Water Resources and Economics 12 (2015) 27–39

Contents lists available at ScienceDirect

Water Resources and Economics

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

Will farmers save water? A theoretical analysis of groundwater conservation policies

Tong Wang [a,*], Seong C. Park [b], Hailong Jin [c]

[a] Department of Economics, South Dakota State University, Box 504, 114 Scobey Hall, Brookings, SD 57007, USA
[b] Texas A&M AgriLife Research, PO Box 1658, Vernon, TX 76384, USA
[c] College of Business and Natural Sciences, Black Hills State University, Spearfish, SD 57783, USA

ARTICLE INFO

Article history:
Received 20 December 2014
Received in revised form
6 October 2015
Accepted 7 October 2015

Keywords:
Groundwater conservation
Economic incentive
Irrigation technology
Subsidy
Water cost
Ogallala aquifer

ABSTRACT

The development of agricultural irrigation systems has generated significant increases in food production and farm income. However, unplanned and unconstrained groundwater use could also cause serious consequences. To extend the economic life of groundwater, water conservation issues have become the main focus for the policy makers. Taking Ogallala aquifer in U.S. Southern Great Plains as an example, this paper analyzes whether current and potential groundwater conservation policies provide profit-driven farmers with incentives to save water. We adopt a theoretical approach to analyze farmer's optimal response when facing following policy alternatives, including (1) irrigation technology subsidy, (2) increased water cost, (3) unit subsidies for water saving, and (4) subsidies on water-conservative crop. Our findings suggest that the effects of water conservation policies vary by region. Specifically, the switching to higher efficiency technology should occur in a preventative stage for the water saving to occur. Similarly, an increase in water cost promotes water saving only when water resource is relatively abundant. In regions where groundwater already poses a constraint, the unit subsidy for actual water saved and price subsidy for water-conservative crops are more effective in achieving the water conservation goal.

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1. Introduction

Globally, irrigated agriculture is the predominant user of groundwater resources [13]. In arid and semi-arid regions where rainfall is scarce and unreliable, particularly in Middle East and North Africa, groundwater makes up the primary source of irrigation; even in mesic regions such as Southeast Asia, groundwater is used as a supplementary irrigation [26]. The development of agricultural irrigation systems in the past several decades has generated significant increases in food production and farm income. However, with few regulatory and control mechanisms, the unplanned and unconstrained groundwater use is also causing serious consequences. In many regions around the world, including northern China, northern India, United States, and countries in the West Asia and North Africa region, excess groundwater pumping compared to recharge has caused widespread groundwater depletion [48].

In India, for example, with about 60 percent of the irrigated food grain production currently depending on groundwater irrigation, groundwater overdraft is common, mainly due to subsidized energy for groundwater pumping [48]. Similarly, in Northern China, where groundwater is depleting at an alarming rate, the share of groundwater use in total water utilization has increased from almost zero in 1950s to 49% in early 2000s. Overdraft of groundwater has created widespread problems such as land

* Corresponding author. Fax: +1 605 688 6386.
E-mail address: tong.wang@sdstate.edu (T. Wang).

http://dx.doi.org/10.1016/j.wre.2015.10.002
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subsidence and seawater intrusion [42]. In the United States, groundwater depletion has been a concern in the Southwest and High Plains for decades.

One of the largest and most exploited freshwater aquifers in the United States is the High Plains aquifer, which encompasses 174,000 square miles and underlies parts of eight states from the Texas panhandle to South Dakota [1]. Of the High Plains aquifer system, the Ogallala aquifer is the leading geologic formation. The Ogallala aquifer contributes to the largest irrigation-sustained cropland in the world and supports a food and fiber production system that is worth approximately $20 billion per year [6]. Such enormous economic activity based on a single Aquifer is thus unprecedented on a global level.

Owing to the improved pumping and the irrigation technologies, groundwater used for irrigation purpose has increased substantially since 1950s [18]. The recharge of the Aquifer, however, is minimal compared to the rate of depletion, due to predominantly semiarid environment of the high plains and low infiltration of surface water [49,30,27]. To prolong the aquifer life and ensure a smooth transition to the dryland production to minimize the impacts on the overall economy, policy makers and stakeholders are investing in different water conservation policy alternatives to extend the economic life of the Ogallala aquifer. Water conservation issues have become the main focus over the most recent two decades [15,31,29,2].

While goal of the government is to conserve water and ensure the long run economic stability, the goal of farmers is more focused on short term profit. With such a conflict of interest, Brill and Burness [7] demonstrated that farmers tend to use more groundwater than the social optimal level as saturated thickness decreases. Among the literature that analyzes the effectiveness of water conservation policies, however, few studies have done to analyze farmer's behavioral responses to various policy alternatives. Two notable exceptions are Huffaker and Whittlesey [20] and Huffaker [21]. However, the consequences of water-conservation policies such as water right buyout program and subsidy to water-conservation crop has not yet been studied. Furthermore, regional differences, farm characteristics and multi-crop scenarios are not accounted for in these studies. Due to the above limitations, many questions remain unanswered. For example, will farmer cut their water use or alter their crop choices under certain water policy alternatives? Will a certain water-conservative policy successful in one region remain effective in another region? Our paper intends to shed some fresh insights on these questions.

In this paper we extend the work of Huffaker and Whittlesey [20] and Huffaker [21] to analyze the water use adjustments by a representative farmer in response to several potential policy alternatives, including: (1) irrigation technology subsidy, (2) increased water cost, (3) subsidies for water saving, which in extreme case, is comparable to the water right buyout program, and (4) subsidies on water-conservative crop. We point out the regional differences may affect the success of these policy alternatives in such a way that a policy works well in one area may not work in another.

Some implemented and potential groundwater conservation policies for Ogallala aquifer will be introduced in the next section as examples of groundwater management practice. Our modeling approach from the farmer's perspective filled in an important void in the literature that analyzed the policy issues of Ogallala aquifer. Meanwhile, the implication of our findings is not limited to one specific region or aquifer. Groundwater conservation issue is on the water management agenda around the world, especially for regions where an overdraft already occurred. Our theoretical modeling results, therefore, can be generalized to the other regions of the world as well and have widespread implications.

2. Water conservation policies for Ogallala aquifer and relevant literature

Possible water conservation policies include voluntary interventions that are supported by the Environmental Quality Incentive Program (EQIP) funds. Provided by U.S. Natural Resources Conservation Service (NRCS), EQIP offers incentive payments for farms that adopt the potential water conservation practices. Among EQIP sponsored interventions, subsidy for advanced irrigation technology adoption and water right buyout programs, either permanent or temporary, are among the most studied examples [3,47]. According to Weinheimer et al. [44], interventions on commodity and energy prices may also prompt farmers to conserve water through economic incentives. Compared to voluntary and incentive based policy interventions, the mandate has not yet been implemented by most water districts, though some of them are already authorized by state legislation. Examples include two mandates evaluated by Johnson et al. [23]: (1) a water pumpage fee of $1 per acre foot; and (2) the 50/50 quota policy that restricts the water use to ensure that 50% of the current saturated thickness remains over the 50-year planning horizon. Tewari et al. [41] studied the effect of multi-year water allocation as an option that might be of interest to policy makers, with regard to its potential to maximize net returns from existing agricultural systems over a planning horizon of 60 years. Three different water use restriction scenarios were considered, which are 15%, 30% and 45% from the baseline scenario.

To evaluate the impact of policy alternatives on Ogallala water conservation potential, a majority of existing literature have modeled the future depletion rate of the Ogallala Aquifer from the perspective of a social planner [5,10,12,22,40,44,45]. That is, a regulatory agency owns the water and can allocate the water use effectively in a dynamically efficient manner. In reality, however, the farmers tend to make short-term decision in response to current period output prices and input costs without considering the long-term profit consequences [17,21]. Asymmetric information and adverse selection may further diminish the effectiveness of water conservative policies. As pointed out by Pfeiffer and Lin [34], farmers tend to enroll their least productive land in the water right buyout program. Thus the program's effectiveness in water conservation was greatly compromised as much of the enrolled land initially did not use much irrigation water.

In addition, while offering some insights on the implications of different policy goals, the dynamic optimization

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