Water-Food Nexus in Citarum Watershed, Indonesia

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Abstract. The water-food nexus is promoted as an approach to look at the linkages between water and food. The articles of Water’s Special Issue “Water-Energy-Food Nexus in Large Asian River Basins” look at the applicability of the nexus approach in different regions and rivers basins in Asia. Citarum River was selected for the case of Indonesia study site of RIHN Water-food Nexus Project with a focus on the Juanda/Jatiluhur dam as the downstream of the three large cascaded reservoirs and river estuary at the Jakarta Bay. As a result, there are a variety of interpretations for the nexus. These include three complementary perspectives that perceive nexus as an analytical approach, governance framework and emerging discourse. Secondly, nexus is a predominantly water-sector driven and water-centered concept. Evaluation of water quality of Citarum River and the increasing demands for water-food nexus revealed the critical status even at present condition that requires strategic decision to modify the water allocation policy to ensure human-environmental sustainability water security.

1. Introduction
The concept of the water-energy-food (WEF) nexus emerged in the international community in response to climate change and social changes including population growth, globalization, economic growth, urbanization [1], growing inequalities, and social discontent. Although the fundamental relationships between water, energy and food have been used to operationalize concepts such as security, no single approach has been deemed suitable for every situation in Water and food Qualitative Methods to Describe the Nexus. Following this concept, one way to evaluate the security is by looking at the convergence of the core properties of water and food systems; such attributes include access, availability, utility, and stability at the individual, household and national levels [2]. Understanding the link between food and water becomes a specific scientific attention. Numerous articles in the scientific literature have pointed the importance and theoretical framing of the water-food Nexus. As a goal, understanding the nexus ideas will conclude to the optimal policies to solve one of the problem areas for future human existence. There are three stages to establish the optimal policies for water and food relation which are:

- Integrated management, which includes integrated water resources management [3]. Integrated water resources management can be defined as how to integrate water policy various water sectors related to food such as agriculture, fishery, industry, and domestic use with different water bodies such as groundwater, surface water and rainwater.
- Water and Food security, the term of security itself can mean a sustainable food availability in the future [4]. The important key for food related to water security will include self-production rate, diversity of the alternate resources and stability of the resources.
• Establishment the “nexus” framework considers the integrated and interconnected nature of the water and energy system, including the associated synergies and trade-offs that are created through the use and management of these connected resources [5, 6, 7, 8 and 9].

2. Development of the integrated nexus method

Many publications suggest to use qualitative and quantitative methods to analyse water and food systems [10]. The qualitative methods employed were Questionnaire Surveys, Ontology Engineering, and Integrated Maps. Questionnaire Surveys [11] stressed that basin-level information would be ideal for an accurate appraisal and can be gathered through a questionnaire that screens the nexus resources. Questionnaire Surveys contributed to a nexus assessment that aimed to address the question of how the population’s security is affected when various natural and social hazards disrupt the linkages among the three systems in Ontology Engineering. Ontology Engineering is one of the base technologies in semantic web technology, where the internet is used to create a knowledge base that computers can deal with directly by means of adding metadata i.e., semantic information for computers, as annotations to information resources on the World Wide Web [12]. An ontology consists of concepts and relationships that are used to describe the target world. It provides common terms, concepts, and semantics by which users can represent the contents with minimum ambiguity and interpersonal variation of expression. Construction of a well-designed ontology presents an explicit understanding of the system.

Integrated Maps is an overlay of various single maps, and it can be used as a method to support the implementation of synthesized policies between the land and the water bodies. Integrated maps can be used as a transdisciplinary method, engaging stakeholders and policy-makers to discuss how to implement integrated management of land and coastal areas through an integrated map.

Along with three qualitative methods, the methodology also has to combine approaches using four quantitative methods: Physical Models; Benefit-Cost Analysis (BCA); Integrated Indices; and Optimization Management Models. This helped to understand the complexities of WEF nexus systems.

Physical Models simulate a biological or ecological system using mathematical formalizations of the system’s physical properties. Such models are often used to predict the influence of a variety of factors in a complex system. Benefit-Cost Analysis (BCA) allows us to gauge an environmental project or investment by comparing an activity’s economic benefits with its economic costs, usually over some fixed time horizons. BCA can be used to appraise a scheme’s economic merit, or to compare the net benefits of competing projects. Integrated Index as a number of studies have shown that a mix of sociology, geography, and natural science is required to effectively analyse the relationship between people and their surrounding environment [13]. Often, a key research objective aims to understand how people cope and develop, given prevailing social inequities and environmental stresses, which are typically area-specific [14]. Optimization Management Models is an appropriate framework when the objective is to evaluate a project’s independent or comparative desirability. A different approach is needed when the goal is to determine optimal allocation of a resource that has linkages to many other resources and may also cross physical, political, and administrative boundaries. In such situations, the Optimization Management Model provides one possible method to look at optimal resource allocation. Such framework is invariant to the extent of transboundary interlinkages, as the objective is to maximize the net present value of total welfare. Once the optimal allocation is identified, however, the most effective way to incentivize behaviour that approximates that social optimum can vary greatly depending on the particular situation.

As an example, where the establishment understanding the water-food nexus is the linkages between land and water bodies through groundwater and dissolved nutrient transport. The water-food nexus interfaces such processes as fresh water coming from the springs or seepage from the periphery and transported to the other water bodies. This research has already been applied in Indonesia, where Indonesian Institute of Sciences (LIPI) together with Research Institute of Human and Nature (RIHN) Japan conducted a nexus research at Citarum Watershed, West Java, Indonesia [15].
3. Description of the Citarum basin, nexus issue and preliminary result

The Citarum River is one of the largest river basins in West Java that has the most developed water resources system in the country and that has already utilized more than 50% of its annual discharge. Issues affecting the Citarum nexus resources were triggered by rapid economic development that has expanded the industrial areas and the residential estates in all Citarum watershed which also contributes significantly to conversion of agricultural land and paddy fields to industrial, housing estates, highly groundwater extraction and water quality degradation issue due to contaminant. High population pressure and encroachment to upstream areas have caused deforestation, severe erosion and basin land degradation that further caused solid waste and water pollutions, flooding and other water related disasters.

The previous research for water-food nexus focused on Jatiluhur dam as a multi purposed dam; major water uses of Jatiluhur dam are for rice irrigation, cultured fisheries, flood control, domestic and industrial water supply, electric power generation, and ecotourism. The basin area of the Jatiluhur dam is 6080 km², with the Jatiluhur dam that has water storage capacity of three billion cubic meters and hydroelectric generation capacity of 187.5 MWs, irrigation service areas for rice of 240,000 ha and some 20,000 units of cultured fish cages, and providing raw water amounting to 16 m³/s for Jakarta drinking water treatment plant that serves almost 80% of domestic water needed for Jakarta population [16]. The main issue was Water for Domestic Use and Jakarta water source, Water for hydro power plant, and Water for fish production (cage culture) which lead to degradation of water quality (Figure 1). Other focus area is located at Jakarta Bay, which acts as Citarum River estuary, with the main issue of Water for Domestic Use (Groundwater abstraction and contamination) and Water for fish production based on groundwater interaction between ocean and land/Submarine Groundwater Discharge (Figure 2).

As a result, integrated coastal management and integration of the management between land and the water bodies (such as lake, dam, ocean etc.) are the issues of the first stage (integrated management) for the establishment of optimal policies. Integration of the water for the fishery resources is the second
stage (Water-food security) and the third stage (Nexus) in terms of the interconnectivity for the establishment of optimal policies [15]. It can be said that food and water nexus concept needs to be promoted and improved more in Indonesia.

Figure 2. Water Food Nexus Issue at Jakarta Bay, Citarum Estuary, Indonesia [15].

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