1

A Review of Irrigation Systems in India Utilizing both Conventional and Non-conventional Water Sources

Hitendra Kumar Singh[1], Munendra Kumar[1†], Anil Kumar[1], Ankhi Gulati[1], Jyoti[2]*
[1]*Department of Electrical Engineering, SET, IFTM University, Moradabad, U.P., India*
[2]*PG Scholar, Department of Civil Engineering, SET, IFTM University, Moradabad, U.P., India*

Abstract: India, being an agricultural country, relies heavily on agriculture for the livelihood of approximately 70 to 80% of rural families. In the current market, there is a strong emphasis on the development of agricultural land. The effective implementation of appropriate irrigation methods plays a crucial role in the agriculture sector. This research paper primarily examines diverse irrigation systems categorized as Conventional and Non-conventional water sources. The study reviews the various water sources commonly used in India for agricultural irrigation. Conventional water sources encompass Wells, Inundation canals, and Water Tanks, while the non-conventional sources include Tube wells, Drip irrigation, and Perennial canals, among others.

Keywords: *Agriculture, Conventional, Irrigation, Non-conventional.*

*Corresponding author: hitensingh11@gmail.com
†Corresponding author: munendrakumar1990@yahoo.co.in

1.1 INTRODUCTION

Water scarcity is a prevalent issue not only in India but also across the world. Numerous methods have been devised to address water conservation because water is vital for plants, animals, and humans alike. Agriculture, being a critical sector, demands a substantial amount of water. Unfortunately, India is facing a decline in groundwater levels due to water wastage and unnecessary consumption. Additionally, the scarcity of surface water and inadequate rainfall contribute to the overall reduction in the earth's water volume [1].

Agriculture serves as the cornerstone of the Indian economy, as it sustains our livelihood. It not only provides essential food but also fulfills many other necessities. In modern times, farmers employ a combination of conventional and non-conventional irrigation sources based on the availability of resources at regular intervals to cultivate their land [2].

In certain regions, Indian farmers resort to various irrigation techniques involving manual control. However, this approach often leads to uneven water distribution, resulting in delayed water supply to fields or excessive water consumption, leading to either dried or overwatered crops. To address this issue, adopting a non-conventional irrigation system, such as a smart irrigation system, can be advantageous. This intelligent system ensures that irrigation occurs only when there is an excessive demand for water, effectively mitigating the problems associated with conventional methods [2].

Figure 1 presents the graphical representation of the percentage use of different water sources for irrigation in India during the year 2005-06. The primary source used for irrigation is tube wells, accounting for 39.02% of the total, followed by canals at 24.68%, wells at 16.80%, and tanks at 6.50%. The remaining sources collectively constitute 13.00% of the total.

Similarly, when considering the percentage of irrigated area by different sources, tube wells cover the largest area at 43.57%, followed by canals at 27.35%, wells at 16.84%, and tanks at 3.865%. The remaining 8.38% of the area is irrigated using other sources.

For more detailed information on the distribution of irrigated holdings and net irrigated area across different sources, refer to Table-1, which provides data for Agriculture Census 2005-06 and 20015-16.

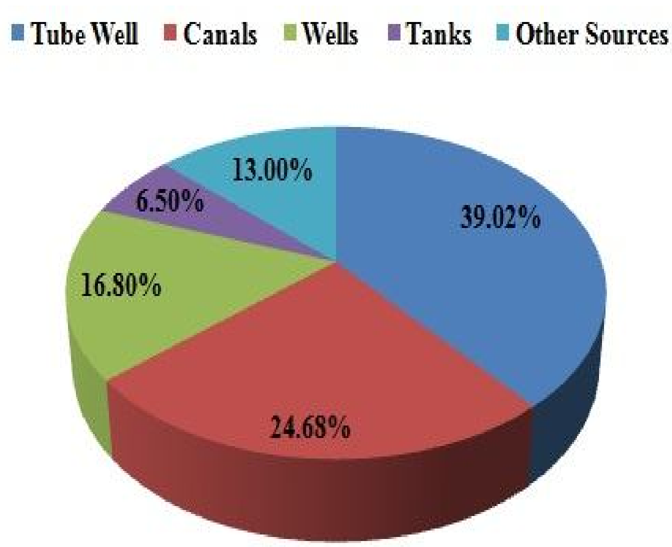

Fig.1: Graphical presentation of percentage use of different sources of water in India for irrigation during the year 20015-16.

Table 1: Source-wise distribution of Irrigated Holdings & Net Irrigated Area during Agriculture Census 2005-06* & 2015-16*

(Area is in Hectare) & (Holdings is in Numbers)

Sr. No	Sources of Irrigation	2005-06		2015-16	
		No. of Holdings**	Net Irrigated Area	No. of Holdings**	Net Irrigated Area
1	2	3	4	5	6
i	Canals	13656 (24.97%)	14578 (28.24%)	15703 (24.68%)	14842 (27.35%)
ii	Tanks	4227 (7.73%)	2258 (4.37%)	4133 (6.50%)	2097 (3.86%)
iii	Wells	9688 (17.71%)	9231 (17.88%)	10691 (16.80%)	9139 (16.84%)
iv	Tube Wells	20399 (37.29)	20711 (40.12%)	24825 (39.02%)	23643 (43.57%)
v	Other Sources	6727 (12.30%)	4849 (9.39%)	8268 (13.00%)	4548 (8.38%)
All Sources		54696 (100.00%)	51626 (100.00%)	63619 (100.00%)	54270 (100.00%)

Source: Chapter – 4, All India Report on Agriculture Census 2015-16

Note: *Excluding Bihar, Jharkhand & Meghalaya.

**Includes holdings irrigated by more than one source. However, the respective exclusive number of irrigated holdings was only 52.6 million & 55.9 million during 2005-06 & 2015-16.

1.2 LITERATURE SURVEY

I. Authors **C.Nivedha, S.Rovina Jerin Auxilia, M.Vaitheeswari** and **M.Murugalingam** researched on the topic, ***"Comparative Study Between Automatic Irrigation System Using Soil Moisture Sensor and Conventional Flooding Method of Irrigation"***. In this research, the authors have developed an automated irrigation system that operates by detecting the moisture content of the soil. The system effectively turns the pumping motor on and off based on the soil's dampness level. By integrating automatic irrigation based on soil moisture, the authors aim to minimize water usage, leading to increased energy efficiency and time savings. The central component of this system is the ARDUINO UNO micro-controller, which is programmed to collect input signals from a moisture detecting system that assesses the varying moisture conditions of the soil [1].

II. Authors **Mr. Rahul Ganpat Ghodake** and **Mr. A.O. Mulani** researched on the topic, ***"Sensor Based Automatic Drip Irrigation System"***. In their research, the authors examined the advantages and disadvantages of conventional irrigation systems, with a specific focus on Drip irrigation. They observed that in the conventional drip irrigation system, farmers face the challenge of maintaining different irrigation schedules for various crops, which can be quite difficult. To address this issue, they explored modern irrigation technologies and proposed a novel approach called the Global System for Mobile (GSM) Based Automatic Drip Irrigation System, utilizing a micro-controller.

According to the authors, this developed irrigation method eliminates the need for manual intervention in flooding irrigation and overcomes the limitations of time-based control mechanisms. Instead, it introduces more advanced control mechanisms like volume-based and priority-based methods, all integrated into a single system [2]. This new approach promises to be accurate, cost-effective, and efficient, providing enhanced automation and ease of use for farmers.

III. Author **N. Beithou** researched on the topic, ***"Non-Conventional Water Resources: Review and Developments"***. In this research, the author conducted a comprehensive review of water resources used for irrigation, categorizing them as conventional and non-conventional sources. During the study, it was discovered that implementing new management technologies such as PLC (Programmable Logic Controller) can enhance the efficiency and effectiveness of conventional water resources. Additionally, incorporating water-saving devices, such as water-efficient devices, can play a crucial role in reducing overall water consumption.

Furthermore, the research emphasized the significance of giving greater consideration to non-conventional water resources. Utilizing non-conventional sources more seriously has the potential to reduce the demand for fresh water in both agricultural and industrial sectors, thereby contributing to more sustainable water usage practices [3].

IV. Authors **Houshang Ghamarnia, Issa Arji, Saloome Sepehri, Samera Norozpour,** and **Erfan Khodaei** researched on the topic, ***"Evaluation and Comparison of Drip and Conventional Irrigation Methods on Sugar Beets in a Semiarid Region"***. This paper presents the findings of a two-year field study conducted on sugar beet to assess and compare the effects of different irrigation methods and treatments on crop yield. The experiments were carried out using a randomized blocks design.

The results of the study demonstrated that adopting drip tape irrigation with various treatments instead of conventional furrow irrigation, with or without soil, water, and root monitoring, resulted in significant water savings for the seasonal irrigation water requirement of sugar beet. The authors observed that by incorporating soil, water, and root monitoring, considerable water savings can be achieved.

Moreover, the study revealed that the average annual water requirement for sugar beet under conventional furrow irrigation with soil, water, and root monitoring was approximately 8.40% and 28.70% lower compared to the estimates obtained from CROPWAT modeling and conventional furrow irrigation without monitoring, respectively. This highlights the significant benefits of implementing soil, water, and root monitoring techniques for water conservation in sugar beet cultivation [4].

V. Author **Rohan Sable, Sagar Kolekar, Adesh Gawde, Sagar Takle,** and **Adesh Pednekar** researched on the topic, ***"A Review on Different Irrigation Methods".*** In this research, the authors investigated and compared different types of irrigation methods, including surface irrigation, sub-surface irrigation, drip irrigation, and smart irrigation. Through their study, they gained insights into the distinctions between automated irrigation systems and manual irrigation systems. The research findings revealed that the automated irrigation system resulted in higher crop production while utilizing a reduced amount of water compared to the manual irrigation system [5].

The results indicate that the adoption of automated irrigation technologies can play a crucial role in optimizing water usage and improving crop yields, making it a promising approach to enhance agricultural productivity in a sustainable manner.

VI. Authors **Jamal O. Jaber** and **Mousa S. Mohsen** researched on the topic, ***"Evaluation of non-conventional water resources supply in Jordan".*** In this paper, the authors described the creation of a decision-support system aimed at assessing and selecting viable non-conventional water resources for supply. The non-conventional sources considered included desalination of brackish and seawater, treated wastewater, water importation across boundaries, and water harvesting. Through the application of the Analytic Hierarchy Process (AHP), the researchers ranked these options based on their potential.

The study's conclusion revealed that water desalination emerged as the top-ranked and most promising non-conventional water resource. Following closely in the ranking was water harvesting. These findings suggest that water desalination holds significant potential as an effective method for addressing water scarcity and meeting water demands in the region under study [6].

VII. Authors **Amali A. Amali, Adey N. Mersha, Eman R. Nofal** researched on the topic, ***"Non-conventional sources of agricultural water management: Insights from young professionals in the irrigation and drainage sector".*** In their discussion, the authors proposed a comprehensive and integrated approach to resource management, linking all forms of water resources together to achieve more effective performance. They emphasized that non-conventional water sources require diverse accessibility and flexibility to be effectively utilized.

The authors concluded by suggesting the importance of moving beyond conventional irrigation systems and drainage practices. Instead, they advocated exploring different approaches to meet the growing population's water needs. This holistic perspective on resource management and the incorporation of non-conventional water sources are crucial steps in ensuring sustainable water supply and supporting the increasing demands of a growing population [7].

VIII. Authors **S. D. Singh** and **Panjab Singh** researched on the topic, ***"Value of Drip Irrigation Compared with Conventional Irrigation for Vegetable Production in a Hot Arid Climate".*** In this research, the authors conducted a comparative study to assess the advantages of drip irrigation over various other irrigation systems, such as sprinkler irrigation and furrow irrigation. They specifically examined the efficiency of water usage and the yield potential of different crops and soil types under these irrigation systems.

The findings of the research indicated that drip irrigation system outperformed the other conventional irrigation methods in terms of water use efficiency and crop yield. The results demonstrated that the use of drip irrigation led to increased crop yield compared to sprinkler and furrow irrigation systems [8].

These findings highlight the potential benefits of adopting drip irrigation technology, which can contribute to better water conservation and improved agricultural productivity, making it a promising option for sustainable and efficient irrigation practices.

IX. Authors **Marlene Tomaszkiewicz, Majdi Abou Najm, Daniel Beysens** researched on the topic, ***"Dew as a Sustainable Non-Conventional Water Resource: A Critical Review".*** In this research, the authors explored the concept of dew harvesting as a water conservation technique that can be utilized for irrigation purposes. Dew harvesting is considered a non-conventional water resource, which can play a significant role in agricultural production. The physical, thermodynamic, and cooling properties of dew make it particularly advantageous for crop growth. Additionally, dew water is typically potable and has specific benefits for rural areas.

In their conclusion, the authors highlighted that dew harvesting is a reliable and promising approach, especially in the context of climate change. Its potential to provide a valuable water source for irrigation, along with its adaptability to changing climatic conditions, makes dew harvesting a favorable option for sustainable water management [9].

X. Authors **N. Maisiri, A. Senzanje, J. Rockstrom** and **S.J. Twomlow** researched on the topic, ***"On farm evaluation of the effect of low cost drip irrigation on water and crop productivity compared to conventional surface irrigation system".*** In this research, the primary objective was to compare the efficiency of drip irrigation techniques with conventional surface irrigation in terms of crop production and water usage. The study involved nine farmers who were using surface irrigation for their fields.

The results of the analysis indicated that the water used for irrigation by the drip technique was 35% less than the water used in the surface irrigation system. This significant reduction in water usage demonstrates the water-saving potential of non-conventional irrigation methods, such as drip irrigation.

Furthermore, the authors observed that drip irrigation is a cost-effective technique, making it a practical and economical choice for farmers. By saving both water and money, drip irrigation proves to be a beneficial and sustainable irrigation method [10].

XI. Authors **M. Qadira, B.R. Sharma, A. Bruggeman, R. Choukr-Allah** and **F. Karajeh** researched on the topic, ***"Non-conventional water resources and opportunities for water augmentation to achieve food security in water scarce countries"***. In this research, the authors delved into the improved techniques of water-use efficiency using conventional water sources. They highlighted the significance of non-conventional water resources as a means to alleviate water scarcity in water-scarce countries. The study explored various methods to generate non-conventional water resources, such as desalination, pre-use treatment, and appropriate soil-water-crop management techniques for irrigation.

Through a comprehensive literature survey, the authors reviewed the challenges and concerns related to the utilization of non-conventional water resources. Their focus was on identifying opportunities to enhance food security in countries facing water scarcity. By examining these opportunities, the research aimed to contribute to the sustainable management of water resources and achieving food security in regions with limited water availability [11].

XII. Authors **Cecile Brugere** and **John Lingard** researched on the topic, ***"Irrigation deficits and farmer's vulnerability in Southern India".*** In this research, the authors conducted an assessment of the risks and vulnerabilities faced by farmers in southern India concerning irrigation losses in cash crops, general farming, and cultivation within the irrigation system. The study aimed to analyze the potential challenges and uncertainties that farmers encounter in their irrigation practices.

Additionally, the authors discussed the development of conventional top-down irrigation systems in the region. These irrigation systems are likely the predominant approach used for water distribution to agricultural fields in the area under study.

Through their research, the authors sought to shed light on the existing issues and vulnerabilities related to irrigation practices in southern India, with a particular focus on cash crop cultivation. Furthermore, they explored the conventional top-down irrigation system as a key aspect of irrigation management in the region [12].

XIII. Author **A. Hamdy** researched on the topic, ***"Sustainable Use and Management of Non-Conventional Water Resources in the Arid Regions"***. In this research, the author conducted a comprehensive and detailed review of modern irrigation technologies, with a particular emphasis on the utilization and management of non-conventional water resources in irrigation practices. The study aimed to explore various innovative approaches to irrigation that go beyond traditional methods.

Moreover, the author emphasized the importance of minimizing any negative impacts on crop production, soil health, and the environment during the adoption of these modern irrigation technologies. Sustainable irrigation practices were a key focus to ensure long-term productivity without compromising natural resources and ecosystem health.

By examining and analyzing these aspects, the research aimed to contribute to more efficient and environmentally friendly irrigation practices, promoting the responsible use of water resources and sustainable agriculture [13].

1.3 IRRIGATION

Irrigation involves the deliberate application of water to agricultural fields and soil as a means of supplementing or replacing natural rainfall. It is particularly essential in areas experiencing insufficient or irregular rainfall, as well as in arid regions where water scarcity is a significant concern for agriculture.

The primary purpose of irrigation is to support the development and growth of agricultural plants and crops by providing them with the necessary amount of water. Additionally, irrigation plays a vital role in preventing soil compaction and aiding in weed control within the cultivated areas. This artificial water supply ensures that agricultural activities can continue even during periods of limited rainfall, contributing to improved crop yields and sustainable farming practices [5].

The application of water to the soil is essential for promoting plant growth and ensuring healthy crop development. Without an adequate and reliable water supply, agricultural productivity can be severely limited, and crops may suffer from water stress or even fail to grow altogether.

Water availability and proper irrigation practices are paramount for successful agriculture, as they ensure the optimal growth and yield of crops, contributing to food security and sustainable farming practices [14].

1.4 TYPES OF WATER SOURCES IN INDIA

Conventional water resources refer to renewable sources such as lakes, rivers, wells, tanks, fresh water wetlands, underground water, and inundation canals. These sources are essential for various living creatures and support the needs of communities and agriculture.

On the other hand, non-conventional water resources are vital for supplementing surface water and groundwater sources, especially in water-scarce regions. These non-conventional sources, like tube wells and perennial canals, play a crucial role in bridging the gap between water demand and availability.

Additionally, modern water sources also fall under the category of non-conventional water resources, providing innovative solutions to enhance water supplies. Fig.2 likely illustrates the various modern water sources encompassing non-conventional options.

The irrigation system is also classified into two categories based on the types of water sources utilized: Conventional Irrigation System, which relies on conventional water resources, and Non-conventional Irrigation System, which utilizes non-conventional water sources [3]. This classification highlights the importance of adopting different irrigation methods based on the availability and sustainability of water resources.

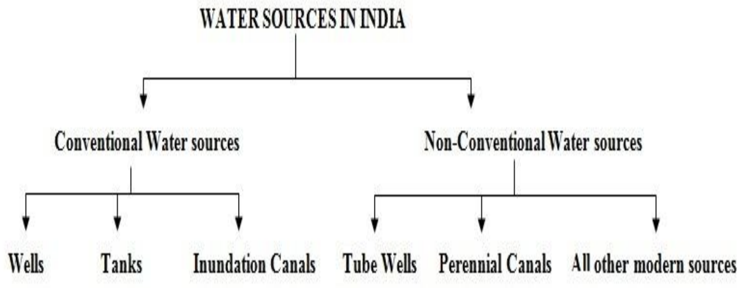

Fig.2: Types of water sources

Some water sources other than surface water and ground water are also known as non-conventional water sources defined as-

- Desalinated Seawater and Highly Brackish
- Rainfall-Runoff Water Harvesting
- Marginal-Quality Water Resources (wastewater treatment)

1.4.1 Desalinated Seawater and Highly Brackish

Desalination is a crucial technique used to convert seawater or highly brackish groundwater into freshwater, making it suitable for various purposes, including agriculture and human consumption.

Seawater contains a high concentration of salts, making it unsuitable for direct use in crop production and general consumption. Desalination plants, which are operational in many countries, utilize heat energy to evaporate the water, separating it from impurities and salts. The evaporated water is then collected and condensed to produce freshwater.

Desalination plays a vital role in regions where freshwater resources are scarce or limited, especially in coastal areas. It provides an alternative and valuable source of freshwater, contributing to water security and sustainable water management practices in water-stressed regions [3]. The comparison of desalination technologies revealed a distinct advantage of the distillation plant system. One of the key benefits is that distillation plants are capable of producing good quality water with a relatively low concentration of dissolved solids. Typically, the water generated by distillation contains dissolved solids in the range of 5 to 50 mg per liter (equal to parts per million, i.e., ppm).

In contrast, the reverse osmosis (RO) system produces water with a higher concentration of dissolved solids, ranging from 250 to 500 mg per liter. This significant difference in the amount of dissolved solids in the produced water highlights the superior performance of distillation technology in terms of water quality.

Furthermore, another advantage of the distillation plant system is that it does not require shutting down any portion for cleaning or equipment replacement. On the other hand, RO plant systems often necessitate shutting down parts for maintenance and equipment replacements. These advantages make distillation plants an attractive option for water desalination, especially when high-quality water with low dissolved solids concentration is required, and continuous operation without frequent interruptions is essential [11].

The reverse osmosis (RO) plant system offers its own set of advantages compared to the distillation plant system. One of the key advantages of the RO system is that the feed water does not require preheating, unlike the distillation process. By not preheating the water, the thermal effects of discharge are minimized, which can be beneficial for the environment and overall energy efficiency.

Another important consideration is the cost. In the RO plant system, the major cost factor is the energy required for desalination. As shown in Fig.3, energy cost plays a significant role in producing fresh water through RO desalination. Although the initial cost of setting up a seawater desalination plant, especially with RO technology, may be relatively high, the overall cost tends to decrease over the years. This reduction is often due to advancements in technology, operational efficiencies, and economies of scale.

Each desalination technology has its own strengths and cost considerations, and choosing the appropriate method depends on various factors such as water quality requirements, energy availability, and cost considerations [11]. As the largest desalination plant in the country, the Minjur Desalination Plant utilizes reverse osmosis technology to produce fresh water from seawater. This facility is located on a spacious 60-acre site in Kattupalli village, a northern suburb of Chennai, situated along the coast of the Bay of Bengal.

The plant's capacity to desalinate seawater and supply it to Chennai city helps address water scarcity and meet the increasing water demand in the region. Desalination projects like this are vital in supporting urban centers and ensuring a sustainable water supply in coastal areas where freshwater resources may be limited. Fig.4 showcasing The Minjur Desalination Plant likely highlights the scale and significance of this critical water infrastructure in India, contributing to the well-being and development of Chennai and its surrounding regions.

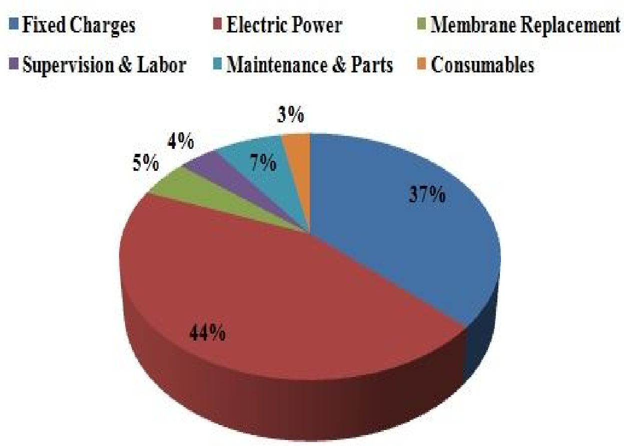

Fig.3: Seawater desalination cost in terms of percentage of total cost using RO Plant system[11]

Fig.4: The Minjur Desalination Plant (Tamil Nadu- Chennai, India)

1.4.2 Rainfall-Runoff Water Harvesting

Rainwater harvesting is a valuable practice that involves capturing and storing rainwater for various uses. By implementing rainwater collection systems, countries can reduce their dependence on conventional water sources, such as groundwater and surface water, especially during dry periods or in regions facing water scarcity.

Rainwater harvesting helps to recharge groundwater, conserve water resources, and mitigate the impact of droughts. It also provides an additional source of water for agricultural, domestic, and industrial purposes, contributing to overall water security.

By promoting rainwater harvesting systems and integrating them into water management strategies, countries can enhance their water resilience and better cope with water challenges, ensuring a sustainable and reliable water supply for the future [6].

In certain regions of India, characterized by arid and semi-arid conditions with scarce rainfall, it becomes imperative to conserve substantial amounts of rainwater during the rainy season. This stored water can then be utilized for irrigation and various other purposes at a later time.[3]

The largest rainwater harvesting project in the world is known as the 'Rainwater harvesting in rural Karnataka' project in India (Fig.5). The Rural Development and Panchayat Raj Department (RDPR) of Karnataka state provided the funding for this ambitious initiative.

Fig.5: Rainwater harvesting plant (Karnataka- India)

1.4.3 Marginal-Quality Water Resources (wastewater treatment)

Wastewater treatment has emerged as a significant non-conventional water source in India. It encompasses treated wastewater from commercial, domestic, industrial sources, as well as drainage water from irrigated agriculture fields and runoff water, which may carry various impurities and soil residues. Through this process, we can save and repurpose nearly fresh water, suitable for applications in irrigation and industrial activities.[3]

The Delhi Jal Board (DJB) in New Delhi, India, is currently constructing a new sewage treatment plant (STP) at OKHLA (as depicted in Fig.6). This upcoming plant is set to become the largest wastewater treatment facility in India and likely even the world. Its impressive capacity will enable it to treat up to 124 million gallons of wastewater per day. For more comprehensive information on sewage water generation in urban areas and the available treatment capacities in different states of India, please refer to Table-2.

Fig.6: Sewage treatment plant (STP) at OKHLA (New Delhi- India)

Table 2: Details of sewage water generation in urban areas and its treatment capacity available in States of India

Sr.No.	State/Union Territory	Sewage Generation, in urban areas (mld)	Installed Treatment Capacity (mld)
1.	Andaman & Nicobar Islands	22	-
2.	Andhra Pradesh	2871	247 .27
3.	Arunachal Pradesh	50	-
4.	Assam	703	0.21
5.	Bihar	1879	124.55
6.	Chandigarh	164	314 .5
7.	Chhattisgarh	951	-
8.	Dadra & Nagar Haveli	26	-
9.	Daman & Diu	29	-
10.	Goa	145	74.58
11.	Gujarat	4119	3062.92
12.	Haryana	1413	852.7
13.	Himachal Pradesh	110	114.72
14.	Jammu & Kashmir	547	264.74
15.	Jharkhand	1270	117.24
16.	Karnataka	3777	1304.16
17.	Kerala	2552	152.97
18.	Lakshadweep	8	-
19.	Madhya Pradesh	3214	482.23
20.	Maharashtra	8143	5160.36
21.	Manipur	132	-
22.	Meghalaya	95	1
23.	Mizoram	90	10
24.	Nagaland	92	-
25.	Delhi	4155	2693.7
26.	Odisha	1121	385.54
27.	Puducherry	136	68.5
28.	Punjab	1664	1245.45
29.	Rajasthan	2736	865.92
30.	Sikkim	24	31.88
31.	Tamil Nadu	5599	1799.72

32.	Telangana	1671	685.8
33.	Tripura	154	0.05
34.	Uttar Pradesh	7124	2646.84
35.	Uttarakhand	495	152.9
36.	West Bengal	4667	416.9
	Total	**61948**	**23277**

Source : GOVERNMENT OF INDIA MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE LOK SABHA ,UNSTARRED QUESTION NO.2541 **, Updated on 28th May, 2018**

1.5 TYPES OF IRRIGATION[15]

Fig.7 illustrates the classification of irrigation systems based on the method of water application to agricultural land.

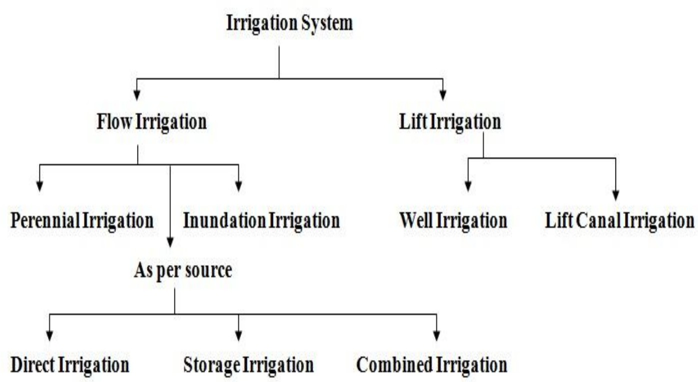

Fig.7: Types of Irrigation System

1.5.1 Flow Irrigation

Fig.8 demonstrates flow irrigation, a method in which the irrigation water is conveyed by gravity to the cultivated land through channels or canals.

Fig.8: Flow Irrigation System

This is further classified into the following types-

1.5.2 Direct Irrigation

As depicted in Fig.9, direct irrigation is a type of irrigation where water is taken directly from a river without any intermediate storage. This method involves constructing a weir or a barrage across the river to raise the water level, and then diverting a portion of the river flow through an adjacent canal, where gravity facilitates the water's flow to the fields

Fig.9: Direct Irrigation System

1.5.3 *Tank/Reservoir/ Storage Irrigation*

In this irrigation system, water is sourced from a river and stored using a barrage, similar to a dam. The key objective is to ensure sufficient water storage even during periods of low or no inflow from the catchment area. This stored water can then be utilized continuously for irrigation purposes through a network of canals. Fig. 10 illustrates the Tank Irrigation system, while Fig. 11 depicts the Storage Irrigation system.

Fig.10: Tank Irrigation System

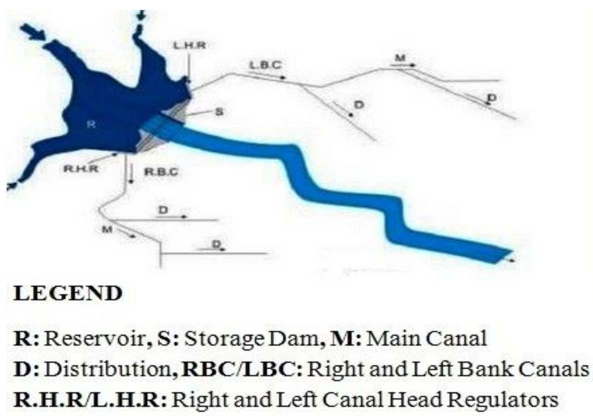

Fig.11: Storage Irrigation System

1.5.4 Lift Irrigation System

In the lift irrigation system depicted in Fig.12, the irrigation water is situated at a lower level than the land that needs to be irrigated. Therefore, to facilitate irrigation, the water is lifted up using motor pump sets or other mechanical devices. Once lifted, the water is then conveyed through channels that allow it to flow under the influence of gravity, reaching the agricultural land for irrigation purposes.

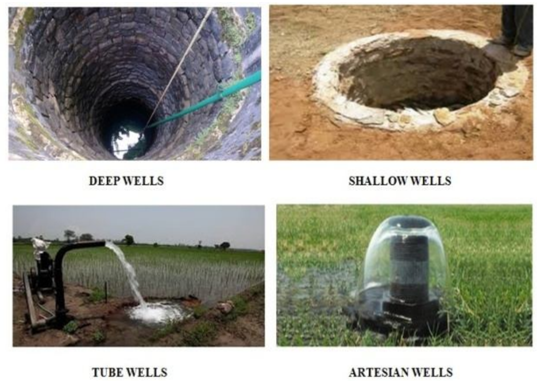

Fig.12: Lift Irrigation System *Fig.13: Well Irrigation System*

1.5.5 ***Well Irrigation***

In India, well irrigation is prevalent in states like Tamil Nadu, Bihar, and Uttar Pradesh, among others. Wells come in various types of construction, including deep wells, shallow wells, tube wells, and artesian wells, as illustrated in Fig. 13. In shallow wells, the water level fluctuates, dropping during dry months, whereas deep wells maintain a relatively constant water level throughout the year, making them more suitable for irrigation. Tube wells can be installed near agricultural fields where groundwater is readily accessible, facilitating irrigation of the land.[16]

Irrigation systems can indeed be classified as canal irrigation based on the duration of applied water. Canal irrigation involves the controlled flow of water through a network of canals to irrigate agricultural fields. This method allows for a continuous supply of water to the fields for a specific period, ensuring consistent and regulated irrigation.

1.5.6 Canal Irrigation

Canals are indeed one of the most effective sources of irrigation, particularly in low-level relief areas with perennial water sources and deep fertile soils. As a result, canal irrigation is commonly found in the northern plain of India, especially in regions such as Punjab, Haryana, and Uttar Pradesh.

Canals are generally classified into two types: Inundation canals (as shown in Fig.14-a) and perennial canals (as shown in Fig.14-b). Inundation canals are directly taken from the river without any intermediate water storage. On the other hand, perennial canals are equipped with a storage system, such as a dam or a barrage, situated between the river and the irrigated land.

(a) *(b)*

Fig.14-a: Inundation canal or Flood Irrigation System
Fig.14-b: Perennial canal Irrigation System

In India, perennial canals are predominantly used for irrigation purposes due to their ability to store water and provide a continuous supply, ensuring a more consistent and reliable water source for agricultural needs.[16]

1.6 Advantages and Disadvantages of irrigation in India[17]

1.6.1 Advantages

Certainly! Here are some common advantages of irrigation:

1. Increased Crop Production: Irrigation ensures a consistent and reliable water supply, which leads to higher crop yields and increased agricultural productivity.
2. Crop Diversification: With irrigation, farmers can grow a variety of crops throughout the year, regardless of the natural rainfall patterns, enabling crop diversification and better income opportunities.
3. Mitigating Droughts: During periods of inadequate rainfall or droughts, irrigation helps to safeguard crops and maintain agricultural production.
4. Improved Water Use Efficiency: Modern irrigation techniques, such as drip and sprinkler irrigation, can significantly improve water use efficiency by delivering water directly to the plant roots, reducing wastage.
5. Increased Land Utilization: Irrigation allows the cultivation of land that would otherwise be unsuitable for farming due to water scarcity.
6. Enhanced Soil Fertility: Controlled irrigation can help regulate soil moisture levels, preventing soil erosion and maintaining soil fertility.
7. Higher Income for Farmers: Improved crop yields and more frequent harvests due to irrigation can lead to increased income for farmers.
8. Sustainable Agriculture: Irrigation practices can contribute to sustainable agriculture by managing water resources effectively and supporting food production.
9. Agricultural Development: Reliable irrigation systems promote agricultural development in rural areas, creating employment opportunities and improving the overall economic conditions of the region.
10. Food Security: Irrigation plays a crucial role in ensuring food security by increasing agricultural productivity and stabilizing food production.

However, it's important to note that improper irrigation practices can lead to water wastage, soil Stalinization, and environmental issues. Therefore, proper planning, water management, and efficient irrigation techniques are essential to maximize the benefits of irrigation while minimizing its negative impacts.

1.6.2 Disadvantages

1. **Waterlogging:** Excessive seepage into the ground can raise the water level and saturate the crop root-zone, leading to waterlogging in that area.
2. Formation of Marshes and Mosquito Infestation: Excessive seepage and leakage of water can create marshes and ponds along the irrigation channels. These stagnant water bodies become breeding grounds for mosquitoes, increasing the risk of diseases like malaria.

3. Temperature Reduction and Dampness: The presence of irrigation water can lower the temperature in nearby areas and create a damp environment, affecting the local climate and living conditions.
4. Loss of Valuable Land: The construction and maintenance of irrigation canal systems can lead to the loss of valuable residential and industrial land, which is used for setting up the canal infrastructure.
5. High Initial Cost and Tax Burden: The high initial cost of implementing irrigation projects often results in higher taxes or levies on cultivators, increasing their financial burden.

It's important to consider these potential disadvantages of irrigation systems and implement appropriate water management practices to minimize their negative impacts. Proper planning, maintenance, and efficient water distribution methods can help optimize the benefits of irrigation while addressing these challenges.

1.7 CONCLUSIONS

Indeed, several countries around the world are grappling with water scarcity issues, and many states in India also face water problems. To address these challenges, water resources can be divided into two categories: conventional and non-conventional water resources.

1. Conventional Water Resources: Utilizing modern technologies for water conservation can help manage conventional water resources more effectively. Introducing water consumption reduction devices, such as water-efficient and flow reduction devices, in irrigation can lead to significant water savings while enhancing crop production.
2. Non-Conventional Water Resources: To alleviate the demand on fresh water resources, non-conventional water sources like rainfall-runoff, desalinated water, wastewater, and harvested water can be employed in irrigation. Integrating these non-conventional sources can contribute to increased food and crop production.

Researchers are continuously exploring new technologies and innovative approaches to tackle water scarcity. Implementing these technologies with proper consideration of the unique climates of different regions in India can bolster water harvesting systems and conserve substantial amounts of fresh water for irrigation and livelihood purposes.

By adopting sustainable water management practices and harnessing both conventional and non-conventional water resources, countries can mitigate water scarcity issues and ensure a more secure and sustainable water future for their populations.

REFERENCES

[1] S. R. J. Auxilia, "Irrigation System Using Soil Moisture Sensor and Conventional Flooding Method of," vol. 7, no. 5, pp. 311–320, 2018.

[2] M. R. G. Ghodake and M. A. O. Mulani, "Sensor Based Automatic Drip Irrigation System," *J. Res.*, vol. 02, no. 02, pp. 53–56, 2016.

[3] N. Beithou, "Non-Conventional Water Resources :," no. June, 2015, doi: 10.13140/RG.2.1.3172.8808.

[4] H. Ghamarnia, I. Arji, S. Sepehri, S. Norozpour, and E. Khodaei, "Evaluation and

comparison of drip and conventional irrigation methods on sugar beets in a semiarid region," *J. Irrig. Drain. Eng.*, vol. 138, no. 1, pp. 90–97, 2011, doi: 10.1061/(ASCE)IR.1943-4774.0000362.

[5] R. Sable and et al., "A Review on Different Irrigation Methods," *Int. J. Appl. Agric. Res.*, vol. 14, no. 1, pp. 49–60, 2019.

[6] J. O. Jaber and M. S. Mohsen, "Evaluation of non-conventional water resources supply in Jordan," *Desalination*, vol. 136, no. 1–3, pp. 83–92, 2001, doi: 10.1016/S0011-9164(01)00168-0.

[7] A. A. Amali *et al.*, "Non-conventional sources of agricultural water management: Insights from young professionals in the irrigation and drainage sector," *Irrig. Drain.*, no. June, pp. 1–17, 2020, doi: 10.1002/ird.2495.

[8] S. D. Singh and P. Singh, " Value of Drip Irrigation Compared with Conventional Irrigation for Vegetable Production in a Hot Arid Climate 1 ," *Agron. J.*, vol. 70, no. 6, pp. 945–947, 1978, doi: 10.2134/agronj1978.00021962007000060013x.

[9] B. Températures, U. J. Fourier, and F. Opur, "Physique et Mécanique des Milieux Hétérogènes , UMR 7636 CNRS — ESPCI — Université Pierre et Marie Curie — Université Paris Diderot , 10 rue Vauquelin , 75005 Paris , France .," pp. 1–63.

[10] N. Maisiri, A. Senzanje, J. Rockstrom, and S. J. Twomlow, "On farm evaluation of the effect of low cost drip irrigation on water and crop productivity compared to conventional surface irrigation system," *Phys. Chem. Earth*, vol. 30, no. 11-16 SPEC. ISS., pp. 783–791, 2005, doi: 10.1016/j.pce.2005.08.021.

[11] M. Qadir, B. R. Sharma, A. Bruggeman, R. Choukr-Allah, and F. Karajeh, "Non-conventional water resources and opportunities for water augmentation to achieve food security in water scarce countries," *Agric. Water Manag.*, vol. 87, no. 1, pp. 2–22, 2007, doi: 10.1016/j.agwat.2006.03.018.

[12] C. Brugere and J. Lingard, "Irrigation deficits and farmers' vulnerability in Southern India," *Agric. Syst.*, vol. 77, no. 1, pp. 65–88, 2003, doi: 10.1016/S0308-521X(02)00108-7.

[13] A. Hamdy, "Sustainable use and management of non-conventional water resources in the arid regions," *Acta Hortic.*, vol. 573, pp. 159–174, 2002, doi: 10.17660/ActaHortic.2002.573.18.

[14] Asawa, G.L., "Irrigation and Water Resources Engineering", ISBN (13) No: 978-81-224-2318-1, New-Delhi, New Age International Publication, April 2005.

[15] D. Emadwian, "Water Resources engineering," *Journal of Chemical Information and Modeling*, vol. 53, no. 9, pp. 1689–1699, 2013.

[16] Drishti, "Different Irrigation Systems," pp. 1–5, 2020.

[17] Garg, S.K., "Irrigation Engineering and Hydraulic Structure", ISBN No : 81-7409-047-9, Delhi, Khanna Publishers, Aug. 2005.