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Analysis

Integrated basin management: Water and food policy options for Turkey ☆

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ABSTRACT

This paper presents a basin scale analysis of the Nilüfer River Basin of Turkey, where agricultural, urban, and environmental users compete for scarce water in an environment where climate change and food security present large and growing challenges. It presents results of a basin scale dynamic nonlinear programming model that addresses economic efficiency, climate change, and food security. Its approach can be applied to other water-stressed regions operating in environments of economic and hydrologic constraints on water use. Basin scale modeling approach provides a general framework for formulating water management policies, consistent with the principles underlying the European Union Water Framework Directive.

1. Introduction

Water and its management influence human health, communities' welfare, and ecosystem sustainability. Despite water's essential characteristics, its scarcity has increased as a result of population growth, emerging environmental values, and global warming. Such impacts have been magnified as water demands for consumptive uses such as irrigation, municipal water supply and industry continue to increase. The Intergovernmental Panel on Climate Change (IPCC) reported that greenhouse gas emissions increase 70% between 1970 and 2004 (IPCC, 2007). Changing climate conditions will have a considerable impact on the hydrology and water resources of river basins.

Climate change will affect food security planning, especially in economies dependent heavily on irrigated agriculture. Every nation wishes to ensure access by its people to strategic food staples, and attempts to secure access to food on a reliable basis through interactions with local markets and home resources (FAO, 2006). So the agricultural sector is a special target of food security planning in developing countries such as Turkey. Impacts of climate change on food security will be higher in developing countries where irrigation, farming, and food processing are least efficient or most vulnerable to unexpected changes. Well-designed water resource policies have considerable potential to improve the allocation of water as well as contributing to food security objectives. Improved water management and irrigation strategies, better basin management and land use planning techniques can be instrumental in addressing impacts of climate change. Managing to meet environmental demands for water can be an important contributor to economic efficiency. That is, protecting the water environment and water ecosystems from degradation can be a good investment, especially where tourism-based outdoor recreation and ecotourism are significant contributors to national income.

Efficient water resources management is based on improving the economic productivity of available water. Achieving economic efficiency requires understanding the availability of water and a notion of how much of it will be needed, in what quantity, for how long, and for which purposes. Thus, it is necessary to have economic information and methods to increase total economic benefits by allocating water more efficiently (Ward and Lynch, 1996). Integrated river basin optimization models provide this kind of mechanism.

The European Water Framework Directive (WFD), adopted in 2000, introduced an integrated approach to water management in Europe. It established a common approach to protecting the water environment and to setting environmental objectives for all waters of the European Union (EU), and also provided a framework for designing future EU water legislation. The main objective of the WFD is for member states to achieve good water status for both surface and ground water and to prevent degradation of existing quality where good water status has been achieved. Economic theories take important part in the WFD, and will play a uniquely central role in characterizing how and to what extent the WFD is implemented across Europe. Basin scale economic analysis in the WFD is one method to provide important information to support major changes in the management of Europe's waters.

In recent years, much work has been conducted on integrated hydrologic–agronomic–economic models. Examples include models designed to support improved irrigation efficiency (Cai et al., 2003), tracking hydrologic and institutional constraints (Dai and Labadie,

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2001), analysis of improved information at the basin scale to support the WFD (Van Ast and Boot, 2003), insights into measures for reducing nitrogen pressure to support both the EU Nitrates Directive and the WFD (Fassio et al., 2005), nutrient management in the Rhine Basin (Van der Veeren and Lorenz, 2002), and climate change assessment at the basin and regional scales (Krysanova et al., 2007).

Many similar researches have been carried out in the world's various river basins. Some of them are the following: Analysis of the Colorado River Basin, USA examined the economic value of competing water allocation measures throughout the basin (Booker and Young, 1994), while a study of the Rio Chama, USA examined economic values and tradeoffs between recreation and hydropower (Ward and Lynch, 1996). An early celebrated analysis was conducted for the Missouri Basin, USA that examined reservoir operation rules for Corps of Engineer projects (Lund and Ferreira, 1996). More recent work for the Po Basin, Italy conducted an integrated analysis of water regulation in connection with the WFD (Bazzani et al., 2004), while integrated analysis of the Syr Darya River, Central Asia addressed basin-scale implications of irrigation-induced salinity (Cai et al., 2003). Hanley et al., 2006 estimated the benefits of water quality improvements for the Motray and Brothock catchments in Scotland. In the Murrumbidgee Basin, Australia Xevi and Khan (2005) examined tradeoffs between environmental and farming uses of water; for the Rio Grande, USA, Ward and Velazquez (2008) described a basin scale optimization to inform management choices affecting water quantity and quality. Two very recent works have examined basin-scale tradeoffs and choices in Turkey, one for the competition for industrial and irrigation water uses in the Gediz Basin (Harmancioglu et al., 2008), and another for a series of hydroelectric and irrigation reservoirs in the Euphrates Basin in Turkey and Syria (Tilmant et al., 2008). While each of these studies has made considerable advances in basin-scale analysis, none of those studies take into consideration principles of economic efficiency of water resources with climate change and the related challenge posted by food security. This paper's aim is to address these existing gaps in the literature. Current paper presents a basin scale optimization analysis that addresses food security, climate change, and environmental values of water. It describes the development and application of a basin scale optimization model to support water policy analysis for Nilüfer River Basin, Turkey.[1] The approach described in this paper is consistent with the principles described by the WFD for integrating economics into water management and policy (Heinz et al., 2007).

Turkey has applied for membership in the European Union (EU). If that application is approved, Turkey will need to conform to EU legislation in sectors such as agriculture, energy, economy, environment, and transportation. Conforming to, applying, and implementing measures required by the EU WFD will be required. Like most of the EU member states, Turkey faces a number of unprecedented challenges related to:

- Comprehensively assessing compliance with existing water management laws and institutions
- Identifying cost effectiveness of various water management measures and assessing the size and distribution of their economic impacts
- Adapting existing institutions to ensure future water resources management and planning is effective at the basin level
- Establishing open communications among people and institutions that contribute to the basin planning process

Basin scale analyses consistently and comprehensively applied, the aim of this paper, could contribute to the water planning process in Turkey. Such analysis could provide a foundation for increasing the nation's water-related economic benefits. It could also demonstrate implementation of the challenging water planning principles established by the EU WFD.

2. Study area and issues

The province of Bursa is located in northwest Turkey. The Nilüfer Basin is its most important renewable water resource supply. The Nilüfer River rises in the Uludag Mountains, and flows about 160 km to the sea. It flows towards the city of Bursa, and is controlled by two important reservoirs, the Nilüfer and Doganci.

According to 2000 census, with a population of 1,194,687, Bursa is Turkey's fourth largest city, as well as one of the most industrialized and culturally important metropolitan centers in the country. After splitting Bursa, the Nilüfer River turns west and flows to the Marmara Sea. The Basin covers an area of about 1539 km^2, of which 54% consists of irrigated agriculture.

Karaer and Küçükballı (2006) state that the Nilüfer River has a poor water quality in its many parts. Untreated domestic wastewaters, industrial discharges and agricultural activities contributed to the total annual organic loads. That study revealed the importance of construction, operation, maintenance and legislation of wastewater collection and treatment programs, as well as the need for tighter control of nutrient loads for the preservation of the Nilüfer's water quality.

The basin has experienced considerable economic and population growth since the 1970s. The City of Bursa has an average household size of 3.8 (Census 2000). The Nilüfer River provides water to about 428,000 households. The upper part of the Nilüfer Basin has high water use in agriculture, partly induced by low water prices charged to irrigators. Water prices in irrigation are typically insufficient to cover operation and maintenance costs (Çakmak et al., 2006). In the lower reaches of the Nilüfer River, agricultural production was the main source of income until considerable water-using industrial growth appeared in the 1970s. The growth of these industries combined with increased population has resulted in conflicts over water allocation and quality. Industrial pollution on the Nilüfer River is high, especially downstream of Bursa. In addition to industrial pollution, urban household discharges have also contributed to water pollution. About 60% of the basin's population is connected to a sewage system (Karaer and Küçükballı, 2006). Therefore, a considerable amount of domestic waste water is unprotected by wastewater treatment plants and is discharged directly into the Nilüfer River and its tributaries, presenting serious water quality issues.

Reservoir water levels of the basin have historically determined haphazardly with little consideration to economic or environmental impacts. The issues described above characterize the importance of developing an integrated model that systematically accounts for interactions of water supply, political constraints, and economic values of water. A basin scale model that optimizes the economic performance of water allocations would help to understand contribution of various water sectors, including urban, agricultural, and environmental values of water. It would also support and inform the recovery of water service costs based on the economic analysis, a principle supported by the EU WFD.

3. Methods

An optimization model was developed to address the issues described above, with the intent of producing a single unified framework for policy analysis. The model consists of 9 river nodes, 9 inflow nodes, 4 diversion nodes, 4 surface water return flow nodes and 5 reservoir release nodes (Fig. 1). That model's economics accounts for agricultural demands for basin's major irrigated areas, recreational values from the water environment, and urban-industrial demands for the City of Bursa.

[1] The model presents a long-run analysis of the economic benefits associated with agricultural, urban, and recreational uses of water. For agriculture, production costs include establishment, capital, operating, and replacement costs of all enterprises. For urban uses, costs include capital, operating, and replacement costs of water supply and distribution. For recreation, costs include management costs of supporting visits associated with reservoir fluctuations.