OUTLINES AND NOTES
for
Britannica Article on Green Revolution

by

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Part One: World Revolution in Agriculture

A. Agriculture and Population

1) In geological terms, agriculture is a relatively recent invention. Domestication of major plant and animal species occurred largely during the Neolithic period, most likely by women—5,000 to 8,000 B.C.

2) Surplus food production led to the development of settled ways of life and more rapid population growth. Neolithic population was estimated to be about 15 million.

3) With improving agriculture, and the advent of irrigation, population grew to an estimated 250 million at the start of the Christian era; 500 million in 1650; and 1 billion by 1850.

3) Discovery of the nature of infectious diseases in the mid 19th century—the dawn of modern medicine—began to lower death rates through improved sanitation and public health. World population doubled in 80 years—to 2 billion—by 1930. Discovery of sulfa drugs, antibiotics, and improved vaccines in the first half of the 20th century led to a substantial reduction in death rates, especially among infants and children. This, and an expanding food supply, brought about another doubling in population—to 4 billion people—in only 43 years, by about 1975. World population growth is slowing; still, the next doubling in world population—to 8 billion—is expected to occur somewhere around 2020.

B. Rise of Modern Agriculture

1) U.S. institutional foundations for high-yield agriculture

Laid in the latter half of the 19th century: In 1862 President Lincoln signed into law three bills that played a vital role in raising the U.S. to its preeminent position: The Homestead Act, which made relatively large (at the time) tracts of land available to landless persons who committed themselves to living on the property and developing it; a law establishing the U.S. Department of Agriculture; and the Morrill Act, which established publicly supported land-grant colleges of agriculture and mechanical arts in every state. These laws were supplemented in 1887 by the Hatch Act, which provided for the establishment of agricultural experiment stations, as well as closer collaboration between the agricultural colleges and USDA, and in 1914 by the ____ Act, which established the cooperative extension service, charged with introducing new technology to farm and ranch families.

2) High-yielding varieties

Until the end of 19th century crop improvement was largely in the hands of farmers who selected seed from the most desirable plants for sowing the following season. By the early decades of the 19th century, a number of progressive farmers in North America were busy developing and selling seeds from superior varieties based on their individual plant selections.

Groundwork for more sophisticated genetic improvement of crop species was laid by Charles Darwin in his writings on the variation of life species (published in 1859) and by Gregor Mendel through his discovery of the laws of genetic inheritance (reported in 1865). Darwin's book immediately generated a great deal of interest, discussion and controversy. Medel's work was largely ignored for 35 years. The rediscovery of Medel's work in 1900 provoked tremendous scientific interest and research in plant genetics.

Armed with a growing knowledge of genetics, soil chemistry, and physics, plant agricultural scientists made enormous contributions to increased food production throughout the world.

a) Corn (maize)—discovery and exploitation of hybrid vigor in the early 1900s. Drs East and Jones at Connecticut Agricultural Experiment Station, 1906-1912; H.A. Wallace in Iowa.

b) Wheat and rice plant: restructuring plant architecture—

reducing plant height and increasing grain weight. Dwarfing genes. Wheat breeding work of Dr. Vogel at Washington Sate University, Borlaug and his colleagues in Mexico; rice breeding work of Beachel, Jennings, and Khush at IRRI in the Philippines.

c) Quantum increases in genetic yield potential of cereals, especially maize, wheat, rice, sorghum and barley (Graph. US maize variety/hybrid yields, 1900-1990)

Figure __. Graph: Adoption of high-yielding maize hybrids in USA, 1930-1990

Figure __. Graph: Adoption of high-yielding wheat and rice varieties in India, 1965-1990

3) Mechanization

Agriculture's transition from muscle power to engine power is one of the great revolutions in humankind's history. Beginning in the late 1800s, steam power made mining easier, clothing cheaper, and transportation faster. By the early 1900s, farmer bought trucks in growing numbers. Between 1920 and 1975, the U.S. farm population declined from 32 million to 9 million people; while tractors increased from 300,000 to 4.7 million.

Table __. Increase in Tractors in 20th Century (USA, Europe, LDCs)

4) Irrigation

Irrigation has greatly expanded the amount of arable land and food production throughout the world. The world's irrigated area increased from 8.1 million hectares in 1800, to 105 million in 1900, and to 273 million in 2000. Irrigated land represents about 15% of all land under cultivation, but contributes 40% of our world food supply. India and China together account for about 40% of the irrigated area; the USA accounts for about 8%.

Table __. Growth in irrigated areas, 20th century

D) Fertilizers

During the mid 1800s, German scientist Justus von Leibig and French scientist Jean-Baptiste Boussingault during the mid 1800's laid down important theoretical foundations in soil chemistry and crop agronomy. Sir John Bennett Lawes, produced superphosphate in England in 1842, and shipments of Chilean nitrates (nitrogen) began arriving in quantities to

European and North American ports in the 1840s. However, the use of organic fertilizers (animal manure, crop residues, green manure crops) remained dominant into the early 1900s.

The first decade of the 20th century brought a fundamental scientific breakthrough, that was followed by the rapid commercialization of the breakthrough. In 1909, Fritz Haber demonstrated the synthesis of ammonia from its elements (In 1918 he received the Nobel Prize for Chemistry for this work). Four years later—in 1913—the company BASF, thanks to the innovative solutions of Carl Bosch, began operation of the world's first ammonia plant. The expansion of the fertilizer industry was soon arrested by WWI (ammonia used to produce nitrate for explosives), then the great economic depression of the 1930s, and then by the demand for explosives during WWII.

It is only since WWII that fertilizer use, and especially the application of low-cost nitrogen derived from synthetic ammonia, has become an indispensable component of modern agricultural production. Total consumption has grown from a few million metric tons in 1950 to over 140 million metric tons in 1998.

It is estimated that 40% of today's 6 billion people are alive, thanks to the Haber-Bosch process of synthesizing ammonia (Vaclav Smil, University Distinguished Professor, University of Manitoba).

Table__. Growth in synthetic fertilizer consumption, 20th century

C. . The Green Revolution in the Developing World

> "A Green Revolution is sweeping across India, Pakistan, and other parts of the developing world, as farmers adopt new high-yielding wheat and rice varieties and modern production practices."
>
> William S. Gaud
> Administrator, USAID
> 1968 Semi-Annual Report to Congress

1) Institutional agricultural research in the developing world.

   a) Few agricultural research programs in developing countries before WWII. Most oriented toward high-value traditional export crops (coffee, rubber, cacao, tea). Those food crop research programs that existed were often academic and esoteric (India, Argentina).

b) Pioneering Rockefeller and Ford Foundation agricultural programs, 1943-1970s.

c) U.S. foreign assistance programs Marshal Plan; Point IV; USAID (involving U.S. Land Grant Universities).

d) United Nations programs (FAO, UNDP, World Bank).

e) International Agricultural Research Centers, 1960-2000 IRRI in the Philippines was the first; CIMMYT the second There are now 16 centers supported by the Consultative Group for International Agricultural Research (CGIAR).

2) Mexico—the quiet wheat revolution, 1950s and 1960s

3) Rapid spread, 1965-75, of high-yielding wheat and rice varieties spread through Asia (India, Pakistan, China, Bangladesh, Indonesia, Philippines) 1965-1975. Policy changes made fertilizers, improved seeds, credit, and access to grain markets available to farmers at attractive prices.

D. Criticisms of the Green Revolution

1) Rich got richer; poor got poorer; landless rural labor displaced by tractors and harvesting machines.

2) Intensive irrigation and overuse of fertilizers and pesticides have led to a decline in land (soil) and water quality, and dangerous pollution.

3) High yielding varieties have pushed out local cultivars and resulted in loss of biodiversity in major crop species.

E. Impact of 20th Century Science on World Food Production

1) Cereal production statistics in industrialized countries, 1950-2000. Maize, wheat and rice production (USA, other industrialized countries, India, China, other developing countries. World production has nearly tripled since 1960. (Table___).

2) Declining real cereal prices—poor consumers were the greatest beneficiaries. Real prices have nearly dropped in half in wheat, rice, and maize, over the past 40 years. (Graph___).

3) Land saved through the adoption of modern cereal production technology, 1950-2000 (USA, Europe, China, India).
Figure__. Roughly 700 million ha used in world cereal production today. One billion hectares of land saved due to modern technology.

4) Food insecurity continues in Green Revolution countries. South Asia and sub-Saharan Africa has the most food-insecure people, for different reasons (Africa because of wars). Unless poverty is reduced, there never will be a food-secure world, no matter how much food is produced.

Part Two: Feeding the World in the 21st Century—Challenges Ahead

A. World Food Supply

Table 1. World Food Supply, 1998
(update of 1988 Britannica feature article)

1) Dependence on the land for 99% of our food supply; only 1% from the oceans and inland waters. (A third source of food, microbial fermentation is used primarily to produce certain vitamins and amino acids. These products are important nutritionally, but the quantity is small.)

2) Plants account for 92% of our food supply. The eight cereal species (maize, wheat, rice, sorghum, barley, millet, oats and rye) account for 70% of our food supply.

3) Animal and fish species account for 8% of our food supply (calories) although a much larger percent of our protein intake.

4) Equity issues in food availability. 80% of the world gets 70% of their calories directly from plants (Third World diet). 20% of the world gets 70% of their calories from animal products (Industrialized world diet). If all the word ate a Third World diet, there is roughly enough food produced today for 6.8 billion people. On the other hand, if everyone ate an Industrialized world diet, there is only enough food produced to feed about 3 billion, or half of the world population.

B. Future food demand and supply projections and challenges

1) Population projections, 2000-2020. Ninety percent of world population growth will occur in the developing countries, and among poor people, mainly in Asia and Africa. It is increasingly clear that the impact of AIDS in sub-Saharan Africa is likely to be substantial.

2) IFPRI 2020 projections on food demand and supply (Table__). Production will have to be increased by 50-80%, depending upon how fast the incomes of the poor rise in developing countries.

3) Declining availability of new land for farming and irrigation. Only in the ***Cerrados*** of Brazil and parts of central and southern Africa are there still large tracts of unused land suitable for agriculture.

3) Global crop yields must be doubled in the next 20 years. Most of the increased in food production must come from the lands currently in cultivation. To double yields in environmentally sustainable ways is one of the great challenges facing humankind and the scientific community.

4) Rapid rural migration to urban areas in low-income, food-deficit countries—shifting from subsistence food producers to poor food consumers. Urgent need to develop commercial and modern agriculture.

C. Modernizing traditional agriculture—a world divided

1) Contrast between a U.S. farm and a smallholder African farm

   a) Farm size
   b) Traction power (human, animal, motor).
   c) Input use
   d) Labor efficiency

   Table__. Person-hours for farmers to produce one ton of maize in selected countries using different levels of technology (USA, Europe, Asia, Africa).

2) Technologies already exist—or are well-advanced in the research pipeline—which to keep global food supplies growing ahead of demand, at least for the next 20-25 years, if farmers, especially in the low-income, food deficit nations, are permitted and able to employ them.

D. Prospects for genetic engineering

1) Improved tolerance/resistance to biotic (diseases, insects) and abiotic stresses (drought, salt, cold, heat, mineral toxicities).

2) Increasing maximum genetic yield potential of major crop species.

3) Improving nutritional (and possibly medicinal) qualities of major crop species.

4) Fixing nitrogen from the atmosphere in non-leguminous crop species, such as the cereals.

E. Science and technology policy imperatives

1) Educating urban populations—who have lost their roots to the land—about agriculture and biology. Need for an informed population to make informed judgments.

2) Assuring equitable access to the benefits of biotechnology for all.

3) Balancing food and fiber needs for a growing world population with conservation of global natural resources.

4) Assuring that agricultural modernization in food-deficit, low-income, agrarian-based nations is given high priority.