How Engineering Has Helped the Human Race to Develop

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Executive Summary

In 1779 Thomas Malthus argued that human being's unquenchable urge to reproduce would ultimately lead to us overpopulating the planet, consuming all its resources and ultimately die in a mass famine. (Malthus, 1798) This concept became known as a Malthusian catastrophe, which under Neo-Mathulsian theory was re-examined and the effect of modern mechanised agriculture was considered when looking at Malthus' original prediction. The population boom of the mid-20th century led to scientists such as biologist Paul Ehrlich to predict an imminent Malthusian catastrophe. (Hopkins, 1966) We believe and will aim to show that engineers are required to avoid such a disaster. Their role in solving problems that originate from overpopulation is an essential one and is our main motivation to emphasise the importance of engineering in this short report.

Introduction

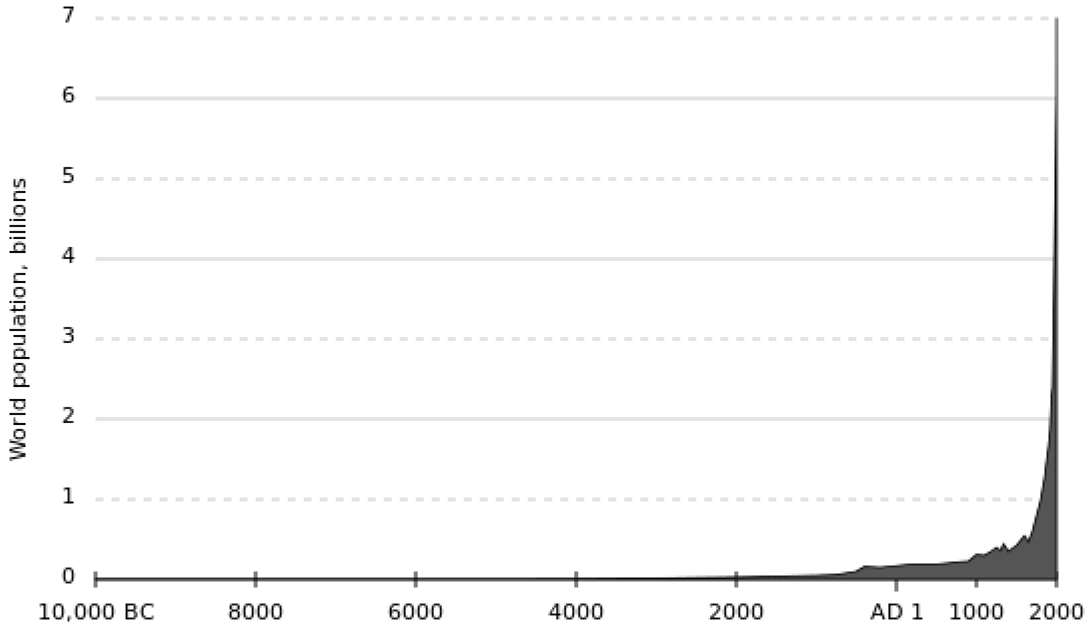

Fig. 1. Estimated size of human population from 10,000 BCE to 2000 CE. (Kremer, 1993)

As Figure 1 shows, the human population first began to grow significantly around 500 BCE and I aim to demonstrate the importance of engineering in enabling this growth and its continued importance in sustaining the approximately 7.125 billion people living on Earth today.

I will examine how advances in irrigation supported population booms in ancient civilisations that were previously limited by their reliance on dry land farming and how more recently engineers developed methods to harness the power of flowing water.

To initially demonstrate the point, consider the ancient city of Angkor, capital city of the Khmer Empire (in modern day Cambodia) in comparison to London. In 1100 CE London's population was around 18,000 (Schofield, 2003), in contrast, Angkor, considered to be a "hydraulic city" due to its complex water management network, may have supported up to 1 million people at that time. (Evans, 2007)

A Thirsty World

Modern methods of agriculture in our connected world are not just the product of over 10,000 years of innovation but are the product of many cultures who developed the technologies independently, in this way an investigation into the development of irrigation techniques can be as geographical as it is historical.

Perennial irrigation (in which water is controlled so that the land can be irrigated at any time) was first practiced in the Mesopotamian plain (largely modern day Iran) in the 4th millennium BCE whereby crops were watered at intervals throughout the growing season by manoeuvring water through a matrix of small channels throughout the field. (Hill, 1996) This led to the mathematical problem of finding the most efficient way of irrigating the crops, similar in some ways to the “Chinese postman problem” from modern graph theory. (Kwan, 1960) Modern irrigation methods look to supply the entire field uniformly, supplying each plant the exact amount of water it requires, neither too much nor too little. Modern farmers use the following equation to determine water efficiency in the field.

Field Water Efficiency (%) = (Water Transpired by Crop / Water Applied to Field) X 100

Until the 1960s, most believed water to be an infinite resource. However, population increase and a greater consumption of water-thirsty vegetables and meat has led to rising levels of water scarcity. It is currently estimated that 2.8 billion people live in water-scarce areas. (Molden, 2007) Worldwide, it was estimated that 2,788,000 km^2 of fertile land was equipped with irrigation infrastructure around the year 2000 – by 2008 this figure had increased to 3,245,566 km^2. (CIA, 2013) This represents an increase of 16.4% in just 8 years, a rate of increase that is potentially unsustainable if we are to avoid a global water crisis. The solution to this problem is engineers working in conjunction with farmers to increase productivity in order to meet growing demands for food and working with industry and cities to find ways to use water more efficiently. (Chartres & Varma, 2010)

Water for Power

Ancient Greek engineers are credited with the development of the water wheel around the 3rd century BCE (Wikander, 2000) building off the invention of paddle-driven water-lifting wheels called sakias that had appeared in ancient Egypt circa 4th century BCE. (Wikander, 2008) These were used as a power source, replacing animal or human operation right up until the latter half of Industrial Revolution where they were largely replaced by turbines, first developed in 1827. (Thomson, 2009)

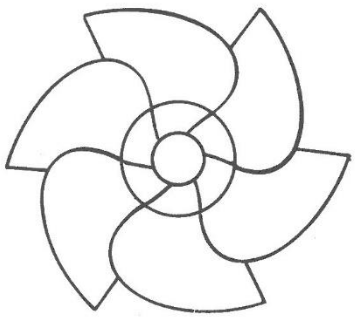

Fig. 2. The schematics of an ideal modern sakia, a mechanical water lifting device that used animal power to raise water developed in Nubia (southern Egypt) in the 4th century BCE. (P. Fraenkel)

Modern hydroelectric dams could be viewed as descendants of water wheels – as they also convert the gravitational potential energy of water on a higher elevation into useful energy. Today engineers evaluate a potential hydropower resource's available power using the following equation.

$$P = \eta \rho Q g h$$

Where

- **P** is the power in watts
- **η** is the dimensionless efficiency of the turbine
- **ρ** is the density of water in kilograms per cubic metre
- **Q** is the flow in cubic metres per second
- **g** is the acceleration due to gravity
- **h** is the height difference between inlet and outlet in metres

In 2015 hydropower generated 16.6% of the world's total electricity and 70% of all renewable electricity (REN21, 2016) and was expected to increase about 3.1% annually for the next 25 years. However, in the UK, hydroelectric power stations account for only 1.3% of the country's total electricity production. While the principle of a conventional hydroelectric dam is relatively simple there are still potential innovations and optimisations to be made, especially in turbine technology that could allow the UK's engineers to better utilise our sources of hydroelectric power.

Conclusion

By using just a few examples of how engineering has helped the human race to develop and illustrated how there is still room for considerable innovation in these areas we hope to have shown just how important engineering is to the future prosperity of not just the UK, but the world. We hope to have further emphasised how the continually rising global population creates an even greater need for engineers to solve problems related to using the Earth's resources as efficiently as possible.

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