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Population, water, food, energy and dams

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ABSTRACT

Should the construction of large dams continue? This question has raised an enormous amount of controversy in recent years, in terms of both socio-economic development and environmental sustainability. This paper addresses this question through a study of some key global socio-economic data (population and water, food, and energy consumption) and the vital role of large dams in sustaining societies. The analysis indicates that construction of large dams has essentially been the result of population growth and the associated consequence of increased consumption of water, food and energy. With population projections indicating continued growth in the future (especially in the developing and least developed countries), dam construction should be considered in order to meet future water demands, and it is time that human beings think more about how to better construct, operate and maintain dams and reduce their negative impacts.

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Nomenclature

BRICS	Brazil, Russia, India, China, and South Africa
GRanD	Global Reservoir and Dam
IEG	Independent Evaluation Group
LDCs	the Least Developed Countries
OECD	Organization for Economic Co-operation and Development
TGR	Three Gorges Reservoir
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
WCD	World Commission on Dams

1. Introduction

Regarded as a driving force in the demand for water, food and energy, the world's population has been increasing rapidly since the beginning of the 20th century, from about 1.6 billion in 1900, 2.5 billion in 1950, 6.1 billion in 2000, to 7.0 billion in 2011, according to estimates by the United Nations Population Fund [1,2]. However, the growth rate has also been diminishing since the mid-1960s, peaking at 2.2% per year in the mid-1960s and decreasing to 1.1% per year in 2010 [3]. According to the medium-growth projection scenario of the United Nations [2], the global population will reach 9.5 billion by 2050. Moreover, in response to global population growth, worldwide demand for water, food and energy also increased rapidly in the past century.

At the global scale, agriculture accounts for over 70% of all water withdrawn by the municipal, industrial (including energy) and agricultural sectors [4]. Indeed, it has been argued that water management began in association with agriculture and the ancient hydraulic civilizations of Mesopotamia and the Nile valley [5]. In addition to its importance for agriculture, water is also essential for industrial production, domestic or municipal use, ecosystem services, and many other uses [6]. While these sectors have and continue to use far less water compared to the agricultural sector, their growth rates over time have been much higher. Globally, water consumption for agricultural use grew 2-fold during 1950–1995, compared against a 4-fold increase for other uses [7,8].

Food consumption has grown steadily in response to global population growth, however developments associated with modern agriculture meant that, at an aggregate global level, food production outpaced population growth [9,10]. As represented by grain, globally, food production and consumption were generally in balance during the period 1960–2009 [11]. However, food production experienced considerable inter-annual variation [11]. The problem of food security occurred in some years and regions because food production could not meet the requirement of food consumption. As projected, the absolute increase in food demand will be sizable, especially in those countries with large population growth (e.g., countries in Asia will account for over 50% of global population growth). Moreover, it is worth noting that per capita food consumption of the world has been increasing in recent decades. Changing diets, which is consequent upon economic growth and individual wealth, and its impact upon water consumption, also needs to be recognized [4].

Similarly, global energy consumption has been increasing nearly linearly over the past several decades, and is expected to maintain this rate of growth in the near future. According to statistics, oil, coal and gas are still the main energy sources at present; however, they are non-renewable and not clean, and have also resulted in a steady increase in greenhouse gas emissions [12]. Therefore, it is important and necessary to accelerate the development of clean energy sources (e.g., hydropower) [13], which currently account for only a small proportion of the total energy consumption [12].

Water is the key factor among the above-mentioned factors. The total volume of available water resources over the world is estimated at about 42,700 km^3 per year, and is sufficient to meet all of the demands if it were evenly distributed in space and time [14]. Unfortunately, this is not the case, as significant spatial and temporal variability exists in the distribution of water resources around the world and, when coupled with population, there is often a mismatch between water resources and people [15]. Moreover, farmland, including both rain-fed and irrigated, is critical for food production. The rain-fed lands account for 58% of world food production [6]. In the past five decades, the area of farmland has been increasing largely due to the increase in irrigated land, while the area of rain-fed agriculture has remained nearly constant at about 1220 million hectares. However, on a per capita basis, the area of farmland has decreased rapidly, because population growth has been much faster than the expansion of farmland [16]. Consequently, it will be a challenging task to feed more and more people that are projected for the future, and so it is necessary to raise the water productivity of the food product of both rain-fed and irrigated agriculture, especially in developing countries [10]. Furthermore, hydropower is considered as the major renewable energy source [17], and it offered significant potential for carbon emission reduction in the past.

For much of the 20th century, infrastructure projects were used to increase water withdrawals from rivers and groundwater in order to meet the needs of an expanding population. River basin development during the second half of the 20th century was boosted by the construction of large dams for hydropower generation, flood control and water storage for irrigation (e.g. [18–26]). Dams also play an important role in reducing risks from natural disasters [4]. Dams have, perhaps to a lesser extent, delivered improvements in transportation along rivers, and many large dams, once built, may also be used for recreation, tourism and aquaculture [27]. About one-third of large dams serve two or more purposes and recently multi-purpose dams have been favored [27]. It has been suggested that dam construction has been integral to human population growth and technological innovation [28]. Dam construction, along with other infrastructure, enhanced societies' capabilities in the planning and management of water resources and, by association, the related issues of food and energy security. The World Bank notes the multidimensional role of hydropower in poverty alleviation and sustainable development in developing countries [13].

This paper examines the impact of global population growth and the increases in consumption of water, food and energy on the development of large dams, a form of water infrastructure. Furthermore, this paper deliberates upon the strategy of further dam development, for dealing with the challenge of water security, along with the associated issues of population growth and food and energy security in the near future. The analyses over different continents, countries and groups of countries are conducted.