to test the efficacy of 'anti-aggression' medications or for studying the effects of alcohol and other drugs on aggressive behavior.

4. Postscript

This article has focused primarily on one example of agonistic behaviors, namely aggression. The need for quantitative measures to study aggression was emphasized, as well as the problems related to predicting aggressive behaviors. It is important to realize that there are different types of aggression with different sets of precursors or risk factors for each. The greatest hindrance to advancing aggression research at this time is the lack of a discipline-neutral model which can be used to synthesize discipline-specific data in the search for precursors of aggression.

See also: Aggression in Adulthood, Psychology of; Behavior Therapy: Psychiatric Aspects; Hypothalamic–Pituitary–Adrenal Axis, Psychobiology of; Neurotransmitters; Sex Hormones and their Brain Receptors

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E. S. Barratt

Agricultural Change Theory

Agricultural change refers not just to the difference between the first plantings 10,000 years ago and today's computerized, industrialized, genetically engineered production systems; agricultural change occurs on a daily basis, as farmers in every country of the world make decisions about what, where, and how to cultivate. The importance of the topic goes well beyond how much food is produced, how much money is made, and how the environment is affected: agriculture is intimately linked to many institutions in every society, and to population. This article examines the most influential theories of agricultural change in general, with particular emphasis on the role of population growth.

1. Overview

Scholarship on agricultural change has been anchored by two small books with enormous impacts, both focused on the relationship between farming and population. In 1798, British clergyman Thomas Malthus argued for an intrinsic imbalance between rates of population increase and food production, concluding that it was the fate of human numbers to be checked by 'misery and vice'—generally in the form of starvation and war. Although intended mainly as an essay on poverty, population, and Enlightenment doctrines, *An Essay on the Principle of Population* (Malthus 1798) infused popular and scientific thought with a particular model of agricultural change, in which a generally inelastic agricultural sector characteristically operated at the highest level allowed by available technology.

In 1965, Danish agricultural economist Ester Boserup claimed to upend this model of agriculture by arguing that, particularly in 'primitive' agricultural systems, farmers tended to produce well below the maximum because this allowed greater efficiency (output:input ratio). She maintained that production was intensified and additional technology adopted mainly when forced by population.

Each model is quite simple—dangerously oversimplified, many would now argue—but they provide invaluable starting points from which to address the complexities of agricultural change.

2. Malthus

Malthus's famous maxim from *Population* was that 'the power of population is indefinitely greater than the power in the earth to produce subsistence for man… Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio.' Subsequent empirical research has made this position appear dubious. He used sketchy accounts of population booms in New World colonies to show that unchecked populations double every 25 years, but such growth rates have been shown to be highly exceptional. His view of agricultural production as relatively inelastic, with output increasable chiefly by bringing more land into tillage, has also fared poorly in subsequent comparative agricultural research.

Equally problematic has been the correlation of Malthus's 'positive checks' of starvation and warfare with populations outpacing their food supply. As Sen (1981) shows, famines result from political failures more than from inability of agriculture to keep up with population. For instance, history's greatest famine, which claimed 30–70 million Chinese peasants during Mao's Great Leap Forward in 1958–60 (Ashton et al. 1984, Becker 1996), was no Malthusian disaster, although in 1798 Malthus had opined that Chinese numbers 'must be repressed by occasional famines.' In fact, population had grown substantially since then, and has grown more since recovering from the Great Leap Forward; Chinese peasants have shown a historic capability of feeding themselves at such densities, principally through the ingenuity of highly intensive wet rice cultivation (Bray 1986). (The 1958–60 famine resulted from policies that disrupted locally-developed intensive practices as well the social institutions needed to sustain those practices (Becker 1996, Netting 1993)).

The Malthusian perspective nevertheless has proved remarkably durable in its effects on common perceptions and theories of agricultural change. Its survival is probably less related to empirical analysis than to the ways theories of agricultural change affect, and are affected by, their political context. For instance, Malthus wrote during the early stages of the Industrial Revolution in England, a time marked by a rapidly growing urban underclass and debates about obligation to feed them. Subsuming food shortages under inexorable laws of population and agricultural change was obviously appealing to prosperous segments of society, and Malthus was rewarded with a chair in political economy at the University of Haileybury. When the Irish Potato Famine hit in the late 1840s, it was widely interpreteted as a Malthusian disaster, despite Ireland's relatively low population density and the fact that food exports continued (in fact, increased) throughout the crisis (Ross 1998). The British director of relief efforts, a former student of Malthus at Haileybury, characterized the famine as 'a direct stroke of an all-wise and all-merciful Providence' (Ross 1998, p. 46).

Most recently, the perpetuation of the Malthusian perspective on agricultural change can be seen in debates on the merits of genetically modified (GM) crops. Parties in government, industry, and biological science with vested interests in GM products routinely cite famine and malnourishment in developing countries as a justification for the technology. The notion of an inelastic agriculture incapable of feeding the populace is entrenched enough that few question this claim, despite lack of evidence pointing to inadequacy of current crop plants or even the likelihood of GM plants offering higher levels of production.

3. *Boserup*

Boserup's *The Conditions of Agricultural Growth* (1965) brought an important new perspective on agricultural change. Since Malthus's time, there had been much comparative agricultural research, especially on peasant (i.e., not entirely market-oriented) systems, which Boserup used in developing a 'dynamic analysis embracing all types of primitive agriculture' (1965, p. 13). Rather than technological change determining population (via food supply), in this model population determined technological change (via the optimization of energetics). This countered Malthus's assumption that agricultural systems tended to produce at the maximal level allowed by available technology. Instead, land was shown often to be used intermittently, with heavy reliance on fire to clear fields and fallowing to restore fertility in the widespread practice of 'slash and burn' farming (Boserup 1965, p. 12). Therefore, comparisons of agricultural productivity had to be in terms of output per unit of land per unit of time—what some call 'production concentration.'

Boserup held that extensive agriculture with low overall production concentration is commonly practiced when rural population density is low enough to allow it, because it tends to be favorable in total workload and efficiency (output:input). Rising population density requires production concentration to rise and fallow times to shorten. Contending with less fertile plots, covered with grass or bushes rather than forest, mandates expanded efforts at fertilizing, field preparation, weed control, and irrigation. These changes often induce agricultural innovation but increase marginal labor cost to the farmer as well: the higher the rural population density, the more hours the farmer must work for the same amount of produce. In other words: as the benefits of fire and fallowing are sacrificed, workloads tend to rise while efficiency drops. It is because of this decreased labor efficiency that farmers rarely intensify agriculture without strong inducements, the most common inducement being population growth. Changing agricultural methods to raise production concentration at the cost of more work at lower efficiency is what Boserup describes as agricultural intensification (Fig. 1).

The model of peasant agriculture being driven by optimization of energetics, with population serving as the prime engine of change, brought a sea change in agricultural change theory. Boserup's name has become synonymous with this perspective, and indeed it was in *The Conditions of Agricultural Growth* that it was crystallized, but others have contributed significantly to this perspective. Most notable was the Russian economist Chayanov (1925), who analyzed peasant farming in terms of energy optimization, with change driven mainly by the demographic makeup of households.

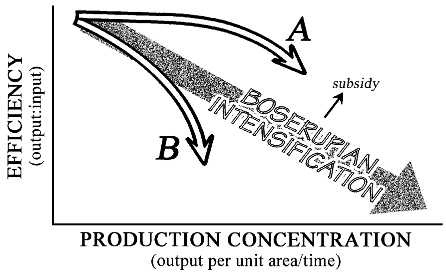

Figure 1
Schematic view of relationships between production concentration and efficiency (output:input) of agricultural methods

Agricultural change theory has now been carried far beyond the simple outlines presented in 1965. Boserup initially stressed that intensification's costs came in the field as fallows were shortened, but she (1981, p. 5) and others have also identified other modes of intensification. Capital-based intensification is characteristic of industrialized societies. The amount of human labor required to produce food generally decreases, whereas the total direct and indirect energy costs can climb to exceedingly high levels. In infrastructure-based intensification, the landscape is rebuilt to enhance, or remove constraints on, production. Land improvements used well beyond the present cropping cycle—such as terraces, ridged fields, dikes, and irrigation ditches—are termed 'landesque capital' (Blaikie and Brookfield 1987). Since landesque capital depends on long-term control (although not necessarily formal ownership and alienability), Boserup posited a general association between intensification and private land tenure, which has been supported in subsequent research (Netting 1993).

At a very general level, the Boserup model of agricultural change has been found to fit fairly well: farmers with abundant land do tend to rely heavily on methods that are land-expensive and labor-cheap; farmers under more crowded conditions do tend to adopt labor-expensive (or capital-expensive) methods; and the decline in marginal utility on inputs does offer a causal mechanism for the change. The model has an impressive record of empirical support from both cross-cultural and longitudinal studies, and it has been indispensable in explaining cross-cultural agricultural variability (Netting 1993, Turner et al. 1977, Turner et al. 1993, Wiggins 1995).

4. *Post-Boserup Research*

The Boserup model has been widely influential, but its broad-brush success comes at the cost of neglecting many important aspects of agricultural change, and researchers from various fields have fault it. Major factors shaping agricultural change beyond Boserup's simple model may be grouped into the categories of ecological, social, and political-economic.

4.1 *Ecological Variation*

Boserup depicts intensification as a universal process cross-cutting environment, but her model relies heavily on agroecological features of fire and fallow that are hardly universal. Thresholds of intensification vary with local environment (Brookfield 1972, p. 44), and the relationship between production concentration and efficiency may be quite variable among environments (Turner et al. 1977, Turner and Brush 1987).

Figure 1 schematically depicts different concentration/efficiency trajectories. The large arrow represents the global pattern emerging from the many cases where productive concentration can be raised, but only at the expense of lowered efficiency. This is the broad pattern confirmed by the empirical studies cited above: Boserupian intensification, defined as the process of raising production concentration by accepting higher labor demands and lower efficiency. In general, this trajectory fits when the labor costs of intensification are both necessary and sufficient to raise production concentration: necessary in that higher production requires proportionately more work, and sufficient in that the proportionate increase in work succeeds in raising output. Where lowered efficiency is not necessary for higher production concentration, the slope would be flatter, as indicated by non-Boserupian trajectory A. The other non-Boserupian pattern occurs where productive concentration cannot be raised, or where the cost of raising it is intolerable: trajectory B. Such a trajectory requires nonagricultural responses to rising population pressure (Stone and Downum 1999).

Although the issue is by no means settled, paddy rice production appears to exemplify trajectory A in many cases. Although it requires high labor inputs (e.g., Clark and Haswell 1967), the pattern of declining yields may be overridden by the distinctive ecology of the paddy in which fertility tends to increase rather than decrease (Bray 1986). Trajectory B is exemplified by arid areas where increasing inputs into reduced land areas cannot overcome the moisture limitations on crops, and would only serve to increase risk (Stone and Downum 1999).

4.2 *Social Factors*

Social context affects both the demands for agricultural products and the relative efficiency of different production methods. Food requirements may be affected not only by calorific needs but by what

Brookfield (1972, p. 38) calls social production, meaning 'goods produced for the use of others in prestation, ceremony and ritual, and hence having a primarily social purpose.' Among New Guinea groups, Brookfield observed production levels that were 'wildly uneconomic' in terms of energetics, but which earned a very real social dividend.

But agriculture is not only practiced partly for social ends; it is practiced by social means, which can have marked effects on how agricultural methods respond to changes in population. Nonindustrialized agriculture is run largely through social institutions for mobilizing resources. Therefore, efficiency of production strategies can vary culturally, and even a purely 'calorific' analysis must consider social institutions that affect costs and benefits.

A comparison of Kofyar and Tiv farmers in central Nigeria provides an example. Expanding out of a crowded homeland on the Jos Plateau, Kofyar farmers began to colonize a frontier near Assaikio in the 1950s. By the early 1960s, there were Kofyar living in frontier communities with population densities below 10/km^2 and agriculture was mostly extensive. By the mid-1980s population density had risen to 100/km^2 and there had been considerable agricultural intensification, with a mean yearly labor input of over 1,500 hours per person (Stone 1996). Intensification was aided by the social institutions that facilitated intensive farming in the homeland, including social mechanisms for mobilizing labor with beer, food, cash, specific reciprocity, or generalized reciprocity. The Kofyar found the main alternative to intensification—migration—expensive and risky, and tended to avoid it.

Nearby were Tiv farmers whose agricultural trajectory followed a different course. Tiv began migrating northward in the 1930s from a homeland known for settlement mobility (Bohannan 1954), and settlement was also highly mobile in the Assaikio area. Their population densities grew more slowly than the Kofyar's, and they showed a clear aversion to the intensification of agriculture. Where the Kofyar had relied on pre-existing institutions for mobilizing labor to facilitate intensification, the Tiv relied on a set of interlocking institutions to facilitate movement (Stone 1997). As long as they could maintain a relatively low population density, they could keep in place an agricultural regime that was extensive enough to allow substantial amount of free time. Much of this time went towards travel and development of social networks that lowered the costs and risks of moving.

4.3 The Role of Political Economy

Agricultural change is shaped by external economic systems, and most farmers have to contend with economic factors that affect the cost of inputs and value of output beyond local energetics. Market incentives can induce farmers to intensify in the absence of land shortage (e.g., Turner and Brush 1987). Eder's (1991, p. 246) observation that farmers 'make their production decisions in terms of pesos per hour, not kilograms per hour' is apt, although it is not so much a cash/energy dichotomy but a gradient. Few small farmers today grow crops exclusively for subsistence or sale; most do both, and they often favor crops that can be used for food or sale. Market involvement does not totally negate the Boserup model (Netting 1993), but it clearly introduces variables that can override effects of local population and energetics.

But of the factors neglected by the Boserup model, the most critical to many contemporary scholars is the variation in farmers' ability to intensify agriculture as they may wish (e.g., Bray 1986, p. 30). As Blaikie and Brookfield (1987, p. 30) put it, the Boserup model 'may be likened to a toothpaste tube—population growth applies pressure on the tube, and somehow, in an undefined way, squeezes out agricultural innovation at the other end.' Even within a single set of ecological, technological, and demographic conditions, population pressure may prompt very different patterns of agricultural change because of differences in farmers' ability to invest, withstand risk, and attract subsidy. While population pressure may stimulate technological change and creation of landesque capital, 'what appears at the other end of the tube is often not innovation but degradation' (Blaikie and Brookfield 1987, p. 30). For instance, Durham's analysis of environmental destruction in Latin America compares two separate feedback loops, both of which include population increase (Durham 1995, pp. 252–4).

The 'capital accumulation' loop leads to intensified commercial production and land concentration, while the 'impoverishment' loop leads to deforestation and ultimately reduced production; the loops feed each other.

The Boserup model is resolutely local in outlook: the cost and benefit of an agricultural operation such as plowing or tree felling is reckoned on the basis of effort required and crops produced. This holds constant the effects of external subsidy that is often available. Farmers may well achieve a higher marginal return on efforts to attract subsidy (e.g., fertilizer from a government program, irrigation ditches constructed by an NGO, or new seed stocks from a development project) than on plowing or tree felling. From the farmer's perspective, this allows new possibilities of raised production, as represented by the small arrow in Fig. 1. There may have been no absolute improvement in efficiency at all, merely a shifting of some costs to the outside by capturing subsidy. The ability to attract such subsidy is politically mediated, and it often varies sharply among segments of a farming population.

See also: Agricultural Sciences and Technology; Agriculture, Economics of; Farmland Preservation;

Internal Migration (Rural—Urban): Industrialized Countries; Population and Technological Change in Agriculture; Population Cycles and Demographic Behavior; Population Ecology; Population Pressure, Resources, and the Environment: Industrialized World; Rural Geography

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G. D. Stone

Agricultural Sciences and Technology

1. Introduction

The agricultural sciences and technology are usually seen to encompass the plant, animal and food sciences, soil science, agricultural engineering and entomology. In addition, in many research institutions related fields such as agricultural economics, rural sociology, human nutrition, forestry, fisheries, and home economics are included as well. The agricultural sciences have been studied by historians, economists, sociologists, and philosophers.

Most of the early work in Science and Technology Studies focused on physics, said to be the model for the sciences. Unlike the agricultural sciences, theoretical physics appeared disconnected from any clear social or economic interests. Indeed, one early study of the agricultural sciences described them as deviant in that they did not follow the norms found in physics (Storer 1980).

Prior to the 1970s studies of the agricultural sciences tended to be apologetic and uncritical. Then, critical historical, economic, sociological, and philosophical studies of the agricultural sciences began to emerge. These studies built on earlier work that was not within the purview of what is usually called STS. Moreover, despite attempts to incorporate perspectives from this field, it would be an exaggeration to say that studies of the agricultural sciences form an integrated body of knowledge. Indeed, fragmentation has been and remains the rule with respect to theoretical frameworks, research questions, and methods employed.

2. History

Recent historical studies have challenged the hagiographical approach of official histories, demonstrating how the organizational structure of agricultural science encouraged particular research strategies and products. Of particular import were studies of the role of the state-sponsored botanical and zoological gardens, and later the agricultural experiment stations, in the colonial project. In particular, historians began