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Economic performance of water storage capacity expansion for food security

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SUMMARY

Continued climate variability, population growth, and rising food prices present ongoing challenges for achieving food and water security in poor countries that lack adequate water infrastructure. Undeveloped storage infrastructure presents a special challenge in northern Afghanistan, where food security is undermined by highly variable water supplies, inefficient water allocation rules, and a damaged irrigation system due three decades of war and conflict. Little peer-reviewed research to date has analyzed the economic benefits of water storage capacity expansions as a mechanism to sustain food security over long periods of variable climate and growing food demands needed to feed growing populations. This paper develops and applies an integrated water resources management framework that analyzes impacts of storage capacity expansions for sustaining farm income and food security in the face of highly fluctuating water supplies. Findings illustrate that in Afghanistan's Balkh Basin, total farm income and food security from crop irrigation increase, but at a declining rate as water storage capacity increases from zero to an amount equal to six times the basin's long term water supply. Total farm income increases by 21%, 41%, and 42% for small, medium, and large reservoir capacity, respectively, compared to the existing irrigation system unassisted by reservoir storage capacity. Results provide a framework to target water infrastructure investments that improve food security for river basins in the world's dry regions with low existing storage capacity that face ongoing climate variability and increased demands for food security for growing populations.

1. Background

Continued climate variability, population growth, and rising food prices present ongoing challenges for achieving food and water security in poor countries that lack adequate water infrastructure. Undeveloped storage infrastructure presents a special challenge in northern Afghanistan, where food security is undermined by highly variable water supplies, inefficient water allocation rules, and a damaged irrigation system due three decades of war and conflict. Afghanistan is a developing Asian country with livelihoods heavily dependent on agriculture that has suffered ongoing consequences of military conflict since the late 1970s (Fig. 1). These conflicts have severely damaged the country's irrigation infrastructure, institutions, and capacity to adapt to ongoing climate variability. Balkh Province is located in the northern part of the country with total population around 1.12 million (Torell and Ward, 2010). In that province, agricultural activities in the Balkh Basin (the basin) are a major source of income, livelihoods, and food security. That region is an important producer for the country's most important grain and staple food crops, especially wheat (Reeling et al., 2012; Chabot and Dorosh, 2007). Runoff into the basin is the main source for fresh water for irrigation in the Balkh Province.

Farmers in this province face highly fluctuating water supplies with no significant reservoir storage capacity, which places heavy stress on food production in dry years, especially in the low part of the watershed. Reliable water availability is a major determinant of the recovery and expansion of irrigated agriculture activities in Balkh Basin to its former high levels of the mid 1970s (Kugbei et al., 2005; Walters et al., 2012). In the basin, weak water institutional capacity (e.g., rules for defining water rights) limits farmers' ability to adapt to highly fluctuating flows supplied from runoff in the Balkh River and its tributaries. Average annual water supplies in the river are estimated at 1540 MCM per year (Torell and Ward, 2010). Moreover, the basin has a high fluctuation in yearly water supply that can undergo severe drought. This occurred in the period 1998–2002 (Chabot and Dorosh, 2007).

Weak water institutions combined with virtually no reservoir storage capacity limits irrigators' capacity to earn a sustainable income and sustain adequate food security in drought periods, especially in downstream areas. These weak water-sharing

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Fig. 1. Map of Afghanistan showing the Balkh River Basin (adapted from United Nations, 2000).

arrangements result in high fluctuations in food supply and production, and increasing the country's dependence on national food aid and imports from neighboring countries like Pakistan. While foreign food aid and imports temporarily supplement grain needs in any given year, such aid causes reductions in domestic grain prices, reduces future production and more generally is not sustainable (Chabot and Dorosh, 2007). Furthermore, high variability in water supply negatively influences the net farm income and food production in downstream agricultural production.

Numerous previous studies have examined irrigation, water institution, agricultural systems, and food security in Afghanistan. Many national and international projects intend to examine ways to improve and rehabilitate the irrigation infrastructures and agricultural system. Example includes studies aimed at estimating crop water consumption (Senay et al., 2007), agricultural productivity (Sharp et al., 2002), impacts of the 2008 Afghan Water Law (Wegerich, 2010). However, few existing studies have aimed to improve the Balkh Basin's water and irrigation institution capabilities. Torell and Ward (2010) investigated a water allocation framework that aimed to improve water use and food security in the Balkh Basin. Reeling et al. (2012) applied a linear programming approach to investigate impacts of a range of reservoir and water right allocation systems on the basin's agricultural activities. However, no previous work to our knowledge has systematically integrated the hydrological, economic, and institutional characteristics of the basin as a part of science-based policy assessment to improve food security and farm livelihoods.

In light of these gaps, this paper aims to investigate the economic returns associated with a range of storage capacity expansions that would benefit farm income and food security in the Balkh Basin, Afghanistan. Using available data, an integrated basin framework is developed and applied that addresses the basin's hydrology, economics, culture, and institutions that uses a dynamic mathematical optimization framework. Based on our integrated framework, results are examined for three reservoir capacity expansions: small, medium, and large. Impacts are identified for several outcomes: regional farm income, land use, and irrigated crop production. These results are compared to the base condition in the basin, where no significant water storage currently exists.

2. Methodology

2.1. Data

With a history of more than three decades of military conflict, continuous research grade records of hydrological and agricultural data do not exist for our study area. This work employed the (very limited quality) available data on irrigated land, crop water use coefficients, and net revenue for fourteen canals in the basin (Fig. 2). Data used in this study, including average annual water inflow for the Balkh headwater were obtained from previous works of Torell and Ward (2010) and Reeling et al. (2012). Estimated available land for irrigation considered for this study, is 5762 paikals, where each paikal is a local measure of water that is sufficient to irrigate 80 ha of land. Data on irrigated land, crop water use per ha, and net revenue show variability by sub-region (Fig. 2). In this paper, eight of the basin's most important crops are included: wheat, alfalfa, rice, cotton, melon, potato, tomato, and pulses (a legume crop).

The fourteen canals that take water from the Balkh River are divided into three regions that have similar water supply reliability