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Working Paper No. 2015-10

July 11, 2015

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Water, energy, and food Security in the Asia Pacific Region

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Abstract
Security measures of three resources; water, energy and food are analysed for thirty two countries in the Asia Pacific region, in terms of amounts of the resource, self-production, and diversity of souces of each resource. We find that the Asia Pacific countries contain almost half of the world's income and population, and are more self-sufficient in food production than the rest of the world, but are less self-sufficient in energy production. The self-production ratio of food within the Asia Pacific region has been decreasing since the 1960's, though the ratio is still over 100 %. On the other hand, the self-production energy rate within the Asia-Pacific region increased from 82 % in the 1970's up to 95 % in 2010. Diversity for all the three resources is also analyzed using surface water and groundwater for water sources; hydro power, geothermal power, solar, and biomass for energy; and cereals, vegetable, fruit, meat, and fish for food. We see high diversity of sources of water in the US and the Philippines, and a low diversity of sources of food in the US, Canada, and Indonesia.

1. Introduction

Water, energy, and food are the most important resources for societies around the world. Demands for these resources are increasing rapidly due to increasing population, increasing income, and changing lifestyles. The Asia Pacific region is made up of thirty two countries including the US, Canada, Russia, China, Japan and others, where large-scale human activities occur including economic, agricultural/fishery, industrial, and commercial activities. In addition to these human activities, this area is a hot spot for drivers of environmental change such as global carbon emissions. The population in this area was 3 billion in 2013 (Fig. 1) , which is 42 % of the global population (The World Bank, 2014). GDP in this area was 4.3×10^{13} USD in 2013 (Fig. 1) which is 58 % of global GDP (The World Bank, 2014). Global carbon emissions which are partially

responsible for global warming in this area were 18,990 Million tons in 2010, comprising 62.7 % of global emissions (IEA, 2012).

These large population numbers and their related activities require vast amounts of water, energy and food as resources to support this level of activity. Total water consumption in this area was 1.82×10^{12} m^3 in 2010 (FAO, 2014) and 46.6 % of global water consumption (Fig. 2). Total energy consumption was 7.55 x 10^9 t of oil equivalent in 2010 (IEA, 2014) which is 61.2 % of global energy consumption (Fig.2). Total food consumption was 2.37 x 10^9 t in 2010 (FAO, 2014) which is 54.6 % of global food consumption (Fig. 2).

Water, energy, and food securities have been discussed separately, however these three securities should be considered in an integrated manner, because water-energy-food are inherently connected and their utilization may result in important tradeoffs. The objectives of this paper are to identify the sources and components of three resources: water, energy and food in the Asia Pacific region, to evaluate the magnitude and diversity of these resources in this region, and to identify the dependency of each resource in this region.

2. Water

Water security has been discussed in terms of governance (Huntjents et al., 2012, Pahl-Wostl et al., 2013), climate change (Arnell, 1999, 2004) and others (Cook and Bakker, 2012, Bakker, 2012, and Lawford et al., 2013). According to previous literature, analyses of water security were largely limited to levels of water production/ consumption and the rate of self-production. Here we also analyze the diversity of the sources of water resources, including both surface water and groundwater.

2.1 Water consumption for agriculture, industry, and the domestic sector

The three primary sectors of water consumption in the region of interest are agriculture, industry, and domestic. Fig 3 shows the magnitude and ratio of water consumption in 2010 (FAO, 2014) in 32 countries in the Asia Pacific region for these three sectors. In most countries, water is consumed in the agricultural sector, however in the following five countries; US, Canada, Russia, Singapore and Malaysia, industry is the largest consumer of water. Only three countries show the largest consumption of water in the domestic sector.

2.2 Origins of renewable water resources (water production)

There are two origins of renewable water: river water and shallow groundwater.

Water storage for groundwater is much larger than that of river water, however the short residence time of river water results in rapid water circulation in river network systems. Artificial structures such as dams allow for widespread efficient use of river water. Fig. 4 shows the magnitude and ratio of renewable water resources as river water and groundwater, respectively. As can be seen in Fig. 3, more than 10^{12} m^3/y of river water discharge exists in Indonesia, China, Russia, Canada, USA, Colombia and Peru. On the other hand for groundwater, only China, Russia, and USA, which have relatively less precipitation, exceed 0.8 $x10^{12}$ m^3/y.

According to Fig.4, the countries with more than a 25 % ratio of groundwater use to total water use are the Philippines, USA, Mexico, Costa Rica, Honduras, Guatemala, where agricultural farms are dominant in islands or in developing countries (aside from the USA which has a higher dependency on water for agriculture).

In the face of a changing climate, groundwater has an advantage regarding impacts (Taniguchi and Hiyama, 2014) due to its steady flow. Under conditions of larger variation of precipitation expected under climate change, the variation of river flows is expected to be significant. However the residence time of groundwater is much longer than that of river water, therefore slow recovery of groundwater storage may cause unsustainability if over expliotation of groundwater occurs, particularly in deeper groundwater which is not recovered quickly.

3. Energy

Analyses of energy security requires not only the amount of production and consumption, but also the diversity of energy sources as alternatives, and the rate of self production (Kruyt et al, 2009). In this section we separately analyze (1) non-renwable energy such as coal, oil, and gas, and (2) renewable energy such as hydropower, geothermal, solar power and biomass.

3.1Non-renewable energy; coal, oil, and gas

Non-renewable energy production and imports, as well as non- renewable energy consumption, export, power generation, and losses are shown for coal, oil, and gas in Fig. 5a, 5b, and 5c, respectively, with the self-production ratios of three non-renewable energy shown in Fig.6. The self-production ratio for each country is calculated as energy production within the country divided by total energy consumption.

Larger numbers of coal production and supply are found in China and the USA, and a self-production ratio of more than 400 % for coal is found in Australia, Indonesia, and Columbia (Fig.5a and Fig.6). Larger numbers of oil production/supply are also found

in China and the USA, as well as Russia. The countries with more than a 100 % self-production ratio for oil are Brunei, Russia, Canada, Mexico, Columbia, and Ecuador (Fig.5b and Fig.6). The largest ratios for gas production are found in Russia and the USA, and the countries with self-production ratios higher than 100 % for gas are found in Australia, Indonesia, Malaysia, Brunei, Russia, Canada, Columbia, and Peru (Fig.5c and Fig.6).

3.2 Renewable energies; hydropower, geothermal, solar, and biomass

Renewable energy production, consumption, power generation, and losses are shown for hydropower, geothermal, solar, and biomass in Fig. 7a, 7b, 7c, 7d, respectively. Larger amounts of production and consumption of hydropower are found in Canada, the USA, China, Russia and Japan. Larger numbers of production and consumption of geothermal energy are found in Indonesia, the Philippines, Japan, Mexico, and New Zealand.

Compared to other renewable energy, not much solar energy is produced and consumed, except for in the USA and China. Regarding biomass energy, the USA, China and Indonesia are the largest three users.

4. Food

Analyses of food security requires not only the amounts of production and consumption (Barrett, 2010), but also the diversity of sources of food, as well as the rate of self production. In this section we discuss (1) production and imports into each country, (2) consumption and exports from each country, and (3) the rate of self production separately.

4.1 Productions and imports of food

Production and imports of cereals, vegetables, fruits, meats, and fish are shown on the left side in Fig. 8a, 8b, 8c, 8d and 8e, respectively. Larger imports of cereals are found in Japan, South Korea and Mexico (Fig. 8a). For vegetables, only the USA has larger numbers of imports (Fig. 8b), however larger imports of fruits are found in Japan, Russia, Canada, and USA (Fig. 8c). Large number of imports of meats and fish are found in Japan, Russia, Mexico for meat (Fig. 8d), and Japan, Thailand and the USA for fish (Fig. 8e).

4.2 Consumption and exports of food

Consumption and exports of cereals, vegetables, fruits, meats, and fish are shown on

the right side of Fig. 8a, 8b, 8c, 8d and 8e, respectively. Large numbers of exports of cereals are found in Australia, Russia, and Canada (Fig. 8a). Only Mexico has larger numbers of vegetable exports (Fig. 8b), however the Philippines and Central American countries such as Mexico, Colombia, Ecuador and Costa Rica have larger numbers of fruit exports (Fig.8c). Larger numbers of meat exports and fish exports are found in Australia, New Zealand, Canada, and the USA for meats (Fig. 8d), and Russia, Thailand, USA and Peru for fish (Fig. 8e), respectively.

4.3 Self-production rates

Fig 9 shows the self-production ratios of cereals, vegetable, fruits, meats and fish. As can be seen from Fig.9, low self-production rates for all food categories are found in Singapore and Palau, on the other hand, high self-production rates for food are found in Honduras, Nicaragua, Panama, and Ecuador.

5 Discussion

Compared to the global data, the Asia Pacific 32 countries included in this analysis contain almost half the world's income and population (Fig. 1), and are more self-sufficient in food production than the rest of the world (Fig.2), but less self-sufficient in energy production (Fig. 2). This area is one of the most important regions for global sustainability in terms of economic and human impacts on the environment.

The Millennium development goals (MDG, Annan, 2000) and sustainable development goals (SDGs, United Nations, 2014) discuss the fundamental factors for sustainability as economic, social and environmental perspectives. There are several potential security indices including productivity, efficiency, diversity, stability, equity, and autonomy under the economy, society and environment.

Fig. 10 shows self-sufficiency for the three resources (water, energy, and food) in the Asia Pacific region, which is one of the autonomy indices. Self-sufficiency is calculated as self production of each resource within the country divided by total consumption of each resource. As can be seen in Fig.10, Japan and the Philippines have low self-sufficiency in energy.

Fig. 11 shows the diversity of sources of the three resources: water, energy, and food. The values are calculated as reciprocals of the deviation of the sources. Two sources (surface water and groundwater) are used to calculate water diversity, four sources (coal, oil, gas and renewable energy) are used to calculate energy diversity, and five sources

(cereals, vegetables, fruits, livestock, and fish) are used for food diversity. According to Fig. 11, we see high diversity of sources of water in the USA and the Philippines, and a low diversity of sources of food in the USA, Canada, and Indonesia.

Fig 12 shows the relationships between self-sufficiency (self production rate) and diversity (1/variability of sources) for the three resources (water, energy, and food). As can be seen in Fig 12a, we found a weak positive relationship between self-sufficency and diversity of water souces (surface water and groundwater) below 100 % self-sufficiency. There is a wide variation between diversity of water sources at 100 % self-sufficiency. Fig 12b shows a weak positive relationship between self-sufficiency and diversity of energy, except Burnei with high self-sufficiency and Vietnam with a high diversity of energy sources. On the other hand, Fig.12c shows that there is no relationship between self-sufficiency and diversity of food with the exceptions of Chile and Singapole with high diversity of food sources.

6 Conclusion

Water, energy and food in the Asia Pacific region are discussed as various forms of security, in particular using self-sufficiency which is one of the SDGs autonomy indices, as well as diversity of sources for each resource. The Asia Pacific countries, with almost the half of world's income and population, are more self-sufficient in food production than the rest of the world, but less self-sufficient in energy production. There are many variations in the relationships between water, energy and food self-sufficiency and diversity. Positive relationships are found between water/energy self-sufficiency and diversity, but not between food self-sufficincy and diversity. Self-sufficiency and the diversity of sources for these three fundamental resources, water, energy and food, are important not only in the Asia Pacific region but also for global sustainability.

Acknowledgement

This research was financially supported by the R-08-Init Project, entitled "Human-Environmental Security in Asia-Pacific Ring of Fire: Water-Energy-Food Nexus" the Research Institute for Humanity and Nature, Kyoto, Japan.

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