPrint/Shutterstock; (Right): © OPgrapher/Shutterstock

Conventional and Conservation Tillage

- Conventionally (top)
  - Land plowed in fall
  - Soil broken up and smoothed for planting
- Plowing leaves soil bare and vulnerable during winter
- Conservation tillage (bottom) leaves the soil undisturbed

© Anton Foltin/Shutterstock

© Story/Shutterstock

Conservation Tillage: Trade-offs

FIGURE 14-13 TRADE-OFFS

Conservation Tillage

Advantages and disadvantages of using conservation tillage. Pick the single advantage and disadvantage that you think are the most important.

Advantages

- Reduces erosion
- Saves fuel
- Cuts costs
- Retains more soil moisture
- Reduces soil compaction
- Allows several crops per season
- Does not reduce crop yields
- Reduces CO_2 release from soil

Disadvantages

- Can increase herbicide use for some crops
- Leaves stalks that can harbour crop pests and fungal diseases and increase pesticide use
- Requires investment in expensive equipment

(Left): Photo by Tim McCabe, USDA Natural Resources Conservation Service; (Right): © smereka/Shutterstock

Soil Conservation Methods

Goal: To reduce soil erosion and restore soil fertility

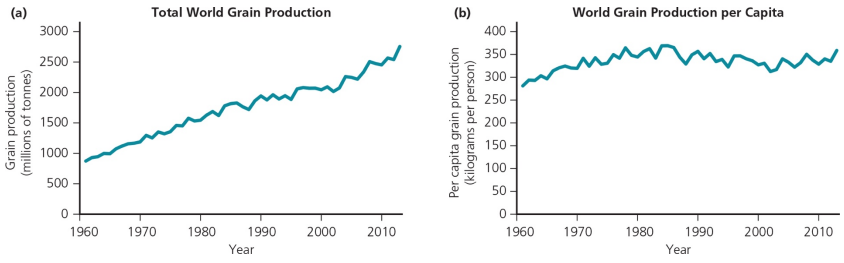
(a) Terracing

(b) Contour planting
Strip cropping

(c) Alley cropping (agroforestry)

(d) Windbreaks

How Much Has Food Production Increased?



Source: Data from U.S. Department of Agriculture, Worldwatch Institute, UN Food and Agriculture Organization, and Earth Policy Institute.

Undernutrition and Malnutrition

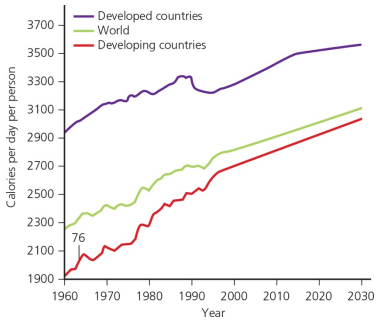
Key nutrient requirements

- **Macronutrients**
  - Proteins, carbohydrates, fats
- **Micronutrients**
  - Vitamins, minerals

Undernutrition in developing nations

- 1 of 6 individuals
- 1 of 3 children under age 5

Nutritional diseases



Source: Data from UN Food and Agriculture Organization

Micronutrient Deficiencies

Affects one in three people

Vitamin A deficiency

- Blindness
- Genetically engineered rice helps

Iron deficiency

- Anemia, fatigue, infection, death risk

Iodine deficiency

- Thyroid issues, brain damage, goitre

Overnutrition

Overweight: BMI > 25
- 4.5 to 14 kg over a healthy weight

Obese: BMI > 50
- 14 kg or more over a healthy weight

Health risks
- Lower life expectancy
- Greater susceptibility to disease and illness
- Lower productivity and life quality

Overnutrition continued

In Canada (2011),
- 60% overweight
- 24% obese

- Second leading cause of preventable deaths in developed nations

Environmental Effects of Food Production

Biodiersity Loss

- Loss and degradation of grasslands, forests, and wetlands in cultivated areas
- Fish kills from pesticide runoff
- Killing wild predators to protect livestock
- Loss of genetic diversity of wild crop strains replaced by monoculture strains

Environmental Effects of Food Production continued

Water

- Water waste
- Aquifer depletion
- Increased runoff, sediment pollution, and flooding from cleared land
- Pollution from pesticides and fertilizers
- Algal blooms and fish kills in lakes and rivers caused by runoff of fertilizers and agricultural wastes

Environmental Effects of Food Production continued 2

Soil

- Erosion
- Loss of fertility
- Salinization
- Waterlogging
- Desertification
- Increased acidity

Air pollution

- Greenhouse gas emissions and pollutants from fossil fuel use
- Pollution from pesticide sprays

Environmental Effects of Food Production continued 3

Human Health

- Nitrates in drinking water (blue baby)
- Pesticide residues in drinking water, food, and air
- Contamination of drinking and swimming water from livestock wastes
- Bacterial contamination of meat

Increasing Crop Production

What options do we have to increase production?

- Modifying crop genetics
- Expanding the green revolution
- Changing land usage
- Changing eating habits and food waste

Crop Genetics

Traditional: Crossbreeding / artificial selection

- **Problems**
  - Slow to yield results (~15 yrs)
  - Pests and diseases adapt (~5 yrs)

New: Genetic engineering (gene splicing)

- Aim to develop strains with targeted resistance
- GM crops now account for 11% of world's crops
- **Problems**
  - Legal complications
  - Suicide seeds

Genetically Modified Foods: Trade-offs

FIGURE 14-20 TRADE-OFFS

Genetically Modified Crops and Foods

Projected advantages and disadvantages of genetically modified crops and foods.
Pick the single advantage and disadvantage that you think are the most important.

Projected Advantages

- Need less fertilizer
- Need less water
- More resistant to insects, plant disease, frost, and drought
- Faster growth
- Can grow in slightly salty soils
- Less spoilage
- Better flavour
- Less use of conventional pesticides
- Tolerate higher levels of herbicide use
- Higher yields

Projected Disadvantages

- Irreversible and unpredictable genetic and ecological effects
- Harmful toxins in food from possible plant cell mutations
- New allergens in food
- Lower nutrition
- Increased evolution of pesticide-resistant insects and plant diseases
- Creation of herbicide-resistant weeds
- Harm beneficial insects
- Lower genetic diversity

(Left): © Jim West/Alamy Stock Photo; (Right): © Prashant Jha/Montana State University

GMO Crops: Science Supports Them

A statement in 2000 signed by 2100 eminent scientists supported their use.

A 2004 UN report states they have great promise for developing countries.

The U.S. Department of Agriculture does not support labelling GM foods: no evidence for alarm.

Can We Continue to Expand the Green Revolution?

Limitations on fertile land, water

Reduced biodiversity limits gene pool

Law of diminishing returns

– *For example,* grain yields

- 1950–1990: +2.1% per year
- 1990–2000: +1.1% per year
- 1997–2008: +0.5% per year

Changing Habits

Cultivating new foods

Replace staple grains with new species

- Higher nutrient content
- Lower resource demand

Microlivestock (insects)

Perennial polycultures

Avoiding food waste

Up to 70% of food produced worldwide is wasted

- Spoilage
- Inefficient processing and preparation
- Plate waste

Canada: Up to 60% wasted

Cultivating More Land?

A possibility is to cut down tropical rainforests and irrigate.

But the losses of this practice would offset any gains.

The land isn't particularly fertile and more useful ecologically.

But food could be grown, on a small scale, in urban areas.

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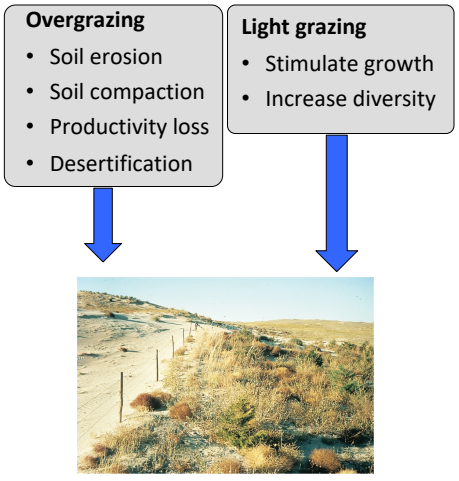
How Are Rangelands Used to Produce Meat?

- Grass and shrubs for livestock
- Rangeland management
  - Limit number of animals
  - Limit grazing duration
  - Fence off riparian zones
  - Suppress invasive species



USDA, Natural Resources Conservation Service

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Is Producing More Meat the Answer?

Energy inefficient

- One calorie of meat requires 11–15 calories of feed.
- Producing one hamburger needs the same energy as driving a small car ~32 km.

Health consequences

- High intakes of animal fats are associated with heart disease, stroke, cancer, obesity.

Feedlots

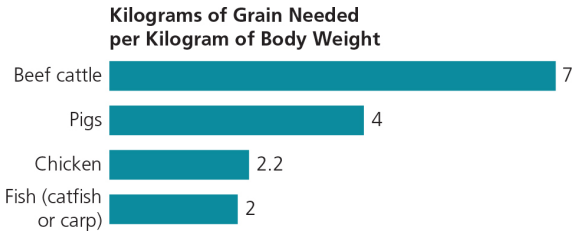
- Produce 43% of beef, 50% of pork, 75% of all poultry

Trade-offs: Animal Feedlots

Advantages	Disadvantages
Increased meat production	Large inputs of grain, fish meal, water, and fossil fuels
Higher profits	Greenhouse gas (CO_2 and CH_4) emissions
Less land use	Concentration of animal wastes that can pollute water
Reduced overgrazing	Use of antibiotics can increase genetic resistance to microbes in humans
Reduced soil erosion	
Protection of biodiversity	

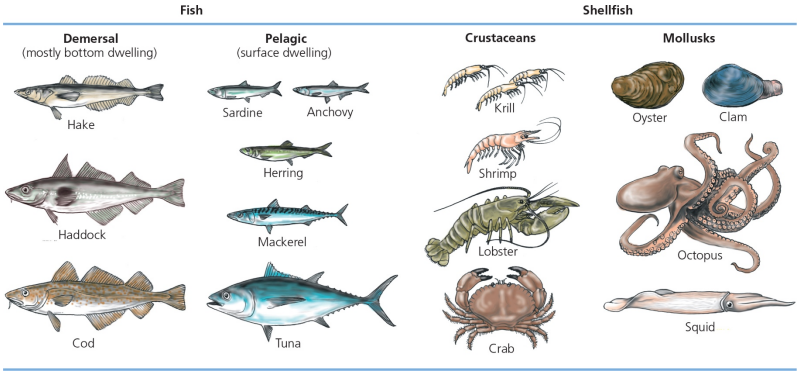
How Can We Produce Meat More Sustainably?

By shifting our meat priorities from beef to chicken and fish, we can conserve rangeland.



Source: U.S. Department of Agriculture

Catching and Raising Fish and Shellfish



Problematic Fishing Methods

Trawler
- Habitat destruction

Purse-and-seine

Longline

Driftnet

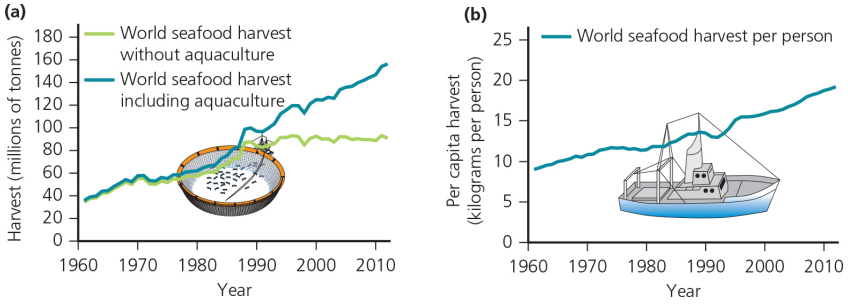
Bycatch issues (*other accidentally caught species*) problematic for all

Effects of Overfishing and Habitat Degradation

Seventy-five percent of commercially valuable marine fish species are **overfished** or fished at their biological limit.

Commercial extinction risks

Effects of Overfishing and Habitat Degradation continued



Source: Data from FAO 2010

Aquaculture: Fish Farming

Cultivating fish in an inland environment

Alternative proposals: farming for algal species

- *For example, spirulina* (70% protein)

© Visions of America, LLC/Alamy

Trade-offs: Aquaculture

Advantages

- High efficiency
- High yield
- Reduced over-harvesting of fisheries
- Low fuel use
- High profits, not tied to oil

Disadvantages

- Large inputs of land, feed, and water
- Large waste output
- Loss of mangrove forests and estuaries
- Some species fed with grain, fish meal, or fish oil
- Dense populations vulnerable to disease

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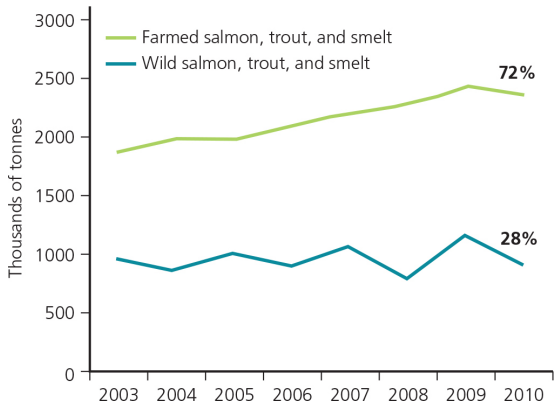
Aquaculture *vs*. Wild Caught



Source: Data from FAO, 2010b

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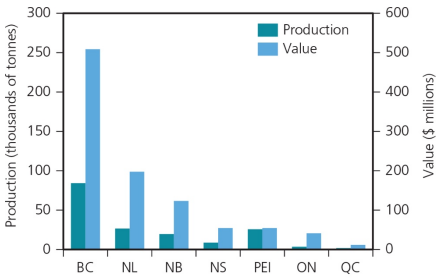
Aquaculture in Canada



Province	BC	NL	NB	NS	PEI	ON	QC
Production (thousands of tonnes)	84.26	26.55	19.63	8.75	25.70	3.60	1.75
Value ($ millions)	507.49	196.97	123.06	54.26	41.20	18.50	11.78

Source: Data from Statistics Canada, 2014

- > 70 farmed species
- Fourth-largest farmed salmon producer
- In B.C., farmed salmon outsell wild

Sea Lice

- Ectoparasites of marine fish
- High concentrations in or near open-net salmon farming
- Juvenile wild salmon migrate past farms
- Possible impact on wild salmon population

Sustainable Aquaculture

FIGURE 14-33 **SOLUTIONS**

Sustainable Agriculture

Sustainable agriculture would involve using more of the items in the left column and avoiding the items in the right column.

More

- High-yield polyculture
- Organic fertilizers
- Biological pest control
- Integrated pest management
- Irrigation efficiency
- Perennial crops
- Crop rotation
- Use of more water-efficient crops
- Soil conservation
- Subsidies for more sustainable farming and fishing

Less

- Soil erosion
- Soil salinization
- Aquifer depletion
- Overgrazing
- Overfishing
- Loss of biodiversity
- Loss of prime cropland
- Food waste
- Subsidies for unsustainable farming and fishing
- Population growth
- Poverty

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More Sustainable Aquaculture

FIGURE 14-34 **WHAT CAN YOU DO?**

Sustainable Agriculture

Ways to promote more sustainable agriculture:

- Waste less food.
- Reduce or eliminate meat consumption.
- Feed pets balanced grain foods instead of meat.
- Use organic farming to grow some of your food.
- Buy organic food.
- Compost or vermicompost (p. 660) your food wastes.
- Support political parties that advocate sustainable agriculture.

How Can We Transition to Sustainable Agriculture?

1. **Research** sustainable agriculture and improving human nutrition.
2. **Demonstration** projects for farmers in each country
3. **Incentives** like startup subsidies and increased foreign aid
4. **Training** programs in sustainable agriculture
   - For farmers and government agricultural officials
   - For college students in agriculture and nutrition

What Can You Do to Promote Sustainable Agriculture?

Waste less food.
East less meat.
Feed pets balanced grain foods.
Use organic farming to grow your own.
Buy organic food.
Compost.
Support political parties that advocate it.

Conclusion

- Food is necessary.
- Producing food sustainably is a challenge.
- Crop production needs to be increased in such a way that it conserves soil.
- Aquaculture also needs improvement.
- Genetically modified and organic crops are promising.
- Need large-scale and small-scale solutions.