Global Environmental Change 37 (2016) 16–30

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

The future nexus of the Brahmaputra River Basin: Climate, water, energy and food trajectories

Y.C. Ethan Yang[a,*], Sungwook Wi[a], Patrick A. Ray[a], Casey M. Brown[a], Abedalrazq F. Khalil[b]

[a] Department of Civil and Environmental Engineering, University of Massachusetts–Amherst, Amherst, MA, USA
[b] The World Bank, Washington DC, USA

ARTICLE INFO

Article history:
Received 14 August 2015
Received in revised form 23 November 2015
Accepted 4 January 2016
Available online xxx

Keywords:
The Yarlung Tsangpo River
The Jamuna River
Water resources systems analysis
Transboundary water management
Ex post scenario analysis

ABSTRACT

Advance knowledge of conflicting trajectories of water–energy–food (WEF) nexus is highly relevant for water policy and planning, especially for basins that cross national boundaries. The Brahmaputra River Basin in South Asia, home for 130 million people, is such a basin. Development of new hydropower projects, upstream water diversions and possible climate changes introduce concerns among riparian countries about future water supply for energy and food production in the basin. This study presents a new hydro-economic water system model of the basin coupled with ex post scenario analysis under the "nexus thinking" concept to identify and illustrate where development paths are in conflict. Results indicate that the ability of future development to remain free of conflict hinges mostly on the amount of precipitation falling in the basin in the future. Uncertain future precipitation along with uncertain future temperature and the unknown amount of upstream water diversion combine to strongly influence future water, energy and food production in the basin. Specifically, decreases in precipitation coupled with large upstream diversions (e.g., diversion in the territory of China) would leave one or more riparian countries unable to secure enough water to produce their desired energy and food. Future climate projected by General Circulation Models suggest a warmer and wetter climate condition in the region, which is associated with an increase in streamflow and easing of conflicts at the WEF nexus in the basin. The methodology presented here is expected to be generally useful for diagnosing the conditions that may cause water resources development goals to not be achieved due to either changes in climate or water use among competing users.

1. Introduction

Advance knowledge of conflicting trajectories of transboundary water resources development at a basin scale is highly relevant for national and international policy making. While military conflict may or may not arise as a result of conflicting water resources development plans (Gleick, 2011; Wolf, 2007), without coordination it is unsurprising that such plans may exceed the available water resources of a basin and not achieve desired objectives of riparian countries. In particular, concerns that the multiple uses of water (e.g., for energy and food production) may overlap and lead to unanticipated consequences for one sector or another, popularly referred to as a "nexus," may be especially vexing in rapidly developing transboundary basins.

The Brahmaputra River Basin (BRB) in South Asia is such a basin, with development of new hydropower/water diversion projects and possible climate changes introducing concerns among riparian countries about future water supply for energy and food production (Ray et al., 2014). The Brahmaputra (also called the Yarlung Tsangpo in China and the Jamuna in Bangladesh) has a total drainage area of about 570,000 km^2. Its main stem and tributaries flow through four countries: China, India, Bhutan and Bangladesh (Fig. 1). It is the foundation of water, energy and food for an estimated 130 million people living within the basin, and since the river flows through some of the most highly disputed areas in South Asia, the potential for riparian conflicts of interest over water resources development is significant. For the Brahmaputra River's water resources that have been largely undeveloped, conflicts of interest have so far taken the form of downstream states' objections to the proposed water-related plans of upstream states. Now that upstream states are enacting water development plans, these plans have a potential for increasing conflict between states. For example, ten dams comprising six gigawatts (GW) of hydropower generating capacity are currently under construction in the basin (Rahaman, 2012). Both China and India are evaluating the potential effects of transboundary water diversions made for

* Corresponding author.
E-mail address: yceyang@umass.edu (Y.C. E. Yang).

http://dx.doi.org/10.1016/j.gloenvcha.2016.01.002
0959-3780/

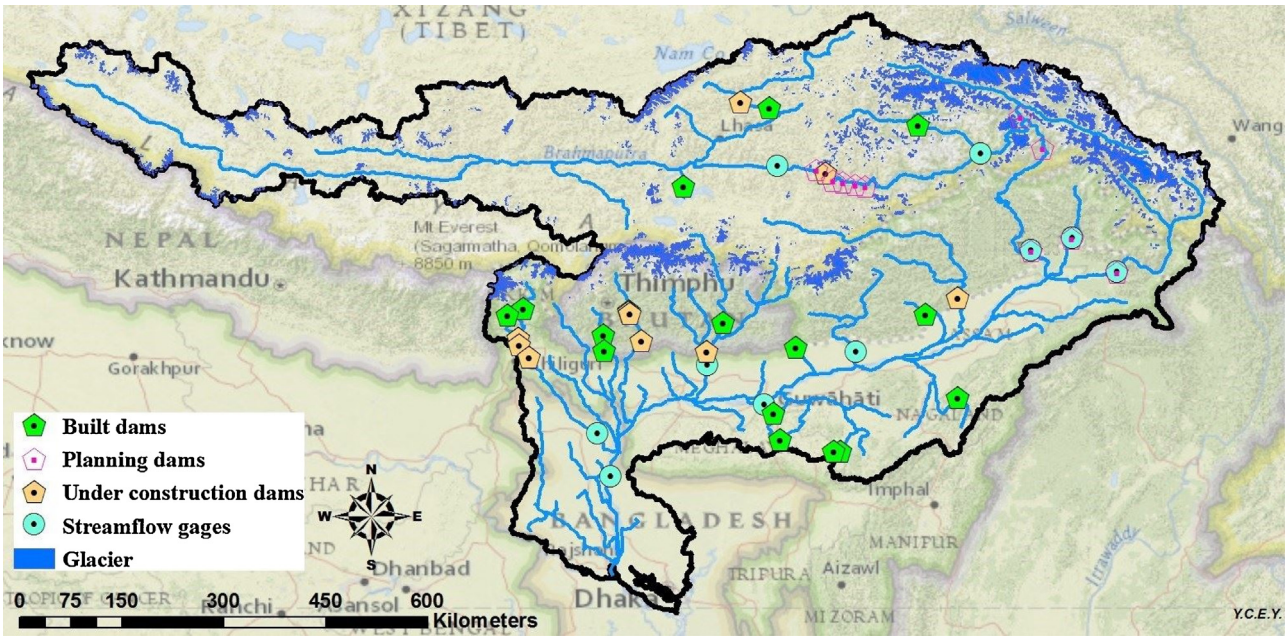

Fig. 1. Map of the location of streamflow gages, current and planned dams, and glacier area in the Brahmaputra Basin.

use both inside and outside of the BRB. Bhutan is rapidly developing its hydropower resources, in partnership with India. Bangladesh is eager to gain greater protection from monsoon floods, and secure water resources for the agricultural irrigation.

To better understand the interconnection of water, energy and food security and reduce the conflicts of interest among riparian countries, "nexus thinking" has been suggested by several previous studies (Biggs et al., 2015; Rasul, 2014; Rasul and Sharma, 2015; Scott et al., 2015). First conceived by the World Economic Forum (WEF, 2011), nexus thinking is advocated as an advance on current and often sector-focused governance of natural resource use. It aims to link water, energy and food together systematically and provide tools to increase resource use efficiency. It ensures policy coherence and coordination across sectors and stakeholders to build synergies and generate co-benefits (Rasul and Sharma, 2015). In South Asia, Rasul (2014) pointed out the limited efforts to understanding the spatial and regional dimensions of the water-energy-food (WEF) nexus in the Himalayan region, and argued that proactive decision-making supported by water resources system models is needed for the development of the region's water resources. Rasul and Sharma (2015) suggested switching from sectoral-focused policy approaches to a nexus approach focusing on policy coherence among sectors.

As summarized by Scott et al. (2015) there are three aspects of institutional performance to be examined when pivoting from a sectoral approach to policy-making toward a nexus approach: (1) institutional levels (or spatial scales), from household to multinational; (2) institutional functions, which foster social consensus, enabling increased economic production and administrating laws and regulations justly; and (3) considering higher human needs of esteem and self-actualization. International water treaties are good entry points to examine the institutional dimensions of the WEF nexus. These treaties usually address the questions of institutional levels and functions. Although transboundary waters in the South Asian river basins have led to international water treaties, such as the 1996 Ganges Water treaty between Bangladesh and India, the 1996 Mahakali treaty between India and Nepal, and the 1960 Indus Water Treaty between India and Pakistan, no multilateral or basin-wide international treaty has yet been established on the use of BRB waters (Uprety and Salman, 2011). We argue that nexus thinking, which includes the international level of cooperative management actions and addresses the socioeconomic needs of different riparian countries would be the first step in the formation of an international water treaty on BRB waters.

When developing an institutional framework for WEF nexus-based policy making, the impacts of change generally, and climate change in particular, must be explicitly addressed. Responses to climate change in the BRB can be distinguished according to the different hydrologic regimes within the basin: snow/glacier melt-dominated in the upper part (mostly the mountainous areas of China, India and Bhutan), and monsoon rainfall in the lower part (mostly the floodplains of India and Bangladesh). While there are numerous studies of the region's historical and future climate, a great deal of uncertainty remains (Annamalai et al., 2007; Yang et al., 2008; NRC, 2012; Pithan, 2013). There is general agreement between observed and projected increases in temperature (Song et al., 2011; Gao et al., 2008; Xu et al., 2009). And the retreat of glaciers in the region has been attributed to the increasing temperature (Yao, 2008; Eriksson et al., 2009; Bajracharya and Shrestha, 2011). However, while projections of future climate have tilted toward increasing precipitation (Li et al., 2010; Turner and Annamalai, 2012; Menon et al., 2013), analysis of observed precipitation indicates decreasing trends (Jain and Kumar, 2012; Deka et al., 2013). Given that the physical processes that drive the South Asian Monsoon are not completely understood (Beniston et al., 1997; Annamalai et al., 2007; Yang et al., 2008) and not fully represented in global/regional climate models, interpretation of climate projections as deterministic limits on the range of future climate change is not warranted (Stainforth et al., 2007; Brown and Wilby, 2012).

Assessing the joint impacts of development and climate change on the WEF nexus in the BRB requires careful consideration and simulation of both physical processes and institutional decision-making. This study presents a modeling framework combining physically-based hydrologic modeling, hydro-economic modeling, and ex post scenario analysis within a decision-scaling framework (Brown, 2010) to elicit the conditions under which development trajectories conflict and where they align. Trajectories represent the transient nature of both climate change and development and