

# Availability, Demand and Reliability of Water for In Situ Water Harvesting in Smallholder Rain-fed Agriculture in the Thukela River Basin, South Africa

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Water productivity in smallholder rain-fed agriculture in sub-Saharan Africa is of key interest for water resources availability, ecosystem sustainability and livelihood security.

A frequently advocated approach to enhance it is to adopt water harvesting and conservation technologies (WH). The objective of this study was to estimate the water availability for in situ WH and supplemental water demands (SWD, i.e. crop water requirements) in smallholder agriculture in the Thukela River Basin, South Africa. It is innovative in several respects. Firstly, it quantifies water availability and demand by incorporating process dynamics governing both runoff generation and crop water requirements at high temporal and spatial resolution (daily, 10x10 m). Secondly, it includes an account of the reliability of in situ WH (i.e. the amount of time the availability equals or exceeds the SWD). Thus, it explicitly considers the erratic nature - or temporal variability - of water, which translates to a variability in the risk of failure of the WH strategy depending on location. In its extension this may carry significant relevance with respect to finding appropriate water management policies for different areas in the basin.

For this purpose, the agro-hydrological model SWAT (Soil and Water Assessment Tool) was calibrated and evaluated with the SUFI-2 algorithm against observed maize yield and discharge in the basin. The water availability was based on the generated surface runoff in smallholder areas. The SWD was derived from a scenario where crop water deficits were met from an unlimited water source. The reliability was calculated as the percentage of years in which the water availability  $\geq$  the peak SWD.

The smallholder crop water productivity is low in the basin (spatiotemporal median: 0.08-0.22 kg•m<sup>3</sup>, 95% prediction uncertainty range (95PPU)). However, there are water resources available for in situ WH (spatiotemporal median: 0-17 mm•year<sup>-1</sup>, 95PPU) which may aid in enhancing it by meeting some of the SWD (spatiotemporal median: 0-113 mm•year<sup>-1</sup>, 95PPU). The reliability of in situ WH is highly location specific but overall rather low in the Thukela. 20-28% of smallholder areas (37 000 - 53 000 ha) display a reliability  $\geq$  25%; 13-16% (24 000 - 30 000 ha) a reliability  $\geq$  50%; and 4-5% (7 000 - 9 000 ha) a reliability  $\geq$  75% (95PPU). Hence, the risks associated with the WH strategy are very diverse such that some areas appear suitable for WH whereas others only to a much lesser extent. This account may be useful as a basis for informed decision making in the basin.

# Integrated Water Management for Food and Environment: The Case of Ghaggar-Yamuna Basin

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Keywords: rice paddies, recharge, salinity, drainage, conjunctive use

## Introduction/Problem Identification

The Ghaggar-Yamuna Basin in Haryana (India) is a grain bowl of the country and makes very significant contribution to surplus production for building buffer stock. But the estimates show that more than 30 percent of the current production is based on mined groundwater and excessive river water diversions. This is leading to unacceptable decline in groundwater and severe river water pollution. Thus both long term food security as well as physical environment in the basin is at risk. The excessive cultivation of rice, salinity, easy access to groundwater, and the public sector energy pricing policy, are said to be responsible for this emerging scenario. Results of research studies, examining the possibilities of sustaining high agricultural productivity by maintaining a favorable salt and water balance in crop root zone, aquifers and the river system, through integrated water management (IWM), are presented.

## Analysis/Results and Implications for Policy and/or Research

The IWM has many facets, but only selected few, having good success potential in this region, including rainwater harvesting in rice paddies, adjustment in crop areas, efficient on-farm irrigation management and the conjunctive use of canals and the marginal quality groundwater, generated through vertical and horizontal drainage systems, are explored. Enhanced storage of rainwater in upper reaches during monsoon period, to support irrigation and environmental flows during non monsoon months also has some possibilities, and is briefly discussed.

**Water harvesting in rice paddies:** Rice is the preferred crop of the region and it occupies 60 - 80 percent of cropped area during monsoon season. The annual rainfall of about 700 mm occurs in few spells and causes surface water logging in flat lands of alkali nature which have impeded drainage. Rice paddies in lower landscapes offer ideal opportunity to store rainwater. Research studies have shown that rice paddies could store up to 150 mm water without any damage to standing crop. It would substantially reduce not only the water required for irrigation, but also minimize the energy required for pumping groundwater. Reduced runoff would permit downsizing of surface drainage network that functions only for few weeks during monsoon period.

**Reallocation of crop areas and improvement in on-farm irrigation management:** Rice-wheat is the dominant cropping system which has a combined annual evapotranspiration requirement of 1000-1100 mm. Although, the overall utilization of rainwater due to rice cultivation is high (of the order of 85 %) ,but it has created a net water deficit as the water requirement of this cropping system are high.. The water availability from all sources (rainfall 500-750 mm, canals 150-400 mm and net groundwater inflow 40-50 mm) falls short of demand by 75-150 mm. This water deficit is largely met by increased groundwater withdrawal in excess of annual recharge, leading to decline in water table. Investigations have shown that stabilization of water table would require 15-25 % reduction in existing land allocation to rice. Higher recharge to ground water can also be generated, if 10 % of the land were left fallow during monsoon period and used for rainwater conservation. Low water requiring winter crops could be raised on this land on residual moisture during winter season. Precision leveling and adoption of raised bed and furrow system of

cultivation in combination with conservation tillage has also shown promise, and is being adopted.

Conjunctive use of fresh and marginal quality waters: The basin has large tracts of land underlain by saline/alkali groundwater. Conjunctive use of aquifers bearing marginal quality waters and canals is therefore an attractive proposition. This practice is in vogue and between 30-40 % current food grain production in the region is attributed to increasing use of marginal quality waters. But the issue is how to make this practice sustainable. Several studies have established that in the short term, exploitation of marginal quality ground water for irrigation not only augments water supply, but also help in maintaining water table within safe limits. But reports from Pakistan and parts of North West India points towards the danger of salinity build up in groundwater. Hence the sustainability of marginal quality water use can only be ensured by disposal of part of saline groundwater (extracted through shallow tube-wells skimming wells and the horizontal sub-surface tile drainage system) through the surface drainage network discharging into River Yamuna. Measurements show that monsoon flows of River Yamuna are very large (of the order of 14000 m<sup>3</sup>/s) and can dilute the salinity of drainage effluents, which relatively small in magnitude, without causing problem to downstream users. Projects to harness additional monsoon flows are also in the offing to enhance the fresh water supplies and provide for increased environmental flows.

In conclusion, the concept of Ghaggar-Yamuna basin as a water machine is invoked. In this scheme green water availability and its utilization in rice paddies is increased. Vertical and horizontal drainage systems that generate marginal quality water for irrigation also lower water table, reduce root zone salinity and create space for storing fresh water recharge in the aquifers. The increased use of marginal quality water and its partial disposal into regional drainage network increases agricultural production and helps maintain a favorable salt and water balance.

Abstracts to be presented by  
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within Workshop 7 – Water Storage Options for Secured Access

## High Arsenic in Ground Water in West Bengal and Its Mitigation

Contamination of ground water due to the presence of Arsenic in excess of permissible limits for human consumption is a major constraint in providing safe drinking water supplies in the States of West Bengal, Bihar and Uttar Pradesh and to a lesser extent in the states of Assam and Chhattisgarh in India. Arsenic contamination of ground water has been reported from 8 districts in West Bengal, 15 districts in Bihar, 5 districts in Uttar Pradesh and 1 district each in Assam and Chhattisgarh states. Arsenic contamination of ground water in these areas is mainly of geogenic origin, involving leaching of geological materials containing Arsenic and dissolution of unstable Arsenic minerals. Adsorption, desorption and chemical transformations have also played a major role in the arsenic mobilization.

Central Ground Water Board under the Ministry of Water Resources, Government of India is actively engaged in various studies involving hydrogeological and hydrochemical field investigations and exploratory drilling for ascertaining the extent and magnitude of Arsenic contamination in the affected areas. It has identified and delineated arsenic free aquifers in such areas and has constructed a number of tube wells to extract water from these aquifers using suitable tube well construction techniques including cement sealing of contaminated aquifer zones to prevent arsenic rich water from the upper/lower zones to mix with the arsenic free water.

Central Ground Water Board is also providing technical guidance regarding the position of arsenic free aquifers, depth of the well and the design of tube well to be constructed in arsenic infested areas for supply of Arsenic free water. The details related to Arsenic contamination of ground water in the State of West Bengal, findings of investigations carried out by Central Ground Water Board and design of tube wells for tapping Arsenic-free aquifer zones are depicted in the poster.

# Palla Well Field, Delhi – A Model of Sustainable Ground Water Development & Management

Flood plain aquifers provide sustainable water supply to meet increasing demands during lean periods. In India, the high runoff in Himalayan rivers is mostly confined to 3 months during monsoons. The floods during this period recharge the adjacent riverbanks and flood plains in the vicinity of the river. Pumping from production wells along the banks from this naturally replenishing ground water reservoir helps in meeting the demand, especially, during the non-monsoon season on a sustainable basis.

New Delhi, the capital of India, needs about 927 Million Gallons of Water per day for its drinking water supply. The present supply from all sources is of the order of about 815 Gallons per day, leaving a demand-supply gap of about 112 Million Gallons per day. Studies taken up have proved that it is possible to tap the ground water from the flood plains of river Yamuna to partly bridge this gap. It has also been proved that the ground water extracted from the unconsolidated aquifer zones in the depth range of 35 to 65 m in the flood plains get replenished during the rainy season, thus providing sustainable water supply to the city.

A well field developed by the Central Ground Water Board in Palla area in the Yamuna flood plains is supplying about 30 Million Gallons of potable water per day to the city. The poster highlights the problem of over-exploitation of ground water resource in Delhi and depicts details of ground water regime in Palla area, along with the schematics of how the phenomenon of induced recharge could be successfully made use of for providing sustainable drinking water supply to the city from the Yamuna flood plain aquifers.

# Impact of Artificial Recharge on Ground Water Regime in Kadapa District, Andhra Pradesh, India

About two-thirds of the total land area of India is underlain by hard crystalline rocks which are devoid of primary porosity and are characterized by limited ground water potential. Ground water, stored mainly in the weathered residuum at shallow depths is often the principal source of water for various uses in these areas. Increasing extraction of ground water to satisfy the needs of increasing population, coupled with vagaries of rainfall and other environmental factors has, in recent decades, resulted in considerable de-saturation of these shallow aquifers in many areas. It is leading to various adverse environmental impacts including drying up of shallow wells, long-term decline in ground water levels and increased energy consumption for lifting water from progressively greater depths. Augmentation of ground water in these areas through suitable artificial recharge structures provides a means of improving the sustainability of ground water resources available in these aquifers.

Demonstrative studies taken up by the Central Ground Water Board, Ministry of Water Resources, Government of India have established the efficacy of artificial recharge in augmenting the ground water resources in the shallow phreatic aquifers in areas underlain by hard rocks. These studies have also helped identify the suitability of recharge techniques for various hydrogeological and geomorphic settings. Impact assessment of the artificial recharge schemes implemented has shown that they have been effective in arresting /reversing the declining trends in ground water levels, increasing the sustainability of existing structures and also in improving ground water quality. The poster depicts the details and positive environmental impacts of one of such demonstrative recharge experiments implemented in the drought-prone Kadapa district in the state of Andhra Pradesh, India.

## Success Stories of Rainwater Harvesting and Artificial Recharge of Ground Water in Delhi, India

Many of the urban settlements in India are characterized by high population density and rapid urbanization and problems related to water supply. Increased extraction of ground water and reduction in ground water recharge due to anthropogenic activities are characteristic of many of such areas, resulting in long-term decline in ground water levels. Delhi, the capital of India, is a typical urban area facing the problems of shortage of water for drinking and domestic uses and declining ground water levels due to extraction of ground water in excess of natural recharge. Rain water harvesting and artificial recharge have been found effective in replenishing the depleted aquifers and preventing/arresting further decline in ground water levels.

Studies carried out by Central Ground Water Board, Ministry of water Resources, Government of India has helped in identifying the techniques for recharge augmentation suitable for various geomorphic and hydrogeologic settings in Delhi and also in finalizing their design specifications for optimum benefits. Many such rainwater harvesting and artificial recharge structures including recharge trenches, recharge wells and shafts have been constructed by the Board in Delhi, which have been highly effective in bringing up the water levels in the surrounding area and also in improving the sustainability of existing wells. These structures have also helped in reducing problems of water logging in the areas in rainy season to a considerable extent. Select success stories of rainwater harvesting/artificial recharge structure constructed in Delhi along with their design particulars, details of the quantum of water harvested and rise in ground water levels observed have been shown in the poster.

# **Artificial Recharge to Ground Water Utilizing Patiala River, District Patiala, Punjab, India**

The State of Punjab in the northwestern part of India is among the top producers of food grains in the country. Development of ground water resources, mainly for irrigation, is quite high in the state and the overall stage of ground water development in the state has been assessed at 145%. The continued over-extraction of ground water resources from the aquifers have resulted in various adverse environmental impacts including drying up of shallow wells and decline in ground water levels. These impacts have the potential of adversely affecting the food security and economic development of the country as a whole unless measures are taken to augment the ground water resources in the depleted aquifers.

Several path-breaking initiatives have been launched by the Ministry of Water Resources, Government of India on pilot basis to achieve this objective. Demonstrative artificial recharge schemes implemented in various places in the state by Central Ground Water Board have been effective in popularizing cost-effective techniques of recharge augmentation, suited for different geomorphic/geologic settings in the state. One of such techniques involved augmentation of recharge using monsoon runoff through recharge trenches and tube wells in the river beds at suitable locations. This technique, successfully demonstrated in Patiala river, district Patiala, Punjab, could be replicated elsewhere in similar settings for ground water recharge augmentation. The design particulars of the recharge structures constructed and their positive impacts on the ground water regime have been depicted in the poster.

Abstracts to be presented by  
**Dr. R.K. Jain**, National Water Development Agency, India  
within Workshop 4 – The Role of Inter-basin Transfers in Accessing Water

## Need for Inter Basin Water Transfer (IBWT) of Rivers

In India, the rainfall is confined to a few monsoon (rainy) months and is unevenly distributed both in space and time even during rainy season. As a result, large parts of the country are either drought prone or are affected by floods. Inter Basin Transfer of flood waters from water rich areas to water deficit areas is a viable proposition to even out spatial imbalances in water availability and to mitigate the ill effects of flood and drought and thus to achieve equitable distribution.

Long distance inter basin transfer of water is not a new concept and has been in practice in India for over five centuries. The Periyar-Vaigai Link Project, Kurnool-Cudappa Canal, Telugu Ganga Canal, Parambikulam-Aliyar Project, Ghagra-Sarda, Madhopur-Beas Link, Beas-Sutlej link, Indira Gandhi Canal Project, Sardar Sarovar Scheme and Tehri Dam Project are good examples of inter basin water transfers executed in India in the 19th and 20th centuries. These inter linking projects have been highly beneficial and have not resulted in any noticeable environmental damages.

## Proposed Inter Basin Water Transfer Links

Govt. of India has formulated a National Perspective Plan in 1980 comprising two components viz. (i) Peninsular river development (ii) Himalayan river development. 30 Inter Basin Water Transfer Links, 16 under Peninsular River Development and 14 under Himalayan River Development have been identified which will give additional benefits of 25 million ha. of irrigation from surface water, 10 million ha. by increased use of ground water and generation of 34 million KW of power, apart from the benefits of flood control, navigation, water supply, fisheries, salinity and pollution control etc.

## River Sutlej, Beas, Ravi & Connected Main Canals

Ravi-Beas, Beas-Sutlej links in combination with the Indira Gandhi Canal Project is a standing example of how the large Inter basin transfers brought about all round socio-economic growth with overall enhancement in the ecology and environment of the region. Ravi-Beas link (4.5 BCM/yr) was built for transfer of surplus water from Madhopur Headworks on the Ravi River to Harike via the Beas River. Bhakra dam is the main multipurpose storage on the Sutlej River while the Pong dam has been constructed on the Beas River. The inter-connected Beas-Sutlej Link has been built up to transfer (4.71 BCM/yr) from the Beas River to Bhakra dam in Sutlej basin in addition to 165 MW power generation. The transfer of surplus waters of Ravi, Beas and Sutlej to Rajasthan (9.36BCM/yr) right up to Jaisalmer and Barmer through Indira Gandhi Canal Project has eliminated drought conditions, provided power benefits, transformed desert waste land into an agriculturally productive area by bringing irrigation and vegetation to about 2 million ha area.