Problems and Prospects of Saving Water and Energy in Agriculture in Upper Ganga River Basin

**Executive Summary**

An initiative by WWF-India’s ‘Living Ganga Programme’
EXECUTIVE SUMMARY

1. INTRODUCTION

All over the world, the gap between water demand and supply is widening fast due to burgeoning population and increasing economic activities. Climate change has further added an unknown variable into this complex equation of water gap calculations. The quantity of water is finite in nature. The growing demand for water in domestic, municipal, industrial, recreational sectors and in other uses has increased the concern that the available water is used most efficiently and effectively. On an average, the global consumption of water in agriculture is around 71% of the total water use. The corresponding figures for India and Uttar Pradesh are 89% and 93% respectively. Hence, water and energy security for India and Uttar Pradesh can only be ensured by improving water use efficiency and productivity in agriculture.

A recent report by McKinsey and Company \(^{ii}\) has concluded that the “business-as-usual” trends are insufficient to close the water gap and the result in many cases could be that fossil reserves are depleted, water reserved for environmental needs is drained, or—more simply—some of the demand will go unmet, so that the associated economic or social benefits will simply not occur.

Uttar Pradesh has a wide network of around 73637 km canals, 27600 State owned tube-wells, 17768 deep tube wells and 3.96 million shallow tube-wells owned by individual farmers \(^{iii}\). These systems irrigate around 13.08 million ha area in which canals share 18 %, State Tube-wells 3% and Private Tube-wells share 70.2 % \(^{iv}\). According to an estimate these systems irrigate at an efficiency of 30-45%. There are good possibilities of improving efficiency, effectiveness, economy and equity of water use in agriculture, thus making it available to other development sectors and environmental needs. As groundwater pumping contributes to 70.2% irrigation in U.P., the saving in irrigation water will cause saving of energy also.

In the Ganga Basin, the canals draw almost all available water from the river Ganga to the point of making the river dry, damaging the downstream river ecosystem. On the other hand tubewells which contribute to 70.2 % irrigation, draw water from underground aquifers using fossil fuels. These private tubewells generally irrigate in conjunction with canal irrigation as well as independently. The inefficiency of the tubewells results in less water delivery for every litre of fossil fuel consumed and thus increases irrigation cost and emissions which pollute the environment.

Keeping in view the environmental flow(s) concerns in River Ganga, WWF-India decided to sponsor a study to evaluate not only the problems but also the prospects of saving water and energy in agriculture in Upper Ganga River Basin (UGRB) under its ‘Living Ganga Programme’.
The Upper Ganga River Basin (UGRB) has 4 off-taking canals from river Ganga. These are namely Upper Ganga Canal, with diversion works at Haridwar in Uttarakhand, Madhya Ganga Canal with head works at Bijnor in U.P., Lower Ganga canal and Parallel Lower Ganga Canal with diversion at Narora in District Bulandshahar in U.P. The irrigation on Eastern Ganga canal and Madhya Ganga Canal Stage II are yet to stabilize.

To conduct this study, Kanpur Branch of Lower Ganga Canal system was selected as representative area in Upper Ganga River Basin (UGRB) to study in detail and the results are then extrapolated to the entire UGRB.

2. LITERATURE SURVEY AND DATA COLLECTION

McKinsey and Company in their latest report titled ‘Charting Our Water Future’ have projected that, in just 20 years, the demand for water will be 40% higher than it is today and more than 50% higher in most rapidly developing countries.

The report says that by 2030, demand in India will grow to almost 1500 BCM, driven by domestic demand for rice, wheat, and sugar for a growing population, a large proportion of which is moving toward a middle-class diet. Against this demand, India’s current water supply is approximately 740 BCM. As a result, most of India’s river basins could face severe deficit by 2030 unless concerted action is taken, with some of the most populous—including the Ganga, the Krishna, and the Indian portion of the Indus—facing the biggest absolute gap. The “business-as-usual” trends are insufficient to close the water gap and the result in many cases could be that fossil reserves are depleted, water reserved for environmental needs is drained, or—more simply—some of the demand will go unmet, so that the associated economic or social benefits will simply not occur.

The most important conclusion of the report is that India’s water gap can be closed in a sustainable manner by improving agriculture’s water efficiency and productivity.

A brief overview of earlier studies on water and energy use efficiencies is given below:

<table>
<thead>
<tr>
<th>Studies at Global Level</th>
<th>Studies at National Level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water Use Efficiency Studies</strong></td>
<td></td>
</tr>
<tr>
<td>Postel : Efficiency of systems throughout the World averages 37%</td>
<td>Irrigation Research Institute, Roorkee: Overall efficiency of UGC: 31% to 38%.</td>
</tr>
<tr>
<td>ICID (M.G.Bos): Project efficiency ranges from 15% to 40% (average 22%)</td>
<td>World Bank UGIMP Project: Overall efficiency of UGC 28%.</td>
</tr>
<tr>
<td>FAO: Study of project efficiencies in all developing countries. It averages 38%</td>
<td></td>
</tr>
<tr>
<td>IWRS: Five Indian Projects. Project efficiencies range from 30-41% (average 36%)</td>
<td></td>
</tr>
<tr>
<td><strong>Energy Use Efficiency Studies</strong></td>
<td></td>
</tr>
<tr>
<td>FAO: Overall efficiency of energy use in an irrigation system can be as low as 0.4% and ranges between 0.4% and 45%.</td>
<td>WAPCOS (UP Sodic Land Reclamation Project Phase I): Average overall energy efficiency: Diesel pump sets 10.24% Electric pump sets 44.85%</td>
</tr>
</tbody>
</table>
A good field study to improve the efficiency of irrigation pumpsets and reduce fossil fuel consumption, emissions and costs has been published by The Energy Research Institute (TERI) in 2002\textsuperscript{vi}. It has brought out clearly that the main drivers of efficiency in agriculture pumpsets are:

\begin{enumerate}
\item Selection of engine horse power and make
\item Friction in suction / delivery piping system
\item Engine cooling temperature
\item Engine speed and
\item Friction in foot valve/ reflex valve
\end{enumerate}

TERI’s publication discusses at length that dissemination is in many ways the hardest part of participatory technology development. Innovations do not necessarily disseminate at their own merit. According to the study, the real challenge lies in the dissemination of pump selection criteria and good operation and maintenance practices among the farmers who go by tradition and myths which are hard to break.

\section{3. PARAMETERS AND DRIVERS OF WATER USE EFFICIENCY IN AGRICULTURE}

The term water use efficiency has many connotations depending upon technical, agronomic or economic perspective.

The International Commission on Irrigation & Drainage (ICID)\textsuperscript{viii} has developed a definition encompassing all technical water use efficiencies which is also adopted by Irrigation Association of Australia\textsuperscript{viii}. They use the term ‘Overall Project Efficiency’ (OPE) which is suitable for all irrigation systems.

\textbf{The Overall Project Efficiency} ($E_{O}$) considers all losses from canal head up to the root zone which is the product of conveyance efficiency ($E_{c}$), distribution efficiency ($E_{d}$) and application efficiency ($E_{a}$).

\[ E_{O} = E_{c} \ast E_{d} \ast E_{a} \]

Throughout this study, irrigation water use efficiency definition by ICID has been adopted as the main criteria of water performance. The use of single normative judgment has the advantage that any physical or socio-organizational feature can be tested against the same yardstick, while it also allows a simple prediction of the combined effects of these features. Criteria like crop yields or financial return per volume unit of water were not applied in the Study as these would only partially reflect the effect of irrigation. Moreover, many and wide variations in agronomic economic conditions would not have allowed comparisons to be made.

Similarly for energy efficiency calculations, Overall Pumping System Efficiency has been adopted as the main criteria of energy performance. Overall Pumping System Efficiency is a combination of several parameters that accounts for all the components of a pumping system, i.e., pump, transmission system, head losses in pipes and fittings including reflex valve, velocity head and prime mover efficiency.
Overall pumping system efficiency is defined as: $e_o = \frac{\text{WHP}}{\text{IHP}}$

Where, WHP= Water Horse Power and IHP= Input Horse Power in terms of power or fuel consumed by the prime-mover.

The following parameters are identified in the Study to have a bearing on water and energy use efficiencies in agriculture:

1. Crop water requirement in the area served
2. Frequency of irrigation
3. Land management and tillage practices
4. Water allowance and capacity factor in designing canals
5. Roster
6. Structural constraints in equity
7. Canal regulation and maintenance
8. Management Information system and decision support system
9. Tubewell installation practices
10. Conjunctive use of surface and groundwater

4. WATER LOSSES IN CANAL SYSTEM

Water losses are inevitable during conveyance and may be categorized as (i) Evaporation in channels (ii) Seepage in conveyance (iii) Leaks from structures in bad condition (iv) Wastage due to incorrect canal operation (v) Evapo-transpiration and (vi) Unauthorized irrigation

The overall efficiency of selected canal system, namely, Kanpur Branch Canal has been computed under this study to 29.2%. Extrapolating these results to Upper Ganga River Basin, it is estimated that 19.33 BCM water drawn directly from Ganges fails to irrigate the intended crops and ends up in evaporation or recharging of the basin aquifers. Reuse of this water for agriculture through ground water pumping requires the additional use of fossil fuel/electricity.

The results show that canal design lacks uniformity in fixing head discharges. Some canals are provided head discharges more than required like Shivrajpur Distributary while others like Narora Distributary and Noner Minor have insufficient authorized head discharges to meet even their authorized outflows. Both the situations, where authorized head discharge is more and where it is less, lead to inefficient use of canal water. It requires revisiting & re-fixing of head discharges of canals accounting for total outflow and seepage losses.

Water Use Efficiency may also be improved through improvement in operation plans. The data related to planned deliveries, actual deliveries and crop water requirement in the command of Kanpur Branch was matched and it is concluded in the Study that 19% of water supplied is wasted as surplus supply or ‘supply at the time when there is no demand ‘although Kanpur Branch is already affected by low supplies, as shown in the graph below.
The study reveals that discharges run in the months of April and May, may be saved if rosters are not planned mechanically. Further analysis reveals that canal has to run for feeding discharges for non-agriculture purposes to supply 252 cusec water for Panki Thermal Power House, Kanpur Jal Sansthan and two ordnance factories. As these establishments are situated at the tail reach, around 400 cusec water has to be released in the canal to supply this 252 cusec and to cover for the seepage losses in the run. If these discharges are arranged locally, at least 148 cusec water which is lost in transit may be saved. Such situation exists in some more systems in UGRB and few more proposals to supply water for non-agricultural use from canals are underway. It requires a policy decision for instance whether such supplies are to be continued / allowed from canals throughout the Ganga Basin. Alternatively, this water may not be lifted from Ganga during non agriculture demand period to augment environmental flows in Ganga and the requirement of industry, energy and municipal supplies be fulfilled from locally available resources including rainwater harvesting and demand management.

The canals and tubewells supply water to crops to meet their water requirements which are a function of climatological conditions and crop stages. The crop data was taken from the statistical diary published by UP Planning Department (also available on their website) and crop water requirement was calculated using computer software ‘CROPWAT’ developed by FAO. The required water depth at field was compared with the water supplied by canals and tubewells to calculate the overall water use efficiency.

The calculation of crop water requirement and water supplied by canal and tubewells were validated from the statements made by farmers during primary survey which testified that the calculations of seepage and operational losses in the study are realistic and reasonably correct. In study area water depth supplied by canals is calculated by analyzing five years actual run of water in canals and finding out the shortage of canal water in meeting out the crop water requirement. The shortage of canal water is supplemented by 35000 private tubewells in study area and 10.84 lakh tubewells in UGRB districts. The computation of crop
water requirement and water depths provided by canal and tubewells in the study area are summarized in the following table:

(Unit: mm)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Crop water requirement at field</th>
<th>Water Depth provided at head / field by Kanpur Branch</th>
<th>Computed Shortage to be met by tube wells at head / field</th>
<th>Water depth provided by tube well at head / field as told by farmers</th>
<th>Total water depth applied at field level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kharif</td>
<td>608</td>
<td>1050 408</td>
<td>153 116</td>
<td>268 204</td>
<td>612</td>
</tr>
<tr>
<td>Rabi</td>
<td>380</td>
<td>620 241</td>
<td>153 116</td>
<td>158 120</td>
<td>361</td>
</tr>
</tbody>
</table>

The table shows that ‘crop water requirement’ of Kharif and Rabi are just met using canal and tubewell water when head supplies of these sources are reduced by their respective conveyance efficiencies at field. It validates farmers’ statement that they use canal and tubewell water in a proportion of 2:1. According to the primary survey, in supplementing water to fields each of these tube-wells run 177 hrs in Kharif and 116 hrs in Rabi. Therefore water poured by 35000 tubewells with a discharge of 11.3 litres per second existing in command serving an area of 68000 ha gives a depth of 620 mm in Kharif and 570 mm in Rabi. The following table summarizes the total water depth provided by canal and tube wells at the system head against water depth required at the field giving overall water use efficiency in Kharif and Rabi seasons:

<table>
<thead>
<tr>
<th>S. Nr.</th>
<th>Crop</th>
<th>Water Depth required (m)</th>
<th>Water Depth Provided by both Canal &amp; TW (m)</th>
<th>Water Use Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kharif</td>
<td>0.608</td>
<td>1.67</td>
<td>36.4 %</td>
</tr>
<tr>
<td>2</td>
<td>Rabi</td>
<td>0.380</td>
<td>1.19</td>
<td>31.9 %</td>
</tr>
</tbody>
</table>

This exercise when extrapolated to UGRB gives more or less similar results. The UGRB districts have cropping pattern slightly loaded in favour of the sugarcane crop in comparison to the study area. Sugarcane, being a water guzzling crop, increases the average crop irrigation requirement both in Rabi and Kharif. This water requirement comes to 722 mm in Kharif instead of 608 mm in study area and 416 mm in Rabi instead of 380mm in study area. With the same approach as in the study area, an efficiency of 42% in Kharif and 33% in Rabi has been calculated for agriculture water use in UGRB. These efficiencies are better in comparison to the study area and may be attributed to the rotational water supply (Warabandi) and improved surface application method in upper reaches of canal systems. These efficiencies may be improved at least by 10% by cutting operational losses through scientifically prepared operational plans, adherence to these plans and schedules, revisiting the head discharges of canals, demonstrating improved surface application method and promoting efficient technological application methods.
5. ENERGY AND WATER LOSSES IN TUBEWELL IRRIGATION SYSTEM

As the inefficiency exists in water conveyance, it also exists in the running and maintenance of tubewells. The primary survey reveals that most of the farmers used movable engines of 10 HP whereas only 4 HP engines are required to serve the purpose. Not only this, the study quantifies that the consumption of fuel is also much higher than required. Selection of improper pumping unit and excessive pipe length are also the causes of inefficiency.

In the UGRB irrigation from groundwater is provided through 950000 shallow diesel pump sets and 134000 electric pumpsets owned by the farmers and 5871 deep state tubewells owned by the Irrigation Department. The overall efficiencies of tubewell irrigation systems are found in the study as below:

<table>
<thead>
<tr>
<th>Type of pump set</th>
<th>Water supplied at field (BCM)</th>
<th>Number</th>
<th>Discharge (lps)</th>
<th>Overall efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Diesel Pump Set</td>
<td>3.29</td>
<td>950000</td>
<td>11.14</td>
<td>5.39 %</td>
</tr>
<tr>
<td>2. Electric Pump Set</td>
<td>4.40</td>
<td>134000</td>
<td>12.50</td>
<td>27.18 %</td>
</tr>
<tr>
<td>3. Deep STW</td>
<td></td>
<td>5871</td>
<td>27.21</td>
<td>28.97 %</td>
</tr>
</tbody>
</table>

Since the tubewells, particularly diesel pumpsets run on very low efficiency, there is a good scope of saving diesel and electricity by improving overall efficiencies of these pumpsets.

6. WAY AHEAD

The possibilities of water and energy saving in agriculture, as found in the study, are summarized below:

**Prospects of Overall Water, Energy and Emission saving in Agriculture per year in Upper Ganga River Basin**

<table>
<thead>
<tr>
<th>S. No</th>
<th>Situation</th>
<th>Water (BCM)</th>
<th>Pumping (hr)</th>
<th>CO₂ emission (tonne)</th>
<th>Diesel (kI)</th>
<th>Electricity (kWh/MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10% improvement in distribution and application efficiencies (i) Canal &amp; shallow T.W. (ii) State Tube Wells</td>
<td>1.82</td>
<td>44827918</td>
<td>140716</td>
<td>52897</td>
<td>63666957 kWh</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.44</td>
<td>4491813</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Improvement due to proper selection of diesel pump and its piping</td>
<td></td>
<td></td>
<td>377747</td>
<td>141928</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>10% improvement in efficiency of electric tube wells (shallow and deep)</td>
<td>2.26</td>
<td></td>
<td>0.52 million</td>
<td>195 million</td>
<td>64m / 82 MW</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>2.26</td>
<td>49 million</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
To achieve envisaged savings demand management, as well as change management strategies are required: (1) demand management comprise of updating the canal & tube well infrastructure, dynamic operation plans, roster, irrigation scheduling and establishing consumption based cost recovery regime and (2) change management strategies which comprise of establishing urgency of environmental flows restoration to Ganges through mass awareness campaigns, top level steering committee to finalize vision and action plan for Ganga and authorize departments, agencies to work on laid down action plan and establishing logistical support mechanism. For the vision of achieving early results, demonstrable success stories thorough pilot projects and gradual extension of work plan to cover new areas is suggested so that gradual embedment of successful interventions in to cultural ethos of society may take place.

End Notes and References

1 U.P. Water Plan Framework ‘by Er. Ravindra Kumar, State Water Resources Data Analysis Centre, Uttar Pradesh
2’ Charting our water future ‘ by McKinsey and Company, 2009
4 ‘Statistical Diary Uttar Pradesh 2009’, page 133, published by Planning Department, Government of Uttar Pradesh
6 ’Technology innovation and promotion in practice: pumps, channels and wells’ published by Tata Energy Research Institute(2002), now The Energy Research Institute
7 Bose et al 1993
8 “Irrigation Efficiencies Gaps-Stock Take” prepared by Aqualinc for SFF & INZ (Report N0.L05264/2)
9 Efficiency of Kanpur Branch up to field level considering seepage = 48% (0.84*0.89*0.85*0.76) ; combining it with operational losses of 19% , the overall efficiency will be 0.48*0.81 =0.3888 , say 0.389 or 38.9 %. Hence 1050 mm water depth at head shall be 1050*0.389 = 408 mm in Kharif and 620*0.389 = 241 mm in Rabi at field level.
10 Efficiency of tube well conveyance is 76% (considering 24% seepage losses in conveyance system). Hence the water depth of 116 mm at field would require depth of (116/0.76) or 153 mm at draft point.
11 Farmers told during field survey that after normally canals have shortage of water and they could hardly get two irrigations from canal and are forced to supplement one irrigation from tube wells. Hence the depth provided by tube well is half of the depth provided by the canal.