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Econometric estimation of groundwater irrigation efficiency of cotton cultivation farms in Pakistan

Muhammad Arif Watto[a,c,*], Amin W. Mugera[a,b]

[a] School of Agricultural & Resource Economics, The University of Western Australia M089, 35 Stirling Highway, Crawley 6009, WA, Australia
[b] The Institute of Agriculture, The University of Western Australia M089, 35 Stirling Highway, Crawley 6009, WA, Australia
[c] U.S.- Pakistan Centre for Advanced Studies in Agriculture and Food Security (USPCAS-AFS), The University of Agriculture, Faisalabad, Pakistan

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ABSTRACT

Study region: Lodhran and Jhang districts in the Central and South Punjab province of Pakistan.
Study focus: Pakistan is amongst the largest groundwater withdrawing countries. With 5.2 million hectares groundwater irrigated area, Pakistan irrigates 4.6% of the global groundwater-fed cropland. However, over the last few decades the groundwater resources are under immense pressure due to overdrafting to meet escalating irrigation water demands. Since most of the groundwater is being extracted for irrigation purposes, examining irrigation water efficiency have become has become inevitable for sustainable groundwater management. This study estimates farm level technical efficiency (TE) and irrigation water-use efficiency (IWE) of groundwater irrigated cotton farms in the Punjab province of Pakistan.
New hydrological insights for the region: Irrigation water-use efficiency (IWE) is generally defined from three perspectives: (i) efficiency of the irrigation system, i.e., water conveyance efficiency; (ii) efficiency in water application at the farm gate and; (iii) the response of a crop to irrigation water application, i.e., the amount of water actually utilized by the crop compared to the amount of water supplied to that crop. These measures of IWE are devoid of economic principles. Hence, irrigation water efficiency has expanded its boundaries from hydrological and engineering principles to economic rationale which is useful to guide targeted farms to improve their irrigation efficiencies. This study advances the frontier of existing economic measure of IWE by employing a restricted production frontier model.

* Corresponding author at: School of Agricultural & Resource Economics, The University of Western Australia M089, 35 Stirling Highway, Crawley 6009, WA, Australia. Tel.: +61 425572555; fax: +61 0864881098.
E-mail addresses: arif.watto@research.uwa.edu.au, arifwattoo@ymail.com (M.A. Watto).

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1. Introduction

Groundwater irrigation is an important factor to agricultural production in large parts of the world especially in South Asian countries (Shah, 2007). In the Indian sub-continent more than 85% of the groundwater extraction is used for irrigation purposes (Mukherjee et al., 2014). India, Pakistan and Bangladesh are the largest groundwater using countries in South Asia. These three countries have 48 million hectares area equipped with groundwater irrigation which constitutes approximately 42% of the global groundwater-fed cropland (Siebert et al., 2010). In Pakistan, irrigated agriculture relies more on groundwater compared to the other South Asian countries due to dwindling surface water resources. Evidences suggest that existing surface water resources are not only deficient but are also highly skewed over time and space. This variation in surface water runoffs has led to the expansion of a large scale groundwater-fed irrigation system in the Indus River Basin of Pakistan. A sharp increase in the groundwater use over the last half-century has evolved as a "silent revolution" carried out by millions of farmers in pursuit of reliable irrigation water supplies. Since 1960, groundwater share to the total irrigation water supply has increased by more than 50% (Byrelle and Siddiq, 1994; Qureshi et al., 2009) and more than one million farmers have installed tube-wells[1] across the country. Fig. 1(a) and (b) shows tube-well development trends and increase in the share of groundwater in irrigation over time. During early 1960s the tube-well adoption was encouraged by the government's support policies such as rural electrification, subsidization of electricity, diesel and drilling services, supply of free pump sets and easy to get long-term loans. However, higher yields and greater economic returns from groundwater use encouraged farmers to adopt tube-wells in subsequent periods (Falcon and Gotsch, 1968; Johnson, 1989; Papanek, 1968; van Steenbergen and Oliemans, 2002). Limited to less than 30 thousands in 1960s, the number of tube-well has now gone over one million. Although tube-well ownership has been on the increase, thousands of smallholder farmers still do not own tube-wells. Those who do not own tube wells irrigate their lands by informally buying[2] surplus pumped water from their nearby tube-well owners (Meinzen-Dick, 1996; Qureshi et al., 2009).

Although groundwater resources have played a key role to agricultural production, overdrafting of groundwater resources is at critical juncture in Pakistan (Khan et al., 2008a; Kijne, 1999; Qureshi et al., 2009; Shah et al., 2000). The recent groundwater abstraction rates ($60\,km^3\,y^{-1}$) have exceeded the recharge rates ($55\,km^3\,y^{-1}$) which have resulted into substantial depletion of groundwater aquifers (Giordano, 2009). Wada et al. (2010) mapped out various hot spots of groundwater depletion in different regions of the world and noted that the highest depletion rates are in North-East Pakistan and North-West India. The rapid depletion of groundwater resources is making relative accessibility of groundwater resources economically unviable and is creating many negative environmental and economic externalities with serious repercussions to the sustainability irrigated agriculture in Pakistan (Kahlown and Azam, 2002; Kelleners and Chaudhry, 1998; Khan et al., 2008b; Kijne, 1999; Qureshi et al., 2009; Shah et al., 2000; van Steenbergen et al., 2014).

Although the agrarian economy of Pakistan is dominated by wheat, cotton, rice and sugarcane crops, cotton production remains the most important agricultural commodity due to its export value in the international trade market. Cotton production accounts for 6.9% of the value added in agriculture and contribute 1.4% to the country's gross domestic production (GDP). Pakistan remained the 4th largest cotton producer with 9.80% share in the global cotton production during the year 2011–12. Over the same period, Pakistan's yarn and apparel exports contributed 26% and 14% to the global market. At national level, cotton exports accounted for 46% of the country's entire exports and employed 35% of the total industrial labour force (FAO, 2012; Government of Pakistan, 2011–12).

[1] A tube-well is a type of water well, drilled to extract subsurface water through a pump. In Pakistan, tub-wells of 5–7 in. diameter are usually drilled to extract groundwater. These tube-wells are mounted with either 15–25 horsepower diesel engine or 15–30 horsepower electrical motor depending upon the depth of water table.

[2] In South Asia (Pakistan, India and Bangladesh) informal groundwater markets have evolved over the time for trading groundwater abstractions between the tube-well owners and non-owners (Meinzen-Dick, 1996). Such markets increase access to groundwater and offer opportunities to overcome production uncertainties for tenants and small farmers (Manjunatha et al., 2011; Meinzen-Dick, 1996; Shiferaw et al., 2008). However, such markets do not guarantee access over spatial and temporal crop water requirements (Jacoby et al., 2004).