# EVALUATING BAMBOO-REINFORCED PRECAST CHANNEL LININGS TO REDUCE WATER LOSS IN IRRIGATION SYSTEMS

**Abstract**

Generally, farmers adhere to recommended irrigation time for most crops, with the exception of summer paddy, where they tend to keep the crop continuously submerged. Conversely, the state of the terrain affects the depth of ponded water. It is typical for farmers to over irrigate in uplands, which causes some of the water to gather in lowlands through lateral seepage and additional submergence. It is believed that between 20 and 30 percent of the water redirected in our country is lost due to seepage in field canals. In an irrigation order, excess loss via an unlined field channel lowers the area that is watered, raises the need for water, and raises the cost of agriculture. Inefficient water application, zigzag distribution following spouts, and high seepage via the earthen channel have caused West Bengal's irrigation command to shrink from 40 hectares to 25–30 hectares for a DTW. Crop fields require irrigation with 80% of the total water used for irrigation; therefore, unless the aforementioned irrigation water loss can be significantly mitigated by suitable means, there will be a considerable deficit in irrigation water. The output of agriculture will significantly decline as a result.

Keywords: Irrigation, DTW, water demand and water loss, Seepage Loss, Precast Channel, Cost-Benefit Analysis

**Authors**

**Uddipta Ghosh**
Department of Civil Engineering
JIS College of Engineering
Kalyani, Nadia, West Bengal-741235, India
ghosh@jiscollege.ac.in

**Debargha Banerjee**
Department of Civil Engineering
JIS College of Engineering
Kalyani, Nadia, West Bengal-741235, India

**Debasish Das**
Department of Civil Engineering
JIS College of Engineering
Kalyani, Nadia, West Bengal-741235, India

**Tanmoy Das**
Department of Civil Engineering
JIS College of Engineering
Kalyani, Nadia, West Bengal-741235, India

**Anusri Sarkar**
Department of Civil Engineering
JIS College of Engineering
Kalyani, Nadia, West Bengal-741235, India

**Nabankur Karmakar**
Department of Civil Engineering
JIS College of Engineering
Kalyani, Nadia, West Bengal-741235, India

**SK Aliul**
Department of Civil Engineering
JIS College of Engineering
Kalyani, Nadia, West Bengal-741235, India

**Abheek Haldar**
Department of Civil Engineering
JIS College of Engineering
Kalyani, Nadia, West Bengal-741235, India

**Abhishek Kundu**
Department of Civil Engineering
JIS College of Engineering
Kalyani, Nadia, West Bengal-741235, India.

## I. INTRODUCTION

In the State of West Bengal, a deep tube well has an Efficient utilisation of current water resources is crucial for a country like India, where 17 percent of the world's population lives on just 2.4 percent of the land. 4 percent of the water resources on Earth Moreover, the average amount of usable water resources per person, which were 5247 m3 in 1951 and remain 5247 m3 now, is expected to decrease to 1170 m3 by the year 2050 from 1453 m3 at the end of the current year [1]. Eighty percent of groundwater is used by the agriculture sector alone. The nation's groundwater levels are trending downward, which implies that maintaining a steady supply of high-quality water will become more difficult as the nation grows [2]. The overall efficiency of the flood irrigation system varies between 25 and 40% [3].In terms of water usage efficiency, energy savings, yield growth, and net return per unit volume of groundwater, micro irrigation outperforms other standard irrigation systems [4, 5]. To satisfy the anticipated population's food security, economic, and nutritional demands in 2050, India's food output will have to nearly quadruple. With the installation of different artificial conservation measures, the groundwater table can be enhanced, as can agricultural yield [6]. Between 1991 and 2007, India invested approximately $4 billion in public canal networks [7]. Despite this, the canal- irrigated area declined by 38 lakh hectares during that time due to outdated infrastructure, poor water delivery, and a lack of incentives. This means that "our administrations have not been able to halt groundwater depletion despite significant public investment on canals." The main reason is the growing disparity between irrigation potential produced and actual use. Punjab, Uttar Pradesh, and Uttarakhand have the largest reliance on ground water for irrigation (79 percent of the land watered is by tube wells and wells), followed by Uttar Pradesh (80 percent), and Uttarakhand (80 percent) (67 percent). According to a 2013 estimate by the Central Ground Water Board (CGWB), India's total yearly replenishes able groundwater resource is about 433 billion cubic metres (BCM), with a net annual groundwater availability of 398 BCM, of which India withdraws 253 BCM (62%) per year. Around 39% of wells, according to the CGWB, are exhibiting a drop in groundwater level. Based on the stage of groundwater removal as well as long-term drop in groundwater level, 1,034 assessment units (in 15 states and two union territories) have been classed as "over exploited"[8,9]. A two-cusec average discharge was used to water 40 hectares of land. The cropping order that a farmer follows in an irrigation command is determined by the crops that are appropriate for that region, the farmer's socioeconomic situation, and consumer demand. With the exception of some supplemental irrigation for winter paddy, tube wells are mostly idle throughout the kharif season but are heavily utilized during non-monsoon seasons. However, the cropping strategy used in the spring and summer has a major impact on how a tube well is used. Despite a progressive increase in total running hours, it has been noticed that the number of operating days in the entire region decreases as the area covered by summer paddy grows. According to calculations, a deep tube well can irrigate just 65% of the irrigation demand if the summer paddy's gross water need is assumed to be 125 cm. This reduces the system's efficiency since the farmers often leave the remaining area of land as command fallow on a rotating basis. In rice fields that require irrigation until the final week of April, when the water table drops dangerously low, farmers typically choose medium- and long-duration types in order to maximize yield. Farmer's shallow machines are often lowered to a depth of 2-3 meters below earth for irrigation in such conditions. Water is a precious commodity. Necessity of conservation of water supply is increasingly felt all over the world as the demand of it continues to increase when the sources of supply are increasingly scarce. The conveyance and proportional distribution of water is one of the most important parts of any irrigation project. Water available in the stream, reservoirs or wells is carried to the field of use through canals. The economy of any irrigation project largely depends on how efficiently the water is being transported and distributed in respect to water losses and cost. Water losses in irrigation channels are mainly due to evaporation from the water surface and seepage from the bed and side of the channels. Seepage losses some time become the single important factor which causes unavailability of water particularly in downstream of the channel in canal irrigation system and excess pumping of water in tube wells and river lift irrigation system. Lining irrigation channels means to cover the channel earthen surface by any substance, which can considerably reduce the seepage loss. The concrete, brick, stone, natural clay of low permeability, bituminous material, plastic compounds, etc., are used for channel lining. Unlike major irrigation commands, farmers generally follow recommended irrigation scheduling for most of the crop exceptions summer paddy where the farmers have a tendency to keep the crop under continuous submergence. However, the depth of ponded water depends on the land situation. Farmers usually over irrigate in uplands and a portion of this water through lateral seepage accumulates in low land resulting deeper submergence. It has been estimated that seepage loss from field canals accounts for 20 to 30 percent of the total water diverted in our nation. In an irrigation command, the excess loss via the unlined field channel decreases the irrigated area, increases the demand for water, and raises the cost of cultivation. In West Bengal, improper water application, zigzag distribution systems following spouts, and excessive seepage via the earthen channel have reduced the irrigation command from around 40 ha to 25–30 ha for a DTW. Since 80% of all water is used to irrigate crop fields, there would be a significant shortage of irrigation water unless the above-mentioned loss of water could be significantly reduced by adequate means. This will lead to a significant decline in agricultural productivity. The studies were undertaken with the following objectives:

**Objectives**

1. To examine the water loss in lined channel with respect to unlined channel
2. To estimate the economy of lined channel

## 1. Forms of Water Losses

There are several ways to cause water losses in tube well irrigation. Those are enumerated as below.

Seepage through the Earthen Channels: Seepage is the downward and lateral movement of water from the wetted area of the channel (Figure 1). It is the continuous process as long as the water is available in the channel and the rate of it mainly depends on the soil characteristics. The coarse soil should have higher seepage loss.

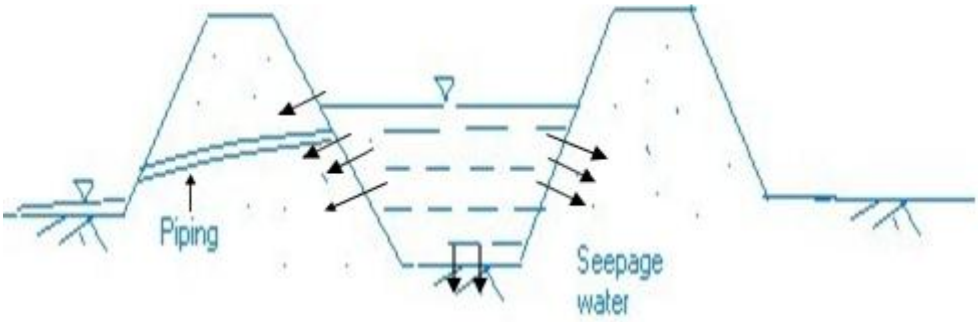


**Figure 1:** Water losses through seepage, cracks & holes

**Losses through Cracks & Holes:** The cracks and holes in the channels are developed due to activities of the burrowing animals and the passages created by the degraded roots of the weeds grow in the channel and channel banks (Figure 1).

Overflow through the channel for low flow velocity due to weed infestation and poor maintenance and low height channel banks.

Loss of water also takes place due to poor maintenance of channel. It allows growing weeds causing reduction in velocity of flow. The depositions of soils in the channel and settlement or soil eroded from channel banks reduce water carrying capacity of the channel (Figure 2).

**Figure 2:** A root infested low height bank channel

Poor application efficiency due to low discharge, uneven land levelling & flood irrigation The percentage of water retained in the root zone depth to the water applied to the agricultural field determines the application efficiency. Only after meeting the infiltration criteria can water applied to the field progress further. Thus, major volume of low discharge contributes to the head end of the field. The uneven field does not allow uniform advancement of water. The depression or low spots hold good amount of water and get enough infiltration opportunity time. The flood irrigation usually has less uniform application of water due to spreading of water in large area (Figure 3).

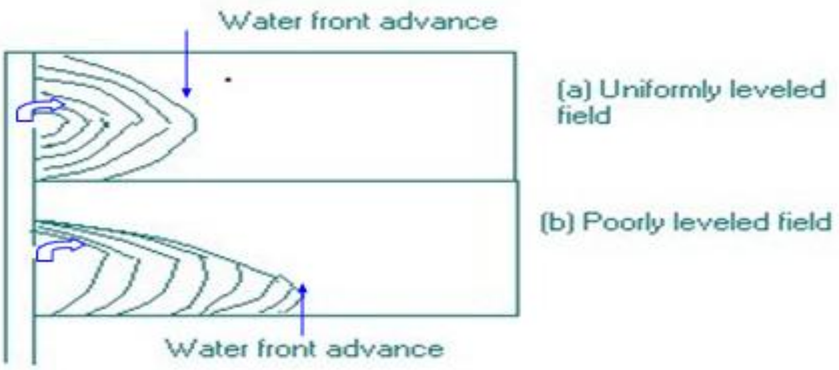


**Figure 3:** Water advance over the irrigation field

**Faulty Method of Channel Construction:** The bottom of the field irrigation channel should be on the ground level or little below the ground level so that the most of the water get delivered to the field when irrigation is stop other than it will provide necessary head of water for easy and sufficient discharge (Figure 5). However, this takes more area of land for channel construction. The farmers prefer deep and small width channel to save the land and maintenance costs (Figure 6). The loss of water apparently does not make them worried due to tax they use to pay for water on the basis of area irrigated.

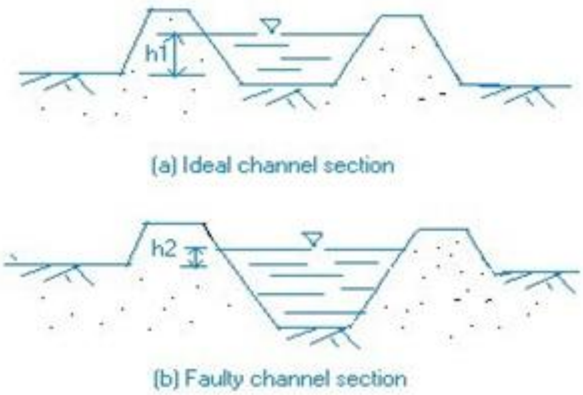


**Figure 5:** Ideal & faulty channel sections

**Figure 6:** Deep channels with low height of banks

Channel slope usually not in conformity to the natural land slope: The field irrigation channels usually follow the boundary of the field plots. The direction is zigzag and the slope it follows always not downward (Figure 7). This cause some time reverse water pressure-causing overflow of water and much decrease in flow towards downward. The low discharge takes much time to cover a plot and huge loss of water in the system.

**Figure 7:** Zigzag direction of the channel

**Ponding of Water at Pump Head and Spout Head:** The head end of a deep tube well usually creates sizeable water body by the accumulated water from the leaks of the pipe joints and discharge of overflow pipe (Figure 8). Similarly, the falling water at the water outlet creates water body covering sizeable area. Both of these are the source of continuous loss of water through percolation and evaporation. It also causes loss of land and wetted surrounding area causing hindrance to usual cultivation practices.

**Figure 8:** Head end of a deep tube well irrigation channel system

**Wastage of Water due to Unavoidable Excess Pumping:** In a deep tube well there are usually 3 sub-surface water carrying pipe originates from the pump. Each pipes distributed water to 4-5 spouts (water outlets) on the ground surface. A deep tube well usually has the discharge capacity of 40-50 l/s and the spout about 10 lps. Therefore, when the tube well operates it needs 4-5 spouts opened to discharge the entire amount of water to the fields. However, situation arises when irrigation is needed only in the fields under the command of 2 or 3 spouts. In that case to save the piping system from excess water pressure, there is the provision to bypass the excess water. Huge water is regularly get lost by this way from the tube wells in upland areas where rice is not the major crop. A drain is required for safe disposal of this excess water (Figure 9).

**Figure 9:** Drain for disposal of excess water

## 2. Percentage of Water Loss

In India about one third of the water diverted from the source is lost in conveyance. In the State of West Bengal 20-30% of the water get lost in conveyance in DTW or STW commands. The application losses of water widely vary in tube well to tube well depending on the soil, crop, land preparation, irrigation method and management. On a most optimistic assumption it should not be more than overall 75%. Let the loss of water due to compulsion of drain out of water at less number of openings of the outlets at a time than the optimum is only 15%. Say, 100 unit of water is diverted from the source. After compulsive drain out of 15 units the conveyance system will receive 85 units. On an average 25% conveyance loss, 63.75 units are to be delivered to the field. Out of these 63.75 units, the root zone depth soil will receive only 47.81 units and the remaining 15.94 units get lost through deep percolation. Therefore, the loss of water in an average tube well is 52.19%.

# II. METHODOLOGY

## 1. Study Area and Site Conditions

The field experiment was conducted at the Instructional Farm of Faculty of Agricultural Engineering, BCKV, Mohanpur, Nadia West Bengal during the year of 2022-23. The area needed for the experiment was cleaned and the soil clods were broken to get a good tilth and making the furrow. The Bouyoucous hydrometer method of determination of soil texture revealed that the relative portions of soil particles for the examined sample were: 65.1 % of silt and clay content, 37.3 % of clay content, 27.8 % of silt content and 38.3 % of sand content and the soil was classified as clay loam.

## 2. Channel Types and Materials

These losses of water and low velocity due to weeds in the channel and the requirement of continuous maintenance of channel can be greatly reduced by lining the channel. In order to reduce seepage loss, safeguard areas that are vulnerable to water logging due to rising water tables, and allow for increased discharge through the channel, irrigation channels are lined with stable materials like concrete, brick, stone, or polyethylene.

**Design Parameters of Bamboo Reinforced Precast Linings**

These half round sections are 5 feet length and of desired diameter cast in designed mould (Figure 10). The reinforcements are used the bamboo sticks of 5mm x 10mm cross-section with the length of 150cm and spacing 10cm x 10cm or 15cm x 15cm. The coarse aggregates are the blast furnace slag pieces or quarter size stone chips. The precast sections are carried to the formation surface i.e. bed of the channel and placed one after another. Both the outer side of the sections to be filled up by sufficient soils so that the sections get the required supports and remained fixed in the position. The 35.56cm (14 inches) diameter channel has been found adequate to the commands of DTW/STW where the outlet discharges are about 10 l/s. The seepage losses through these channels are found 0.015 m3/m2/day (Table 1).

**Figure 10:** Progress of casting the half round bamboo reinforced precast section

## 3. Measurement Approach for Seepage and Cost

The constructed channel was used round the year and the performance of the channel was compared to unlined channel in respect of seepage loss. The performance of the channels was tested for their discharges, velocity, seepage losses, roughness coefficient, etc. the seepage losses were measured by ponding water for about a day (24 hours). The net loss through the unit-wetted area was calculated by deducting the evaporation loss during the period. The cost of fabrication for precast bamboo-reinforced sections to the sites and laying them with proper foundation support and earthing up, etc., have been considered in calculating the cost of per metre length of the channel. Similarly, the cost involved in constructing the channel of same capacity has been considered for giving a comparison to cost of different type of channels.

## 4. Assumption in B:C Ratio Calculations

Lining is justified only when annual benefit of lining exceeds the annual expenditure due to construction of lined canal. The method of calculation of annual benefit and cost are discussed below.

Let C = Cost of construction of lined channel, Rs/$m^2$.
s &S = Seepage losses in the unlined and lined canal respectively, $m^3/m^2$/day.
p &P = Wetted perimeter in unlined and lined sections respectively, $m^2$.
T = Maximum perimeter of lining, m

d = Number of running days of canal, days/year
W = Value of water saved, Rs/$m^3$
L = Length of canal, m
M = Annual saving in rupees in operation and maintenance due to lining.

B = Annual estimated value of other benefits in rupees. The other benefits may include the benefits due to prevention of water logging, reduced risk of breaching, reduce change of health hazards, increased rate of land value, etc.
X = Rate of interest on investment, percent/year.

Annual value of water lost by seepage from unlined section = pLsdW rupees
Annual value of water lost by seepage from lined section =PLSdW.
Annual saving in value of water otherwise lost by seepage = (pLsdW-PLSdW)
= LdW(ps-PS) rupees
Total annual benefits out of lining the canal= LdW(ps-PS) +B+M

Additional expenditure due to lining the unlined channel=TLC

**Depreciation**

It is expected that the cost of the lining should be recovered from the benefits of lining within the useful life of lining. The determination of depreciation is required in estimating the cost of service of any material or establishment. Depreciation is the loss in value and service capacity of the material due to different reasons with the passage of time. Longer the service life of the material in hours, days or years, the lower the annual rate and cost. There are different methods in calculating the depreciation. For the requirement of cost of use of service of the material or establishment, the straight-line and compound method of estimating depreciation are more useful than other methods.

**Straight-Line Method**

The straight-line method reduces the value of the material by an equal amount each year during its useful life. The annual depreciation is

$$D = \frac{C - S}{L}$$

where, C = original purchase price
S = salvage, trade-in or resale value at the end of the service life
L = service life

## III. RESULTS AND DISCUSSION

**Seepage Loss**

The constructed channel was used round the year and the performance of the channel was compared to earthen channel in respect of seepage loss (Table 1&2).

**Table 1:** Seepage through bamboo reinforced lined channel

| Sl. No. | Days after construction | Seepage rate, $m^3/m^2/day$ | | | | Average seepage rate, $m^3/m^2/day$ |
|---|---|---|---|---|---|---|
| | | Dry surrounding | | Wet surrounding | | |
| | | Static | Flowing | Static | Flowing | |
| 1 | One week | 0.023 | 0.027 | 0.020 | 0.024 | 0.024 |
| 2 | 9 months | 0.011 | 0.011 | 0.010 | 0.010 | 0.010 |
| 3 | 1 year 3 months | 0.013 | 0.014 | 0.011 | 0.011 | 0.012 |
| Average | | 0.016 | 0.017 | 0.014 | 0.015 | 0.015 |

**Table 2:** Seepage through unlined channel

| Sl. No. | Days after construction | Seepage rate, $m^3/m^2/day$ | | | | Average seepage rate, $m^3/m^2/day$ |
|---|---|---|---|---|---|---|
| | | Dry surrounding | | Wet surrounding | | |
| | | Static | Flowing | Static | Flowing | |
| 1 | One week | 1.08 | 1.19 | 1.03 | 1.14 | 1.11 |
| 2 | 9 months | 1.148 | 1.52 | 1.33 | 1.43 | 1.44 |
| 3 | 1 year 3 months | 1.13 | 1.22 | 1.10 | 1.16 | 1.15 |
| Average | | 1.23 | 1.31 | 1.15 | 1.24 | 1.23 |

The overall average of the seepage rates in bamboo reinforced lining was found to be 0.015 $m^3/m^2/day$. it is much better compared to unlined lining (1.23 $m^3/m^2/day$), and better than LDPE lining over laid on the sides with cement pointed bricks and with 15cm soil cover on the bottom (rectangular section, 0.02904 $m^3/m^2/day$), less than cement pointed brick lining (1:1 slope, 0.0234 $m^3/m^2/day$), but higher than cement pointed brick underlined with LDPE (2:1 slope, 0.01368 $m^3/m^2/day$ [10].

## 1. Economy of Constructional of Channels

**Table 3:** The cost and savings when building channels with certain lining materials as opposed to brick-lined channels

| Sl. No. | Type of channel | X-section of the channel, | Cost of construction Rs./m length | | Saving in cost (%) |
|---|---|---|---|---|---|
| | | $Cm^2$ | Channel under study | Brick lined channel | |
| 1 | Bamboo-reinforced precast half round channel | 981 | 125 | 390 | 67.94 |
| 2 | -do- | 520 | 95 | 210 | 54.76 |
| 3 | Bamboo-reinforced precast trapezoidal channel | 1696 | 150 | 650 | 61.53 |
| 4 | -do- | 1175 | 135 | 415 | 67.46 |
| 5 | -do- | 880 | 130 | 375 | 65.33 |
| 6 | Bamboo-reinforced precast triangular channel | 750 | 120 | 365 | 67.12 |

## 2. Benefit-Cost Ratio

Of a field irrigation channel of a spout in a deep tube well (DTW) command area was lined by using bamboo-reinforced precast concrete slabs forming in trapezoidal shape:

DTW

- Cost of DTW irrigation system (P)=Rs.850000
- Yearly operating time, T1=1320 h
- Yearly operator's wage=Rs70, 000
- Yearly repair and maintenance cost=Rs50, 000
- Yearly power charge @ Rs3.00/unit=Rs.47520
- Expected life of DTW=30 years
- Rate of interest on investment, r1=12%
- Discharge of DTW, Q1=40 l/s
- Salvage value, S1=10%
- Discharge of the spout=10l/s

Trapezoidal channel (x-sectional area=881.3cm2) made of bamboo-reinforced precast slabs.

- Length of channel=250m
- Cost of construction of channel @ Rs130/m, P2= Rs 32500
- Expected life of channel=15 years
- Interest on investment, r2=12%
- Salvage value, S2=Nil
- Repair and maintenance=Rs1000/year
- Operating period, T2=550 h/year
- Repair and maintenance of unlined channel=Rs.2000/year
- Saving of water due to lining=25% of spout source

Calculation for cost of unit volume of water of DTW

- Depreciation=32500/15=Rs.2167/yr, Interest=32500x12/200= Rs.1950/yr
- Repair and maintenance=Rs.50, 000/yr
- Power charge=Rs.47420
- Operator's wage=Rs.70000/yr Total of (i) to (iv) = Rs.249120
- Discharge=Q1xT1=40x1320x3600 = 190080 l/yr
- Cost of water=249120/190080=Rs.1.31/m3

**Calculation of Cost of Lining**

- Depreciation=$\dfrac{P_2-S_2}{C_2}$=32500/15=Rs.2167/yr
- Interest=$\dfrac{P_2+S_2}{2}$ x$r_2$=$\dfrac{32500 \text{ x}12}{2\text{x}100}$ =Rs.1950/yr

Total of (i) and (ii) =Rs.4117/yr
Saving of water due to lining

- Yearly discharge through the spout=Q2xT2= 10l/sx550h = 10x550x3600 h=19800m3
- Saving of water=$\frac{19800x25}{100}$=4950m3

**Benefit of Lining**

- Saving in repair and maintenance=2000-1000=Rs.1000/yr
- Other benefit= Rs.750/yr (say)
- Benefit due to water saving= Volume of water saved x Cost of unit volume of water =4950x1.31=Rs.6485/yr, Total benefit = Rs.8235/yr So, benefit: cost of lining=8235/4117=2:1

Brick is the most often used traditional lining material in the area. As a result, the cost of building the lined channels under investigation was contrasted with the cost of building brick channels in an equivalent construction area. The saving in cost of construction was 67.94%. The cost of construction varied from Rs.95 to 150/m length of the channel for the channels of cross-sectional area 520 cm2 to 1696 cm2 respectively. For similar cross-sectional area the estimated cost of brick lined channel varied from Rs.210 to 650/m length. Thus, there was saving of cost of construction between 54.76 to 67.94% with average of 64.02 % (Table 3). Alternately, the construction costs would be 2.21 to 3.12 times more for brick lined channels compared to bamboo-reinforced precast channels of different shape. Thorough study is required in respect of cost of construction and maintenance, saving of water, etc. and ultimately the cost: benefit of the lining material, which provides high benefit/cost ratio should be used.

## IV. CONCLUSION

So far few kilometre channels of this type have been constructed in different part of Nadia district in support of the public fund along with the farmers' contribution from 1996 onwards. The performance in respect to longevity, carrying capacity, seepage control and maintenance are encouraging. More and more channels of this type may be constructed into the irrigation commands to save the loss of water and the amount of investment, which have become very urgent.

**Benefit:** Cost ratio was achieved more than 1.0 in construction of channels made of lining materials which proved to be better than the conventional practice in respect of economy. In situations where bamboo is easily accessible, appropriately cared for, and acceptable in the culture, bamboo-reinforced systems scale moderately to highly. But scaling to high-rise urban or industrial uses necessitates funding for training, standards development, industrial treatment infrastructure, and research. For small-scale, rural irrigation and drainage projects, the bamboo-reinforced lined channel method is very scalable, particularly in areas with a plentiful supply of bamboo and locally accessible labour. Unless sophisticated treatments and design controls are implemented, its scalability for larger-scale or urban systems is constrained.

## REFERENCES

[1] Central Water Commission (CWC) 2015. Water and related statistics. Directorate of Information System Organisation, water planning and projects wing Report, New Delhi.
[2] Manivannan, S., Thilagam, V. K. and Khola, O.P.S. 2017. Soil and water conservation in India: Strategies and research challenges. Journal of Soil and Water Conservation 16(4): 312-319.
[3] Amarasinghe, U.A., Shah, T., Turral, H. and Anand, B.K. 2007. India's water future to 2025-2050: Business asusual scenario and deviations. Research Report 123, Colombo, Sri Lanka: International Water Management Institute.
[4] Kumar, D.S. and Palanisami, K. 2010, Impact of drip irrigation on farming system in southern part of India. Agricultural Economics Research Review 23: 265-272.
[5] Chandrakanth, M.G., Priyanka, C.N., Mamatha, P. and Patil, K.K. 2013. Economic benefits from micro irrigation for dry land crops in Karnataka. Indian Journal of Agricultural Economics, 68(3): 426-338.
[6] Paul, J.C. and Panigrahi, B. 2016. Artificial conservation measures on groundwater recharge, irrigation potential and productivity of crops of Bharkatia Watershed Odisha. Journal of Soil and Water Conservation 15(2): 134-140
[7] Dhawan, V. 2017. Water and agriculture in India. Background paper for the South Asia expert panel during the Global Forum for Food and Agriculture (GFFA), pp.15.
[8] Central Water Commission (CWC) 2017. Reassessment of Water Availability in India Using Space Inputs. Basin Planning & Management Organisation, New Delhi.
[9] Central Groundwater Board (CGWB) 2017. Dynamic Ground water resources of India, Ministry of Water Resources. River Development and Ganga Rejuvenation Government of India, Faridabad.
[10] Talley, S.N. & Kohale, S.K. (2021). Performance of the irrigation lining materials. PVK J., 10(2):138-140.