TECHNOLOGY AND POWER IN AGRICULTURE

Charles L. Peterson
University of Idaho, USA

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Summary

The use of technology to reduce the drudgery and manual labor required for tilling, planting, cultivating and harvesting a crop has progressed more rapidly in the last 200 years than it had in the previous 5000 years. The adoption of technology allows one person involved in agricultural production to provide enough food and fiber for 128 others, whereas only a century ago one person could provide food and fiber for only 8 others. The development of the internal combustion engine, which made affordable engines available for traction and transport vehicles, made possible the identification and adoption of many other technologies. Other significant technological advances include such things as: tractors, petroleum and fuel, the moldboard plow, the reaper, the cotton gin, electricity (including the Rural Electrification Administration (REA)), the telephone, the combine harvester, fluid power systems, radio, television, the transistor, integrated circuits, delivery of daily papers, rural-centered and urban-centered magazines, market information services, all-weather roads (which gave speedier access to local and distant markets), low-pressure rubber tires, portable sprinkler irrigation, milking machine, refrigeration, twine knotter, automatic self-tying pickup baler, and precision farming, to name only a few. These advances in technology, while making agriculture more efficient, have also raised social questions. Some of these questions are as follows: where are people going to work, how can cities absorb displaced agricultural workers, what environmental issues are related to increased use of petroleum and emissions of “greenhouse” gases, how can machinery be made more safe, and what is the best allocation of our resources?

Stephen E. Ambrose, in the book *Undaunted Courage*, a story that chronicles the Lewis and Clark expedition, wrote the following analysis concerning the advent of technology in America, which would be true in the rest of the world:

A critical fact in the world of 1801 was that nothing moved faster than the speed of a horse. No human being, no manufactured item, no bushel of wheat, no side of beef (or any beef on the hoof, for that matter), no letter, no information, no idea, order, or instruction of any kind moved faster. Nothing ever had moved any faster, and as fast as Jefferson’s contemporaries were able to tell, nothing ever would.

But only sixty years later, when Abraham Lincoln took the Oath of Office as the sixteenth president of the United States, Americans could move bulky items in great quantity farther in an hour than Americans of 1801 could do in a day, whether by land ([40 km/h] on railroads) or water ([16 km/h] upstream on a steamboat). This great leap forward in transportation—a factor of twenty or more—in so short a space of time must be reckoned as the greatest and most unexpected revolution of all—except for another technological revolution, the transmitting of information. In Jefferson’s day, it took six weeks to move information from the Mississippi River to Washington, D.C. In Lincoln’s, information moved over the same route by telegraph all but instantaneously.

1. Technology

Technology was explained by Harold E. Pinches in an article on revolution in agriculture:

Technology in its broadest sense is any practice that is an application of the findings of science.

Only where agricultural production has advanced faster than a people's needs have the economic conditions been created necessary to release larger and larger segments of the population from limited production on the land and thereby enable more and more persons to advance intellectual, cultural, and social development above static folkways.

Where population increases without offsetting advances in agricultural productivity—except where trade and commerce or military conquest draw upon the products of foreign soils—increasing pressures on the sources of livelihood follow. The scale of living declines. Starvation appears. Famine threatens.

Men did seek to augment the capacity of human muscles for some types of work. They turned to the power in the muscles of cattle, buffalo, camels, elephants, horses.

Here is a very important point, though: Inherent in those very animals were obstacles to bringing capacities and methods on the land comparable to capacities and methods used in manufacturing industries.

The work animals were more than power for plowing, hauling and carrying men and goods. They furnished milk and meat, fibers, and hides. Even their bones had uses. Moreover, as long as land was available beyond men's direct needs, work animals could feed on otherwise unused plants and thus convert the outpouring of the sun's energy into usable power and useful products.

To the usefulness of work animals, further, were added feelings of understanding, even affection of man for his animals. These immediate values and feelings obscured or put off recognition of the need for more and different power. They, men and animals, lived and worked together and were adjusted to the conditions and vagaries of nature in their own parts of the world.

Could a farmer of Pharaoh's time have been suddenly reincarnated and set down in the wheat fields of the early 1800s, he could have picked up the grain cradle and could have gone to work with a familiar tool at a familiar job. And then, within the space of 20 years, the methods of crop production underwent greater changes than they had in the previous 5000 years. At one stride, we covered ground where 50 centuries had left almost no mark.

We can fix no single date or decade as the start of this agricultural revolution through technology. Many experimenters during the first half of the nineteenth century sought better horse-drawn tillage implements and horse-powered machines to replace hand labor in planting and harvesting. Shortage of labor and high grain prices during the Civil War speeded up the adoption of machine methods, especially for harvesting small grains. The numbers of horses and mules rose rapidly during the next half century.

The groundwork, the experimentation, the seeking of new ways occupied the first three decades of the twentieth century. The second three decades have brought about a substantially complete technological transformation of American agricultural operations and processes.

Aspects of the transformation are the substitution of mechanical power for human labor or animal power and the use of larger amounts of energy, materials and equipment to modify or control the physical conditions of agricultural production.

Agriculture has been changed from a comparatively self-sufficient status to an expanding market for products of many industries.

At the time of the First World War, horse and mule numbers were at the highest in our history—more than 25 million—but the rate of technological progress had slowed down. The availability of good new land had dwindled to insignificance. One-fourth of the harvested crop was being used to produce feed for power animals.

Development of farm power sources cannot be linked to any single invention and in fact has its roots in ideas several centuries old. There are, however, some landmark inventions that moved the technology to increasingly higher levels of sophistication. This article will explore a few of those landmark events.

Landmark inventions in the adoption of technology to agriculture include the following:

- internal combustion engine
- tractors
- petroleum and fuel
- moldboard plow
- reaper
- cotton gin
- electricity including the Rural Electrification Administration (REA)
- telephone
- combine harvester
- fluid power systems
- radio
- television
- the transistor
- integrated circuits
- delivery of daily papers
- rural-centered and urban-centered magazines
- market information services
- all-weather roads, which gave speedier access to local and distant markets
- low-pressure rubber tires
- portable sprinkler irrigation
- first milking machine with intermittent suction
- refrigeration
- twine knotter
- automatic self-tying pickup baler
- precision farming

It would be impossible to discuss all of the technological advances of the nineteenth and twentieth centuries that have impacted agricultural production and social life. However, several inventions, such as the development of petroleum fuel and the internal combustion engine, changed the course of agriculture forever; to these few we shall direct our attention.

2. Power

Power is defined as the time rate at which work is done. The work of a mass is the product of weight, W, and the vertical displacement, D, of the center of gravity of the body. When work is accomplished a force must act through a distance.

In the selection of a motor or engine, power is a much more important criterion than the actual amount of work to be performed. A small motor or a large power plant may both be used to do a given amount of work; but the small motor may require a month to do the work done by the large plant in a few seconds or minutes.

If ΔU is the work done during the time interval Δt, then the mean power during this time interval is as follows:

$$\text{mean power} = \Delta U/\Delta t \qquad (1)$$

Letting Δt approach zero, we obtain the limit

$$\text{power} = dU/dt \qquad (2)$$

or power is the time rate of doing work.

When work is done at a constant rate, we may determine the work done during a given time interval and note that each 745.7 J (550 ft-lb) of work done per second is equivalent to 0.7457 kW (1 hp).

Several units are used to measure power; mechanical power is usually measured in kilowatts (kW) or horsepower (hp) and electrical power in watts or kilowatts (kW). These units are defined as follows:

1 watt = 1 joule per second = 1 newton per millisecond (3)

(1 hp = 550 ft-lb per second = 33000 ft-lb per minute) (4)

1 kW = 1000 watts (5)

Power is useless without a means to apply it, and machines are useless without power to run them. In the preface to the *1960 Yearbook of Agriculture, Power to Produce,* Alfred Stefferud defines power thusly:

Power is tools, machines, wheels, levers, oil, energy, structures, the strength in muscles. Power is communication, information, transportation, administration. Power is the ability to think, plan, invent, adapt, use, act, produce.

Power comes from the sun, the earth's stored riches, man's long experience, the sciences that we describe as technology or engineering and that have expanded with revolutionary force in the past few years

We consider the history, potentialities, and physical effects of power but not, except at times in passing, the social, political, and humanitarian problems that the possession of power may bring.

On the farm, power may be described as any source of energy, the use of which helps complete a task requiring work.

Energy—A body is said to possess energy when its state or condition is such that it can do work against forces applied to it. Energy takes two forms: (a) potential energy, or energy of position or condition; and (b) kinetic energy, or energy of motion.

Water in an overhead tank has potential energy because of its position. If water is pumped into a tank under pressure, it has potential energy because of its state. The simplest case of potential energy is that of a weight located above Earth's surface:

$$\text{potential energy} = W\,h \tag{6}$$

$$W = \text{weight} \tag{7}$$

$$h = \text{height} \tag{8}$$

Kinetic energy is the result of motion:

$$\text{KE} = 0.5\,W\,v^2\,g^{-1} \tag{9}$$

$$W = \text{weight} \tag{10}$$

$$v = \text{velocity} \tag{11}$$

$$g = \text{acceleration produced by the force of gravity} \tag{12}$$

Common energy units vary in conjunction with common power units. The derived unit for work is the newton meter (N m), which is given the name joule (J). A joule is the absolute SI unit of work and is equivalent to precisely 10^7 erg or approximately 0.7375 ft-lb. Energy is a capacity for doing work and has the same units as work. Since one joule of work or energy is small, the kilojoule (kJ) is more generally used. Power is the work per unit time. The SI unit for power is the watt (W) and more generally expressed as a kilowatt (kW). An erg is the unit of work equivalent to that produced by a force of one dyne acting through a distance of one cm.

A British thermal unit (Btu) is the quantity of heat required to raise one pound of water one degree Fahrenheit at a specified temperature of 39 °F. Whereas, a calorie is the amount of heat required to raise the temperature of one gram of water one degree Celsius and is equal to 4.19 joules (also called a gram calorie); one thousand gram calories (a kg calorie) equals 3.968 Btu.

2.1. Transformation of Energy

Energy can be neither created nor destroyed, but it can change forms; some of the changes that may take place in an original quantity of energy may be seen in the following chain of events: heat from the sun; stored as coal; liberated as heat of combustion; changes water to steam pressure; transformed by an engine into mechanical energy; transmitted to a generator by a belt or shaft; changed into electricity; transmitted by wire to points of use; changed into light, heat, and/or used to drive motors; or lost to further use through friction and/or radiation of heat; or stored for later use as potential energy.

2.2. Efficiency of Energy Conversion

The mechanical efficiency of a machine is defined as the ratio of the output work to the input work:

efficiency, e_m = (output work)/(input work) (13)

This definition is based on the assumption that work is done at a constant rate. The ratio of the output to the input work is therefore equal to the ratio of the rates at which output and input work are done, and we have

efficiency, e_m = (power output)/(power input) (14)

Because of energy losses due to friction, the output work is always smaller than the input work, and consequently the power output is always smaller than the power input. The mechanical efficiency of a machine is, therefore, always less than 1.

2.3. Carnot Cycle

The second law of thermodynamics states that conversion of heat to work is limited by the temperatures at which conversion occurs. For a cycle with a higher temperature T_1 and a lower temperature T_2 the maximum efficiency, usually called the Carnot cycle efficiency, is

Carnot cycle efficiency, $e = (T_1 - T_2)/T_1$ (15)

which establishes an inherent limit to the maximum useful conversion of energy that may be obtained from a fuel used in a power plant, such as in a tractor engine. In the best tractor engines, only approximately one-third of the heating value of the fuel is converted into useful work.

Further improvements in power plants may be brought about by higher temperatures, but these are limited by materials that possess both the required physical strength and the resistance to high temperatures.

2.4. Motive Force—Development of Power Source

Compared to the age of humankind, it was only a speck of time ago that horses and mules powered the farm—a peak of 26 723 000 work animals in 1918. At that time, it took one farm worker to feed eight people. By 1957 that ability had increased to where one farm worker could feed 20 others, and at the beginning of the twenty-first century one farm worker feeds nearly 128 others.

Farm mechanization is the key to this achievement, and the development of a lightweight, relatively inexpensive power source—the internal combustion engine—revolutionized farm mechanization probably more than any other single invention. The internal combustion engine made possible (a) the farm tractor, (b) new types of farm implements, (c) stationary power sources for many types of implements, pumps, and electrical generators, and (d) rapid transportation of farm goods to market.

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Biographical Sketch

Charles L. Peterson is professor of Biological and Agricultural Engineering at the University of Idaho. He received bachelor's and master's of science degrees from the University of Idaho and his doctorate in engineering science from Washington State University. Dr. Peterson has been employed at the University of Idaho since 1973 and became a full professor in 1978.

Peterson teaches courses in agricultural machine design, instrumentation, fluid power, engineering analysis, and computer applications in biological systems. Dr. Peterson has served as advisor to a number of graduate students at the University. His research projects have included tillage and planting methods to reduce erosion in winter wheat production; precision farming in the dryland areas of the Palouse of northern Idaho and eastern Washington; harvesting handling and storage of sugar beets; and use of vegetable oil as an alternative diesel fuel. He has written many professional and popular articles on these topics. He has two patents.

Dr. Peterson has received a number of awards recognizing his achievements, including the following: Engineer of the Year from the Inland Empire Chapter ASAE, Agricultural Engineer of the Year from the Pacific Northwest Section of ASAE, NACTA VNR/AVI Teacher Award, Outstanding Faculty from the College of Engineering, Gamma Sigma Delta Outstanding Research in Agriculture Award, University of Idaho Award for Excellence in Research, and the Phi Kappa Phi Distinguished Faculty Award.

Dr. Peterson is married, has six children, is active in church and the Boy Scouts of America and enjoys the outdoors in Idaho.