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WHAT IS AGRICULTURAL SCIENCE?

Do we need a new definition?

Gatherers and farmers of ancient times carefully used to balance food production with the availability of environmental resources. In contrast, today's societies are increasingly bringing the environments closer to their limits. Despite growing concerns about this problem, agricultural research faces a crisis of decreased support and funding. Based on past successes of agricultural research, economists have become relatively sanguine about future increases in crop yields, which is the main cause of this decreasing support. We caution against this optimism and show that it is unlikely that the successes of the past can be repeated. Interdisciplinary and new research is needed to assure that in future everyone has access to sufficient food to live a healthy and productive life. For the above mentioned reasons the discussion paper develops a definition of agricultural science from a cultural-historical perspective and points out the relevance of agricultural research for a sustained development of the global food production system.

Ancient gatherers and farmers

It was one of those cold, humid and windy spring days in 1950 when two brothers, Emil and Viggo Hojgaard, went out to the murky swamplands of central Jutland in Denmark to carry out their profession. They were peat diggers. As they were digging in the bog they found a male corpse with a rope around its neck and believed they had discovered a murder victim. Yet, strangely, the body had come to rest in a flattened state, something the two brothers had never experienced before. The authorities told them later that bogs contain acids called tannins, which speed up bone decay and turn skin into leather, thereby preserving it for hundreds of years. The suspected murder victim was in fact around 2400 years old and belonged to a group of people which had lived in northern Europe during the time of the Roman Empire. He was named after the place where he had been discovered, Tollund. The exact circumstances of his death have never been clarified, as with other bog mummies that were found with slit throats, broken skulls, and ropes around their necks. But one of the mummies that were unearthed revealed a scientific sensation: Grauballe Man, as the mummy was called, was so well preserved that researchers were able to analyze the remains of the last meal he had eaten. It was composed of 60 different plant species. After further examining his teeth and hair they concluded that Grauballe Man was a vegetarian gatherer who had a very diverse diet.

At the same time a murderer in central Jutland was getting rid of his victim, 3.500 km further south a family harvested a barley field in the central highlands

Fig. 1
Tollund Man, a bog-mummy found in the swamplands of central Jutland in Denmark. (Silkeborg Museum, Denmark. Reprinted with permission.)

Fig. 2
Barley, pistachio, almond and olive trees grown in an ancient runoff farm in the Negev desert. In the background are the remains of the Nabatean city of Avdat, which was established in the 3rd century BCE. It was a service station located at an ancient spice route and was home of about 400 families.

of the Negev desert. The family belonged to an ancient nomadic tribe assumed to have originated from the wastelands of northern Arabia. The Nabateans, as the tribe was called, had infiltrated the southern areas of Transjordan during the Persian period, where they mixed with the remnants of the former Edomite kingdom. They assimilated the Aramic script and language as well as their knowledge of agriculture. Later, they developed the science, and art, of desert agriculture and living to a degree that is astonishing even by today's standards. From aimless nomads the Nabateans became rich traders, operating a dense network of service stations and cities along ancient trade routes on which camel caravans transported spices, silk, ivory, and medical herbs priced as high as today's perfumes, drugs, and cosmetics.

Food, environment and knowledge generation

From a historical perspective, it is amazing that two cultures existing in parallel developed such remarkably different adaptation strategies to cope with their environments. While bog people had options available to carry out highly productive agriculture, as shown today, they were simply not aware of these options. On the other hand, living under the extreme water-scarce conditions of an arid desert environment, the Nabateans developed sophisticated hydraulic structures for harvesting rainwater to provide them with a sustainable and sufficient food supply.

There was obviously a great difference in knowledge and experience between these two cultures about how to survive in their given environments, letting us wonder about the possible causes. Essentially, this brings us to the question what drives human reasoning?

At the beginning of our planet's life history creatures were able to perceive impressions of their environment and to respond to them with reflex actions. Crocodiles are probably a good example for such creatures. Then there came a time when creatures were not only able to perceive, but also to store information in their memory, thereby collecting individual experience. Every time they were now confronted with a new situation they had to distinguish whether it resembled older information or not. As they gained more experience they developed behavioral patterns. As populations were growing, creatures were not only learning individually, but also shared information by passing experience from one to another, a process which has been called time-binding. Yet, it was also likely that passing information transmitted a disease in the form of mistaken ideas. In consequence, humankind developed an intelligent mechanism to avoid these mistakes by means of critical reflection. By continuously rechecking new direct experience, they were able to quantify the validity of given theories and to determine their logical and empirical contents.

If this definition of human reasoning applies to both the bog people and the Nabateans, their different knowledge and experience did not necessarily result from different levels of intelligence. It is more likely that they simply developed different adaptation modes to cope with their environments.

Low population pressures, sufficient environmental resources and food caused the bog people to become gatherers. Gathering food wasn't a simple task because it included the risk of consuming poisonous plants. If the bog people had been dogmatic, which is a less intelligent way of seeking problem solutions, they would have been unsuccessful in developing a distinguished and well known cultural heritage. Eating 60 different plant species during the same meal involves a 60 times the risk of failure. In statistical terms, Grauballe Man was extremely successful in making the right choices about his food. Unfortunately, this didn't help him much. He had had his throat cut and probably suffered fractures of the skull and legs.

The Nabateans lived in a desert environment with extreme water-scarcity and low plant productivity so gathering was not an option. Initial experiences gained during their passage through Tansjordan made them pay attention to ways of improved water utilization under desert conditions. There were many options to gather, conserve and utilize water in this desert. Yet, the Nabateans quickly detected the major source of water in the Negev, which was surface runoff during

Fig. 3
Ancient rainwater harvesting systems in the Negev desert. A runoff channel is clearly visible in the foreground.

wintertime. By careful observation and experimentation they designed and optimized various types of rainwater harvesting systems that were each well adapted to their immediate environment. They also developed cropping patterns to reduce the risk of crop failure caused by the large variability of annual rainfall in the Negev. The Nabateans were so successful in adapting their technology to desert conditions, that their farmsteads are still used today, after 2000 years. This success was only possible by the cumulative experience of generations, based upon trial and error, careful observation and an interest in diverse areas such as soil physics, hydrology, botany, and economy. Their success is also proof that they were capable of integrating different knowledge areas. The product of this integration process later came to be known as agricultural research.

Agriculture and food consumption today

Today's relationships between agriculture and food consumers are very different from previous times. Despite having access to a vast knowledge base, it seems that we have lost the capabilities of our ancestors to carefully balance food production with environmental constraints. When seeking for the possible reasons for this strange illogical development, we have to distinguish between societies living in more and less developed regions.

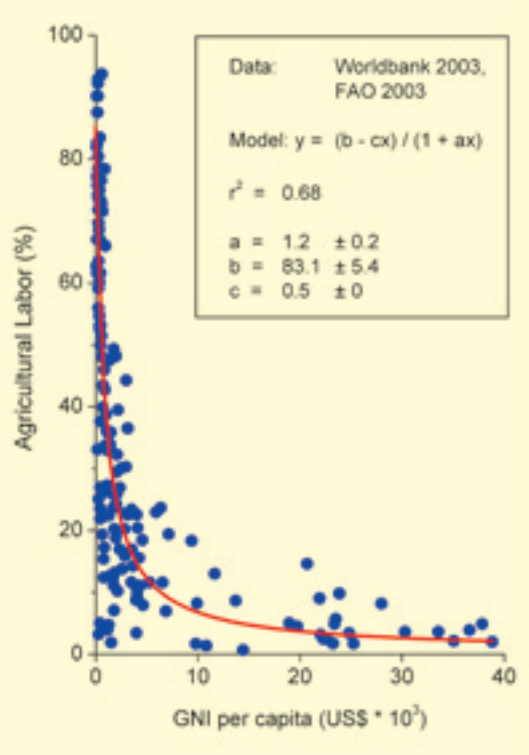

Fig. 4
Relation between per capita income (GNI=Gross National Product, Atlas Method) and share of agricultural labor in the total working population, 160 countries

Population growth in developed countries has stabilized to a level which is close to zero or even declining. Their societies are rich and underwent several stages of transition when approaching the information age. Typically, less than 5 percent of the total population is directly involved in food production. Consequently, the majority of people lost their ability to carefully balance food requirements with environmental constraints. They take abundant food availability for granted and are busy working in other fields, producing high levels of national income. Unlike our ancestors, people of the more developed world are generally less physically active and increasingly show symptoms of obesity. These problems are mainly due to changes in diet such as consuming more refined sugars and fat. This has now led to a situation, where consumers are increasingly becoming aware of health and food quality issues. There are also growing concerns about maintaining our quality of living, which cause increasing support for the development of more sustainable agricultural systems. Yet, being concerned about quality, health, and sustainability issues doesn't necessarily mean that people of the more developed world regained the capabilities of their ancestors to carefully balance food production with environmental constraints. Constantly expecting lower food prices, while at the same time asking for increasing food and environmental qualities is not an indication that rich societies are really aware of the value and mechanisms of food production.

Unlike most areas of the more developed world, food production in less developed countries is severely limited by soil and water resources. People living in these areas are often more aware of the relationships between food production and environment. Yet high population growth rates increasingly bring the environments closer to their maximum capacities. Projections of the International Food Policy Research Institute in Washington forecast the gap between production and market demand for cereals to widen from 1 million tons in 1990 to 24 million tons in 2020 in South Asia, and to triple to 27 million tons in 2020 in Sub-Saharan Africa. Increasing population pressures paired with a degradation of natural resources are accelerating food insecurity in the poorer countries. Today, 800 million people are food insecure. This means, they do not know where they can find their next meal. 165 million pre-school children are malnourished and are thus not able to grow to their full capacity. About 15 children are dying every minute from nutrition-related illnesses. The question is whether this trend is going to continue. Based on past successes of agricultural research, economists are relatively sanguine about future increases in agricultural production. Their projections have led to recent decreases in publicly-funded agricultural research, which is targeted at improving food security in less developed countries. As a consequence, several research institutions like the Consultive Group of International Agricultural Research (CGIAR) have experienced severe budget cuts and are threatened in their very existence.

There are several factors indicating that past successes of agricultural research are unlikely to bolster future linear increases in crop yields: First, the three innovations that caused the Green Revolution in the 1960s – cheap nitrogenous fertilizers, dwarfing, and weed control – seem to be unique. They cannot be repeated. Second, there are severe doubts that agricultural land suitable for crop cultivation is expandable. In fact, there has been no significant increase since the early 1960s. In addition, there are alarming signs that arable land will even decrease due to urbanization, erosion, desertification, salination and toxification. These must all be combated. Third, there is an increasing competition between agriculture, industry and rural households for the most precious resource in agricultural production, which is water. Recent trends in irrigation indicate a minor increase in irrigated areas. For the future, this means that more food must be produced with less water, which poses a tremendous challenge to a number of environmental sciences. Fourth, agricultural production in marginal areas – that is, where most of the poor live – is unlikely to increase due to environmental limitations, which cannot be surpassed even under the best production scenarios.

Fig. 5
Relation between world population and arable area, average cereal yield, N fertilizer use and irrigated area (following Evans 1998; Updated with recent data from FAOSTAT 2003)

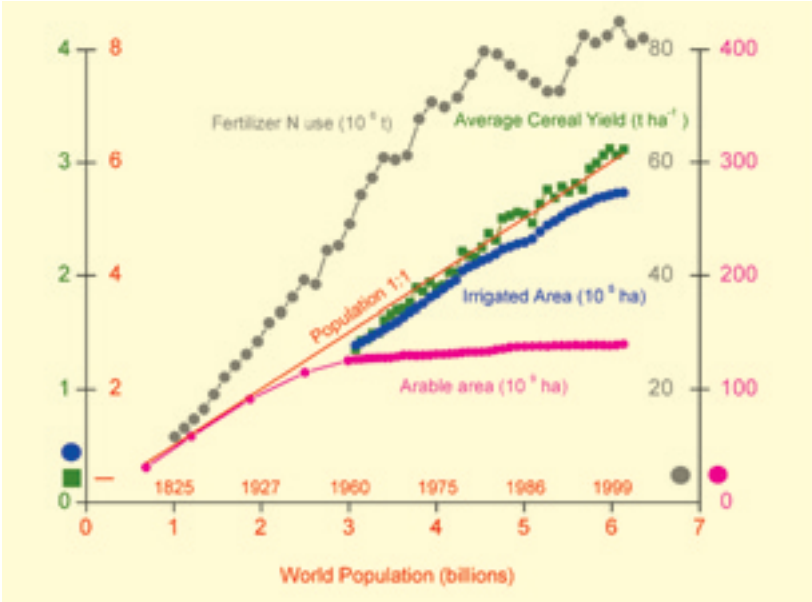

Fig. 6
Computers, modeling and electronics are increasingly used as precision tools in managing agricultural production resources.

Innovating agricultural research

It was the ingenuity of the Nabateans and the bog people that helped them survive in harsh environments and secure their daily food requirements. Unlike our ancestors in Denmark and the Negev desert, we have now access to a paramount knowledge repository of basic natural sciences. The large numbers of food insecure people in the less developed world are proofing, that we are making insufficient use of this knowledge. It is not only our moral obligation but also in our self-interest to stabilize food production and economic growth in these areas. Recent fluctuations in stock-trading demonstrate that destabilizations of the less developed areas directly affect our economies. We are living in one world.

New ways of agricultural production must be sought to secure the food demands of a rapidly growing world population. There is an urgent need for transforming agricultural research towards an innovative and science-based mode. Research must be carried out on different levels of biological organization and integrated to facilitate future increases in crop yield. On one end of the spectrum, molecular biology provides a large variety of options for plant breeding. This includes improvements of physiological functions, as well as pest and disease control. For example, improving the efficiency of CO_2 assimilation by modifying Rubisco – which is the most abundant enzyme in the world and constitutes 20–25% of leaf nitrogen – is a compelling challenge and would, if successful, be a supreme achievement of agro-biological research. On the other end of the spectrum of biological organization, simulation modeling offers a tremendous power to integrate our understanding about complex systems, such as agricultural crops, and to assess the practical risks and consequences of modern agricultural technologies such as genetic engineering.

Defining agricultural science

Agricultural systems are tremendously complex. None of their fundamental processes can be successfully addressed in isolation. Innovative and interdisciplinary research is needed for integrating, rechecking and transforming knowledge in diverse areas of science to assure that everyone has access to sufficient food to live a healthy and productive life. And that is what agricultural science is: the continuous rechecking and integration of knowledge about complex natural systems to balance food production with environmental constraints. Considering how our ancestors tackled their daily lives in often harsh environments our definition seems to be age-old. Whether we need to redefine it, however, will depend very much on the kind of future relations between humankind and nature. Being at the brink of a second green revolution we soon might have to.

We sincerely thank Silkeborg Museum in Denmark for providing us a picture of Tolland Man and for granting us permission to reproduce it in this article

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