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Grand missions of agricultural innovation

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ABSTRACT

This paper discusses three related examples of mission-oriented agricultural institutional innovations associated with substantial crop yield increases in the 20th century. It begins with the implementation of the United States Land-Grant System and then discusses in turn the planning and implementation of the two grand missions that led successively to the yield increases in wheat and rice that heralded the onset of the "Green Revolution." It notes the remarkable role of the Rockefeller Foundation in identifying these two missions, and selecting personnel developed within the land-grant system to execute them with remarkable effectiveness.

> Whosoever could make two ears of corn or two blades of grass to grow upon a spot of ground where only one grew before, would deserve better of mankind, and do more essential service to his country, than the whole race of politicians put together.
> Jonathan Swift, Gulliver's Travels

1. Introduction

The past century and a half have seen a high rate of increase in food demand induced by historically high rates of growth of both population and personal incomes. The percentage of that population working on farms has plummeted, while recruitment of new cropland has been relatively modest (Pardey and Beintema, 2001). The increased share of animal products in human diets has increased the plant calories needed as feed to support a given supply of food calories per capita. Yet the world's current population is both far larger and much better fed (Fogel, 2004).

How was this achieved? Machines have substituted for human labor. Off-farm inputs, including chemical fertilizers that have replaced on-farm nutrient recycling and fossil fuels, have replaced the original agricultural biofuels used as feed for animal draught power. But the major driver of the transformation of agriculture has been increased productivity of the handful of crop species that supply most of the caloric needs of the global population. This was made possible by innovations that public and nonprofit institutions have achieved in organizing and executing agricultural innovation.

The organization of agricultural innovation reflects the fact that, relative to other sectors, agricultural production of plants and animals is much more geographically dispersed and adapted to the local environment. The fundamental influence of the spatial heterogeneity of relevant features of the growth environment is especially important for plants. It means that research and development programs for the crops that supply most of the caloric needs of mankind cannot be centralized. Adaptive research is often needed to apply general agricultural advances in a given region, and continual applied innovation is often necessary to maintain existing local production capacity in a never-ending battle with pests and diseases.

Agricultural innovations with more widespread potential applicability will, *ceteris paribus*, tend to generate more social surplus. Since such generally applicable innovations usually require local adaptation, full development and diffusion might take years, if not decades. Source-region producers might gain from adopting innovations more quickly than their competitors, before prices are much affected. But most of the benefits from agricultural innovations shift to consumers as the innovations diffuse and make agricultural products more affordable and available. At best, producers tend to receive a minor share of the eventual benefits.[2] Not surprisingly, the national consensus needed to fund large innovative advances that will lower the price of food has rarely been observed. Until the

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[2] If these innovations can be monopolized via patents or by other means, including hybridization, much of this surplus can be collected as rents. Hence, it has long been possible for the private sector to dominate the breeding of hybrid corn seed and many hybrid horticultural varieties.

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19th century, the rate of yield increase was very slow, and hunger was commonplace worldwide.

One area in which national innovative efforts that benefit agriculture have a long tradition is the introduction of new plants and animals from other countries. Since the dawn of recorded history, leaders have sent expeditions to acquire plant genetic material appropriate for given production environments or for meeting particular consumer needs. For example, in 1495 B.C., Queen Hatshepsut of Egypt sent an expedition to Ethiopia to collect frankincense or myrrh trees.[3]

At the onset of the industrial revolution, achievement of increased agricultural productivity, globally and nationally, was considered a noble goal, as the opening quote from Swift implies. Heightened recognition of the economic value of plants, and the need for their scientific documentation and classification, encouraged the spread of botanic gardens across Europe in the 18th and 19th centuries. In particular, Britain's Royal Botanic Gardens at Kew excelled in the acquisition, development, and dissemination of economically important plants (Juma, 1989). Experimentation with domestic plants by a London physician with boyhood experience of plant collecting in Jamaica led to his invention in 1829 of the Wardian Case, or terrarium, an enclosed glass container. This vastly increased the efficiency of international transportation of live plants between the new and old worlds (Schoenermarck, 1974). For example, use of the Wardian case reduced losses of plants shipped from China to England from 99.9% to 14%. Sir William Hooker of Kew Gardens imported six times as many plants in 15 years, using the case, as had been introduced to the Gardens in the previous century (Juma, 1989, p. 47). But significant increases in the growth of yields of major staple food crops did not occur until the 20th century.

In this paper, I discuss three related examples of mission-oriented agricultural institutional innovations associated with substantial yield increases in the 20th century. Section 2 discusses the implementation of the United States Land-Grant System as an institutional innovation that was the culmination of a grand mission. Then, in Sections 3 and 4, I discuss the planning and implementation of the two grand missions that led successively to the yield increases in wheat and rice that heralded the onset of the "Green Revolution." Human capital developed in the land-grant system at a time when it helped tilt the trends in United States crop yields sharply upwards and was crucial to the success of these later missions. They in turn provided the lead models that were followed by the larger group of centers that today constitute the Consultative Group on International Agricultural Research (CGIAR). In Section 5, I consider the relation in these grand missions between underlying motives, the choice of mission, and the technological solution. A brief conclusion follows.

2. The development of the U.S. land-grant system

From the beginning, U.S. political leaders, including George Washington, Benjamin Franklin, and Thomas Jefferson, understood the benefits of acquiring diverse plant and animal resources and endeavored to introduce improved plant varieties into the country. Echoing Swift, Jefferson wrote, "The greatest service which can be rendered any country is to add a useful plant to its culture" (1904–1905). He backed up his words with action, going so far as to smuggle rice from the Piedmont region of Italy into the United States, sewn into the lining of his coat pockets, even though such a crime was punishable by death (Fowler, 1994).

Henry Ellsworth, the first commissioner of the Patent Office, shared Jefferson's enthusiasm for the acquisition and distribution of novel plant varieties. In search of varieties that might be useful to farmers, Ellsworth distributed seed and plant material acquired from other lands. The U.S. Patent Office thus became the main repository for plant genetic material in the country, while the U.S. Navy imported foreign seed and the U.S. Post Office disseminated those seeds through the mail. Ellsworth produced a number of documents on proven and potential economic benefits of plant resources, and championed federal support for agriculture and the creation of an independent national agricultural research bureau. Since farmers have shared their seeds and their local innovations with neighbors from time immemorial, it is natural that the largely agrarian nation would support pubic distribution of new breeding materials. In 1839, Congress began formally to support seed collection, distribution, and research efforts by establishing the Agricultural Division of the Patent Office, which became the United States Department of Agriculture (USDA) in 1862 (Harding, 1940; Huffman and Evenson, 2006). By its very genesis, the USDA was identified with the encouragement of innovative activity and with the implicit recognition that private-sector investment alone would not suffice to achieve optimal innovation in the agricultural sector.

Also in 1862, in the foundational 1862 Morrill (Land-Grant Colleges) Act (7 U.S.C. § 301 et seq.), the government signaled that it recognized the benefits of technical education in a democratic system—especially one that suddenly lacked many states with large slave-labor agricultural systems. The adoption of the Act also confirmed the dominance of farmers in the geographically dispersed U.S. electorate. Named for Congressman and later Senator James Morrill of Vermont, the Act allotted 30,000 acres of federal land to each state to support the development of a college to teach agriculture, military tactics (reflecting the exigencies of the Civil War), and the mechanic arts, as well as classical studies, so that members of the working classes could obtain a liberal, practical education (7 U.S.C. § 304).

Like most great innovations, the Act originated in the mission of one man. Jonathan Baldwin Turner from Worcester, Massachusetts, a Yale-educated Congregational minister, moved to Illinois in 1833 to teach "rhetoric and belles-lettres" at Illinois College, an aspirational "Yale of the West." He was also a farmer who experimented in horticulture and is credited with identifying the Osage orange, a native of Arkansas, as the best hedge plant to choose for prairie fencing.[4] In 1848, after leaving Illinois College, he displayed visionary rhetorical creativity in suggesting to John Blanchard, President of Knox College, that the college should create a professorship in the "green Earth" (with vaguely specified responsibilities).

In 1851, Turner presented an address at Granville Illinois. His "Plan for an Industrial University in the State of Illinois" focused on the need to educate farmers and mechanics "in the science and art of their several pursuits" (Brown, 1962, p. 376). In the following year, in a letter to the *Prairie Farmer*,[5] Turner urged that "if farmers and their friends will now exert themselves they can speedily secure for this State, and for each State in the Union, an appropriation of public lands adequate to create and endow in the most liberal manner, a general system of proper Industrial Education . . .." (Turner, 1852).

Turner's proposal,[6] including the land-grant idea, was circulated in Illinois and beyond as the "Granville Plan." In June 1852,

[3] Juma (1989) gives several other examples of early plant-collecting expeditions.

[4] The account here on Turner's role in the mission to establish a national land-grant educational system relies principally on Brown (1962).

[5] *Prairie Farmer*, XII (March, 1852), 114.

[6] The Turner initiative was innovative in combining familiar elements in a new application. The idea of practical tertiary education was embodied in the private Rensselaer Polytechnic Institute founded in 1824, and the use of land-grants to support education had been implemented by the Congress of Federation, which in