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Experimental Assessment of Sub Surface Irrigation on Parched Territories by using Clay Porous Pipe in a Model

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Abstract:
Drought can be devastating and unlike earthquakes or hurricanes, there is no immediate response for disaster management. At Gokhale Institute of Politics and Economics (GIPE), a ten-member team will go to drought-prone Beed, Latur and Osmanabad districts and take a week-long survey to understand why authorities fall short in taking planned and immediate steps. Dr Rajas Parchure, Director of GIPE, told The Indian Express that the survey was not a fact-finding one to assess the ground reality. "There has been ample evidence reported from various districts about the scarce water scenario. Migration of people living in these droughts hit areas to other cities has also been recorded. What we aim to find out is why there has been a failure in planning policies and identify the loopholes," said Parchure. The state government has officially declared that 60 per cent of its villages were facing a 'drought-like' condition. Drought comes in several degrees and hence at times it may not qualify to be termed as a disaster. The research team's plan is to study the norms and check what should be the proportion or severity of drought to term it as a disaster and what kind of response should be anticipated.

Keywords: Subsurface Irrigation, Parched Regions, Terracotta Clay, Porous Pipe.

I. INTRODUCTION

Figure 1. Drought in Marathwada

Marathwada region has been reeling under drought condition since 2013. It is in a part of the scanty rainfall area of Central Maharashtra. The region coincides with the Aurangabad Division of Maharashtra. It includes districts of Aurangabad, Jalna, Beed, Osmanabad, Nanded, Latur, Parbhani and Hingoli. Out of these eight districts, five are the worst affected, namely Beed, Jalna, Parbhani, Nanded and Osmanabad. Marathwada region has a population of about 1.87 crore and geographical area of 64.5 thousand sq.km. The region had faced several droughts in the past. Droughts have occurred in the years 1899, 1918, 1972 and 2012 onwards. The 1972 drought is in the recent past; which people still remember. In 1972, food and fodder were the main concerns, but now drinking water is more important. It is multi-dimensional drought. Global climatic situation is also playing in the process, which was not so acute 50 years before.

1.4 Introduction to Porous Clay Pipe:

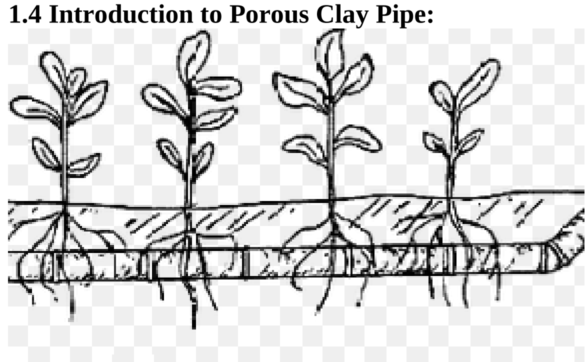


Figure.1.2 Subsurface Porous Clay Pipe Irrigation

The porous clay pipe is a traditional method of sub-surface irrigation in which porous clay pipes are buried in the soil at regular intervals and water is supplied continuously to these pipes from a source. Water seeps out of the porous wall of the pipe and moves radially outwards from the pipe which creates a wetting front along the length of the lateral. Porous clay pipes are a means of water application that conserve water by applying water directly to the roots of plants, thereby limiting evaporation lossesThe Porous clay pipes are consist of baked short length pipes (10 to 15 cm) made from clay.The geometry of wetted zone around a pipe in the soil depends on many factors such as permeability of pipe, applied volume of water, and the soil type.
In this system, conveyance and seepage of the water are done instantaneously by the Pvc pipe and Porous Clay pipe

respectively. This method of irrigation can be used in many arid and semi-arid regions of the world. It can be suitable for row crops grown in rows such as vegetables and trees.

II. LITERATURE REVIEW

2.1 Experimental Investigations on LocalizedPorous Clay Pipe Irrigation Techniquefor Sustainable Agriculture:A New Paradigm for Soil and Water Management in Rain-fed Areas By Neelkanth J. Bhatt, Rajendra(GatesaniyaDepartment of Civil Engineering ,Government Engineering College, Rajkot. Department of Civil EngineeringC.U. Shah College of Engineering and TechnologyWadhwan)

Abstract:
In this experiment the unglazed hollow clay pipes were manufactured from a mixture of clay (locally available) and saw dust in the ratio of 3:1 and with asufficientporosity ranging from 50-60% at a local Manufacturing unit primarily manufacturing Filter Clay Candles. The porous clay pipes were madeas unglazed toretain their natural porosityi.e.the walls remain micro-porous. The pipes were then temperedby burning them in a pit fire from firewood atanundetermined temperature to eliminate the swelling and shrinking properties of clay, which would cause cracking of the pipes. The outer diameter of the clay pipe was 5 cm,theinnerdiameter of the clay pipe was 3 cm and length of the pipewas 17.5 cm. Claypipes were connected using a plastic (PVC) coupler of suitable size and pipes were then assembled to producearequiredlength of pipe that can be installedinrespective rows.

Conclusion:
The proposed "Porous Clay Pipe" irrigation can facilitate sufficient moisture to the soil and crop. There was adequate moisture distribution beneath the porous pipe even after 10days following water application to the crops. Theamount of moisture retained by the soil was higher when compared to the unirrigatedsoil. The Porous Clay Pipe Irrigationoffers double yield as compared to Rain-fed agriculture. The growth of crops during the cropperiod and the quality of yield under Porous Clay Pipe Irrigationwas much superior to the Rain-fed agriculture. Considerable water saving in agriculture can be attained using this method of irrigation. The method is slightly costlier but considering its ease ininstallation, maintenanceand operation, and if the same pipes are usedfor up to 3-5 years,the cost can be considerably reduced. The persistent use of this technique would payhigh returns to the farmer inthelong runin areas facing water scarcity. Instead of depending only on rain taking-up of this technique can help farmers in improving their economic conditions and thereby the local and national economy. The methodalso demonstrates that productivesoil and water conservation can be attained usingPorous Clay Pipe Irrigation technique.

Background Information

3.1 Subsurface Irrigation:

Subsurface irrigation uses a network of polyethylene pipes located just under the ground's surface to apply disinfected effluent in the root zone of plants, preventing airborne drift and minimizing runoff. Note that effluent that has not been disinfected, such as from septic tanks must be disposed of below the soil (at least 300 mm deep). Subsurface irrigation requires less maintenance than surface irrigation, and there is also less chance of surface saturation and effluent runoff. By reducing the chance of human contact, it also significantly reduces the public health risks.

Figure. 3.1 (b) An installed subsurfaceirrigation

Subsurfaceirrigation puts effluent largely below the depth of the root zone of most crops. This means there is limited nutrient uptake and it is unlikely to result in a healthy growing crop. Careful hydraulic design of subsurface irrigation is essential to ensure correct sizing and choice of components, including providing for adequate effluent pumping, effluent filtration, line flushing, placement of vacuum release valves, and correct spacing of laterals and emitters. Consideration of rainfall is as important for sizing subsurface irrigation areas as for surface irrigation, however subsurface irrigation may allow for higher nutrient uptake in the same location.

3.1.1 Advantages of Subsurface Irrigation
- Health risks are minimized.
- The system is easily automated.
- Consumption of nitrates by the plant material is increased.
- The systems are durable and have a long life.

3.2 Black Cotton Soil:
These are mostly clay soils and form deep cracks during dry season. An accumulation of lime is generally noticed of varying depths. They are popularly known as "Black cotton soils" because of their dark brown color and suitability for growing cotton. These are also known as Indian regurs. These soils are deficient in nitrogen, phosphoric acid and organic matter but rich in calcium, potash and magnesium. Black cotton soils and other expansive soils have typical characteristics of shrinkage and swelling due to moisture movement through them. During rainy season, moisture penetrates into these soils, due to which they swell. Most of the fine-grained clays, including black cotton soils have their grains which are more or less in the form of platelets or sheets (just like leafs of a book), and their grains are not round. When moisture enter between the platelets under some hydrostatic pressure, the particles separate out, resulting in increase in the volume. This increase in volume is commonly known as swelling. If this swelling is checked or restricted (due to the construction of footings over it), high swelling pressure, acting in the upward direction, wilI be induced. This would result in severe cracks in the walls etc. and may sometimes damage the structural units, such as lintels, beams slabs etc. During summer season, moisture moves out of the soil and consequently, the soil shrinks. Shrinkage cracks are formed on

the ground surface. These shrinkage cracks times also known as tension cracks, may be 10 to 15 cm wide on the ground surface and maybe½to2mdeep.

3.2.1 Characteristics of Black Cotton Soil:

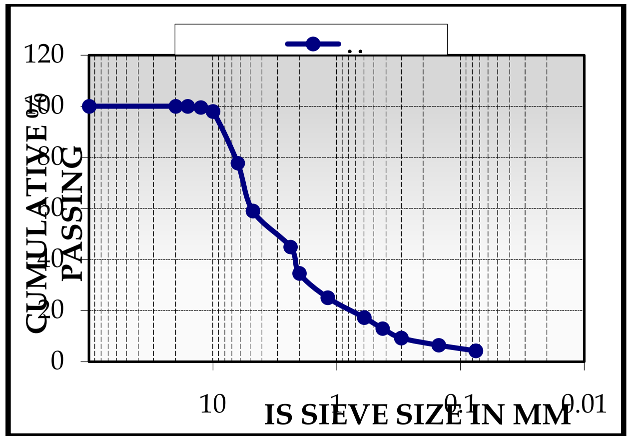
Black Cotton Soil is considered as a very poor type of soil having black colour with very fine grain. This type of soil contains pure clay particles with about 85-100 percentages passing through 75-micron Sieve. Atterberg Limits tested in laboratory is tabulated in Table-1. The test shows the Liquid limit for BC Soil samples are ranging 55-60 and Plastic Limit for the same ranges 30-40. Thus, Plasticity Index of BC Soil found to the range of 20-35. At the liquid limit, the volume change is of the order of 200 to 300% and results in swelling pressure as high as 8 kg/cm^2 to 10 kg/cm^2. As such BC Soil has very low bearing capacity and high swelling and shrinkage characteristics. Primitive pieces of terracotta were just left to harden and bake in the hot sun, while later pieces (before kilns) were fired in the ashes of open fires. Another great property that terracotta has is that it can withstand varied temperature changes with a lower chance of cracking, making it incredibly functiona

3.3 Tests Conducted

1. Grading Test of Soil

A sieve analysis (or gradation test) is a practice or procedure used (commonly used in civil engineering) to assess the particle size distribution (also called *gradation*) of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass.

GRAIN SIZE ANALYSIS OF SOIL (WET METHOD)



1.3. Result: - The soil sample tested in this test was found to be fine graded soil

2. Liquid Limit Test

The liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 10 mm on being given 25 blows in a standard manner. This is the limiting moisture content at which the cohesive soil passes from liquid state to plastic state. Liquid limit is significant to know the stress history and general properties of the soil met with construction. From the results of liquid limit, the compression index may be estimated. The compression index value will help us in settlement analysis. If the natural moisture content of soil is closer to liquid limit, the soil can be considered as soft if the moisture content is lesser than liquids limit, the soil can be considered as soft if the moisture content is lesser than liquid limit. The soil is brittle and stiffer.

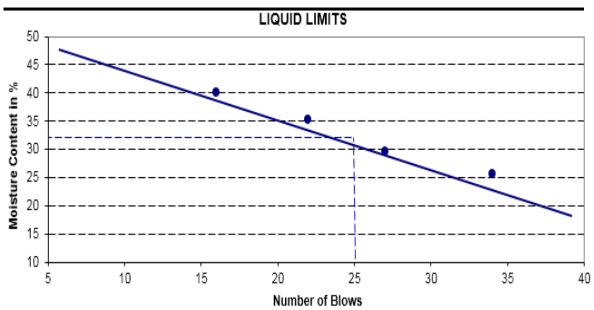
Table No. 5.1 Test Report- Physical Property of Soil

GRAIN SIZE ANALYSIS OF SOIL (DRY METHOD)						
Sr No	IS Sieve Size (mm)	Wt. Retain (gm)	% Wt. Retain	Cumulative % Wt. Retain	Cumulative % Passing	Classification
1	100	0.00	0.00	0.00	100.00	**Cobbles 0%**
2	75	0.00	0.00	0.00	100.00	
3	53	0.00	0.00	0.00	100.00	**Gravel Coarse 17%**
4	37.5	75.00	5.67	5.67	94.33	
5	25	96.00	7.26	12.93	87.07	**Gravel Medium 19.35%**
6	19	59.00	4.46	17.38	82.62	
7	16	48.00	3.63	21.01	78.99	**Gravel Fine 21.47%**
8	12.5	68.00	5.14	26.15	73.85	
9	6.3	140.00	10.58	36.73	63.27	**Sand Coarse 13.30%**
10	4.75	49.00	3.70	40.44	59.56	
11	2.36	108.00	8.16	48.60	51.40	**Sand Medium 17.16%**
12	2.0	127.00	9.60	58.20	41.80	
13	1.18	98.00	7.41	65.61	34.39	**Sand Fine 7.94%**
14	0.600	78.00	5.90	71.50	28.50	
15	0.425	48.00	3.63	75.13	24.87	**Silt & Clay Size 14.97%**
16	0.300	57.00	4.31	79.44	20.56	
17	0.150	45.00	3.40	82.84	17.16	**Total Sample 1323.00**
18	0.075	29.00	2.19	85.03	14.97	
19	Pan	198.00	14.97	100.00	0.00	

2.3 Observation:

Table No. 5.2 Test Report- Atterberg Limits(Liquid Limit)

TEST REPORT- ATTERBERG LIMITS (LIQUID LIMIT)						
A) LIQUID LIMIT TEST:						
No of Blows	**16**	**22**	**27**	**34**	a) Liquid Limit %:	**32**
Crucible No.	A1	A2	A3	A4		
Weight of Crucible + Wet Soil (g)	38.29	34.74	36.33	50.86		
Weight of Crucible + Dry Soil (g)	33.12	30.05	31.89	44.51		
Weight of Water (g)	5.17	4.69	4.44	6.35		
Weight of empty Crucible (g)	20.20	16.73	16.83	19.79		
Weight of Dry Soil (g)	12.92	13.32	15.06	24.72		
Moisture Content (%)	40.02	35.21	29.48	25.69		
No of Blows	**16**	**22**	**27**	**34**		



2.4 Computation / Calculation

Plot the relationship between water content (on y-axis) and number of blows (on x-axis) on semi-log graph. The curve obtained is called flow curve. The moisture content corresponding to 25 drops (blows) as read from the represents liquid limit. It is usually expressed to the nearest whole number.

$$\text{Flow index } I_f = \frac{(W_2-W_1)}{\text{Log}(N1/N2)}$$

2.5 Result: - Liquid Limit % =32%

3. Plastic Limit Test

The plastic limit (PL) is determined by rolling out a thread of the fine portion of a soil on a flat, non-porous surface. The procedure is defined in ASTM Standard D 4318. If the soil is at a moisture content where its behavior is plastic, this thread will retain its shape down to a very narrow diameter. The sample can then be remolded and the test repeated. As the moisture content falls due to evaporation, the thread will begin to break apart at larger diameters. The plastic limit is defined as the moisture content where the thread breaks apart at a diameter of 3.2 mm (about 1/8 inch). A soil is considered non-plastic if a thread cannot be rolled out down to 3.2 mm at any moisture possible.

Observation: -

Table No. 5.3 Test Report-Plastic Limit Test

B) PLASTIC LIMIT TEST:				
Crucible No.	A6	A7	b) Plastic Limit (%):	**20**
Weight of Crucible + Wet Soil (g)	21.93	21.18		
Weight of Crucible + Dry Soil (g)	21.24	20.47		
Weight of Water (g)	0.69	0.71	c) Plasticity Index (%):	**12**
Weight of empty Crucible (g)	17.74	16.83		
Weight of Dry Soil (g)	3.50	3.64		
Moisture Content (%)	19.71	19.51		

Result: -

The Plastic limit shall be determined for at least three portions of the soil passing 425 microns IS sieve. The average of the result calculated to the nearest whole numbers shall be reported as the Plastic limit of soil.

4 Free Swell Index Test

The clay and specially the black cotton soils have a tendency to swell in small or more proportion when submerged in water. Free swell or differential free swell also termed as free swell index, is the increase in volume of soil without any external constraint when subjected to submergence in water.

Observation:

Table No. 5.4 Test Report - Free Swell Index Test of Soil

Particular	**Test No 01**	**Test No 02**
Volume of the soil specimen read from the graduated cylinder containing distilled water (Vd)	12	13
Volume of the soil specimen read from the graduated cylinder containing kerosene. (V_k)	9.00	10.00
Free Swell Index (%)= $\frac{Vd-Vk}{Vk}$ X 100	**33.33**	**30.00**

Result: -

Shrinkage Limit (average of two determinations), WS =31.665

Methodology

4.1 Data Collection

4.2 Materials and Testing:

i. **Material**

- **Clay**

ii. **Testing**

- Grading test of soil
- Liquid Limit Test
- Plastic Limit Test
- Free Swell Index Test
- Water Absorption Test on pipe
- Flexural Strength Test on pipe
- Compressive Strength of Pipe
- Percolation Test\

4.3 Installation of Porous Clay Pipe:

Figure.4.1 Installation of Porous Clay Pipe

To design, install and operate a Clay porous pipe/subsurface irrigation system, one must an understanding of:
1. The components of the irrigation system (porous pipe, controller, valves, filters, meters, installation equipment, etc.)
2. The soil.
3. The irrigation waters.
4. The plant life to be irrigated.

Experimental Work Performed

5.1 Introduction:

The aim of the experiment is to study Clay porous pipe system in Sub-surface irrigation and to compare the existing irrigation system with clay porous pipe system in the term of efficiency, productivity, life span etc. For this study purpose the experiment has been performed at Bharati Vidyapeeth's college of engineering, Lavale,

5.2. Description of Model:

1. Length = 1100 mm
2. Width = 335 mm
3. Height = 170 mm
4. Area = (1100*335) =368500 mm^2
5. Volume = (1100*335*170) = 62.64×10^6 mm^3
6. Height of Water Tank = 545 mm

5.3.5. Description of Pipe:

1. Outer Diameter (D) = 50 mm
2. Inner Diameter (d) = 35 mm
3. Height = 142 mm
4. Area = $\pi\left\{\left(\frac{D}{2}\right)^2\right\} - \pi\left\{\left(\frac{d}{2}\right)^2\right\}$ = 1001.38 mm^2
5. Volume = $\pi R^2 h - \pi r^2 h$ = 142.19×10^3 mm^3

5.4 Experimental Procedure:

Figure. 5.3 Experimental Arrangement of Model

1. In the model there is water tank installed at certain height which is controlled by valve which regulates the velocity of flow passing from the pipes
2. At certain length there are sections of CPVC pipe and clay porous pipe situated in subsurface.
3. The porous pipe is installed at 6 cm below the soil.
4. Water is allowed to flow from the tank then water reaches the normal pipe which act as a normal pipe function then water flows through porous pipe here the pipe allows the water to get into the soil by pores.
5. Aggregates are provided around the whole porous clay pipe to reduce the pressure of water and to prevent the blockage of pipe.

1.5 Testing on pipe:

1. Water Absorption Test On Pipe

Water absorption refers to the property of absorbing water when materials are exposed to water. It is expressed by the water-absorption ratio. A test to determine the moisture content of pipe as a percentage of its dry weight. The sample is weighed, dried in an oven, then reweighed under standard conditions. It is calculated as the moisture content, which is equal to: divided by the difference of weights then multiplied by 100 to express it as a percentage.

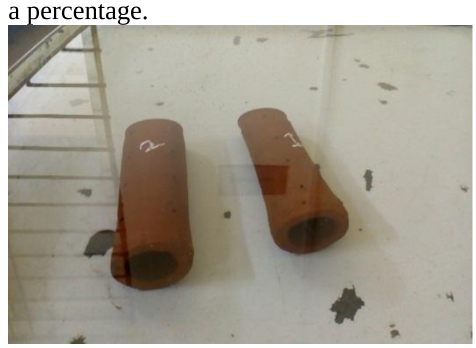


Figure.5.6 Water Absorption Test

Observation: -

Table 5.5 Test Report- Water Absorption Test of Pipe

S.No.	Observation & Calculation	Unit	Determination No.	
	Observations		I	II
1	Pipe No		1	2
2	Mass of Wet Pipe (M_1)	g	280 g	305 g
3	Mass of Dry Pipe (M_2)	g	250 g	270 g
Calculation				
5	Mass of water MW = (M1 – M2)	g	30	35
6	Water Content (M1-M2) /100	g	0.3 %	0.35%

Result: -
Average of two determinations shall be taken. The water content of the sample = 0.325%

2. Flexural Test on Pipe
Flexure tests are generally used to determine the flexural modulus or flexural strength of a material. A flexure test is more affordable than a tensile test and test results are slightly different. The material is laid horizontally over two points of contact (lower support span) and then a force is applied to the top of the material through either one or two points of contact (upper loading span) until the sample fails. The maximum recorded force is the flexural strength of that particular sample. Unlike a compression test or tensile test, a flexure test does not measure fundamental material properties. When a specimen is placed under flexural loading all three fundamental stresses are present: tensile, compressive and shear and so the flexural properties of a specimen are the result of the combined effect of all three stresses as well as (though to a lesser extent) the geometry of the specimen and the rate the load is applied. The most common purpose of a flexure test is to measure flexural strength and flexural modulus. Flexural strength is defined as the maximum stress at the outermost fibre on either the compression or tension side of the specimen. Flexural modulus is calculated from the slope of the stress vs. strain deflection curve. These two values can be used to evaluate the sample materials ability to withstand flexure or bending forces.

Figure. 5.7 Arrangement of Pipe for Flexural Strength Test

2.1 Observation Table:
Table No. 5.6 Test Report- Flexural strength of Clay Porous Pipe

S.No.	Dimension of Pipe		Condition	Breaking Load (N)	Average Breaking Load (N)
	Outer Dia (mm)	Inner Dia (mm)			
1	49	34	Dry	76.2	76.2

2.2 Result: Flexural strength of Clay porous pipe is = 76.2 N.

3. Compressive Strength of Pipe
Crush tests are carried out on pipes to test their strength and ductility. These characteristics can be of considerable significance in situations where the integrity of pipework must not be affected by earthquakes, especially when pipes are laid directly in the ground.

3.1 Observation:
Table No. 5.7 Test Report- Compressive Strength of Terracotta cube

Sample No.	Dimensions (mm)		Area (mm^2)	Load (N)	Compressive strength (N/mm^2)	Average Compressive Strength (N/mm^2)
	Length	Width				
1	209.55	99.02	20744.69	14	7.38	
2	209.56	99.05	20756.91	14	7.62	7.48
3	209.58	99.11	20771.47	14	7.42	

3.2 Result: Compressive Strength of the clayey soil is = 7.48N

Result and Discussion

Irrigation through 'Porous Clay Pipes':
The amount of volume of water applied was 5 liters to grow fenugreek (methyl) plant during the study.For irrigating cm^2 of land using "Porous Clay Pipe Irrigation" technique a total of 5 liters of water would be required. The irrigation frequency for the experimentation was of 10 days. This duration was selected because the soil was black cotton which has higher field capacity as compared to soils such as sand, sandy loam. Further, from the previous experiences of the farmer, and by calculation it was known that the requirement of water to irrigatecm^2 land with surface irrigation method was 10-12 liters. Thus 70 to 80% water savings were obtained with subsurface Porous clay pipe irrigation system.

III. CONCLUSION

Experiment on growing fenugreek (methyl) with subsurface porous clay pipe irrigation method showed that water savings up to 80% were achieved with this method compared to that of surface flood irrigation method. The proposed "Porous Clay Pipe" irrigation can facilitate sufficient moisture to the soil and crop. There was adequate moisture distribution beneath the porous pipe even after 10 days following water application to the crops. The amount of moisture retained by the soil was higher when compared to the surface irrigation method. The "Porous Clay Pipe Irrigation"offers double yield as compared to Rain-fed agriculture. The growth of crops during the crop period and the quality of yield under "Porous Clay Pipe Irrigation" was much superior to the Rain-fed agriculture. Considerable water saving in agriculture can be attained using this method of irrigation. The method is slightly costlier but considering its ease in installation, maintenance and operation, and if the same pipes are used for up to 3-5 years, the cost can be considerably reduced. The persistent use of this technique would pay high returns to the farmer in the long run in areas facing water scarcity. Instead of depending only on rain taking-up of this technique can help farmers in improving their economic conditions and thereby the local and national economy. The method also demonstrates that productive soil and water conservation can be attained using “Porous Clay Pipe Irrigation”technique.

Future Scope

Porous Clay Pipe Irrigation will help farmers as it will have a long durable period compared to normal techniques as this method can last upto max 25 years as other methods just have a conventional life of 5-6 years. Porous Clay Pipe Irrigation it also has an efficient saving of water than the normal techniques as its save more than 80% of water than conventional methods which may result in saving water which will be a concern in future time.

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