# The Impact of Water Distribution Inconsistency in the Rural Settlements of Punjab and to Extrapolate a Nature Based Sustainable Technology to Enhance Livelihood

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**Abstract.** Water, is undoubtedly one of the most indispensable needs for the human population to survive. In India, almost 70% of the population reside in rural settlements and a large share of this population is often caught up in the gaping open traps of ignorance and lack-of-knowledge. According to the World Water Development Report 2018 by the UN, India is facing a stark water crisis with the report citing that over 40% of the renewable water sources in Central India would be withdrawn by 2050. Availability of water plays the role of a key indicator in the measure of a village's prosperity and moreover it is an index of India's development. As a part of the Live-in-Labs® the purpose of our study was to identify the most prevalent challenge that played the antagonizing role of holding back the development index in a small, destitute village tucked away in the northern part of Punjab, India by the name of Dodeneer. The paper aims at shedding light on the status of the key development indicators in the village, provide quantitative and qualitative measurables like the available resources in the village using a pragmatic approach to scrutinize the same and to propose a judicious solution to the pervasive challenge through an anthropocentric outlook. This paper would address the predominant water management issues of


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Dodeneer and also provide affable solutions to tackle the same and provide insights as to how Nature Based Solutions (NBS) would help address many of India's water challenges while simultaneously delivering additional benefits vital to all aspects of sustainable development.

**Keywords:** Live-in-Labs® · Rural settlements · Renewable water sources · Nature based solution · Sustainable development

## 1 Introduction

Water is undoubtedly one of the most indispensable needs for the human population to survive. Water as a resource is spread across the globe in a non-uniform manner and this disparity has caused top organizations like the FAO (Food and Agricultural Institute) to create two categories—Water Rich and Water Poor countries [1]. The World Resources Institute (WRI) through its survey had created a visualization that clearly depicts this huge water disparity among nations. India according to WRI's data, is a region with a high-water stress (Ratio of total withdrawals to total renewable supply) ranging from 40 to 80% [2, 10]. In India, almost 70% of the population resides in rural settlements and a large share of this population is often caught up in the gaping open traps of ignorance and lack-of-knowledge. Just like any human settlement, even rural parts of India have their prosperity directly correlated to the number of resources it has access to [3]. India is facing a stark water crisis with the World Water Report 2018 by the UN citing that over 40% of the renewable water sources in Central India would be withdrawn by 2050 [4]. Dodeneer, a small, destitute village tucked away in the northern part of Punjab, India was our area of study for the Live-in-Labs® initiative. Live-in-Labs® is a multidisciplinary experiential learning program that breaks the paper aims at shedding light on the status of the key development indicators in the village, provide quantitative and qualitative measurables like the available resources in the village using a pragmatic approach to scrutinize the same and to propose a judicious solution to the pervasive challenge through an anthropocentric outlook [5]. Dodeneer houses around 58 houses of which 31% of the people receive water in quantities that are largely positively deviant from the average supply in the village per person. The availability of water per household ranges from a relatively small amount of 60 L to exorbitant amounts of 4000 L. This sheds light onto the fact that the water shortage in the village is not a result of the non-availability of water, but it rather is a direct consequence of the lack of management of water as a resource. Our purpose of the study was to observe in the supply of water across the village and after thorough analysis, it was understood that the disparities among the households with regards to the water they received were large. This problem of poor water management coupled with a few other factors such as terrain, unauthorized use of motors caused the team to center in on the research problem of the paper as "The Non-uniform distribution of water rising due to poor water management in the village" (Fig. 1).

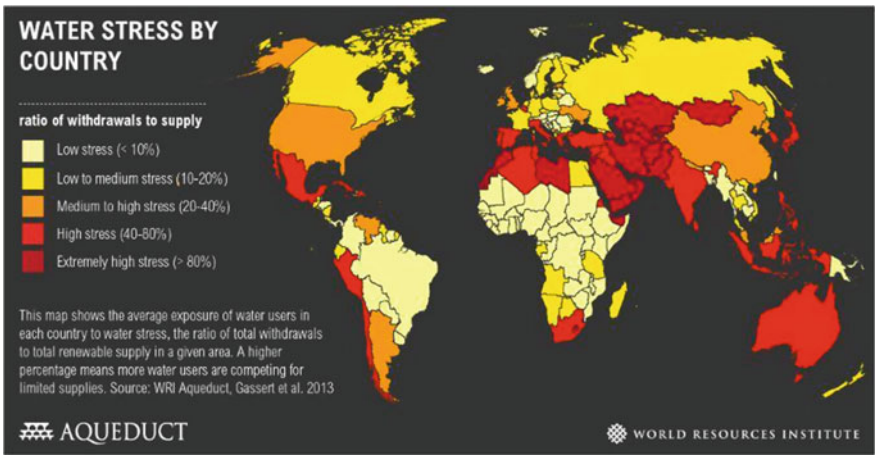


**Fig. 1.** Water stress by country [10]

## 2 About the Village

Dodeneer is a village situated 14 km away from the bustling city of Pathankot in Northern Punjab, and the village is in a backward state unlike most villages around it. The village is officially known by the name of New Tharyal, however the Caste divide has caused all the scheduled caste families to live away from the main village and this has led to the birth of Dodeneer, a name which is not very pleasant for the tenants of the village to hear as they feel it is a conspiracy of the upper caste to tease them, something very common in most backward villages [6]. The whole village houses 58 families and is characteristic of its single lane structure where the center lane is 365 m long and spans the entire village of Dodeneer. The 58 registered houses are all made of bricks and stones, with the people painting these buildings with shades of white, red or green. The people speak in Punjabi and 90% of the village survives on skilled and semi-skilled labor. There are two teachers, two painters, four auto drivers, few ladies work as housekeepers and remaining all are labourers. This village has a partially built Anganwadi [7] whose construction has been temporarily stalled due to the lack of government funds and so children have to go to the nearby village of Mutpharkha which is almost 3 km away from their village for schooling. They do not have any primary health care centers and in an emergency, the ambulance takes almost half an hour to reach the village from Pathankot. Toilet construction has begun in the village, yet several people still find it more convenient to practice their open defecation procedures. They have a good supply of electricity with subsidized bills. But the drainage system in the village is below average with sewer water spilling on the roads and open drains act as breeding grounds for mosquitoes. The village has no agrarian activities. The people of the village are not very sociable, except for the evenings when all the men of the village join together to end their day with alcohol and beedis.

## 3 Challenge Identified

Dodeneer is a very pleasant and charming village. The people were very welcoming and amiable. Nevertheless, the happy village faced a few challenges in their daily life which disturbed the harmony of the village. The village acquires water supply from two sources, one from a PWSSB (Punjab Water Supply and Sewage Board) from Tharyal village and the other from a Bore well which is situated in the far end of the village. We noticed that no pipeline in the village has a tap to control the flow of water during the supply. This brought in a major water wastage concern across the village. Due to this wastage of water from the pipelines along the initial houses, and also the well-offs tend to use water motor to suck water using their own electricity and also some try to acquire water from the Borewell without a legal authority over it.

This created the non-uniform distribution and scarcity of water in some parts of the village. We also found that the flow rates of water from each pipe were also found to be varying, resulting in variable accessibility rate. All of these factors brought us to the conclusion that the village had a non-uniform distribution of the source water across the village. According to the WHO organization, the minimum quantity of water needed is 20 L per capita per day [8]. It is noticed in the village that if we plot a graph of the amount of water accessible by each person, the series of points would not fit along the curve of the average requirement line. Thus proving that water distribution is one of the main concerns to be looked into, so that the people of the village can be given uniformity in their access to water resources in the village, thus narrowing the water-rich vs water poor divide and resolving the lack of water issue in the village.

## 4 Research Methodology

PRA or Participatory Rural Appraisal is a set of tools that embodies various characteristics of a chosen region in which we get a clear picture of the village and it provides validation of the chosen thematic challenge and affirms the necessity to solve this challenge. Starting with observational activities such as the AEIOU frameworks and Six senses, we were able to develop a rational perception about the village and its occupants and the factors that were affecting the village in both positive as well as negative ways.

### 4.1 Resource Map

The resource map helps in identifying the major resources available in the village and to highlight the facilities/resources which the village lacks (Fig. 2).

### 4.2 Transect Map

Transect mapping is one of the most crucial parts in village mapping and is instrumental in creating an accurate sketch of the village with particulars like distance, number of houses, resources, landmarks, boundaries, etc. well-marked. To draw out a transect map we have to choose a limited area and within that boundary, we have to

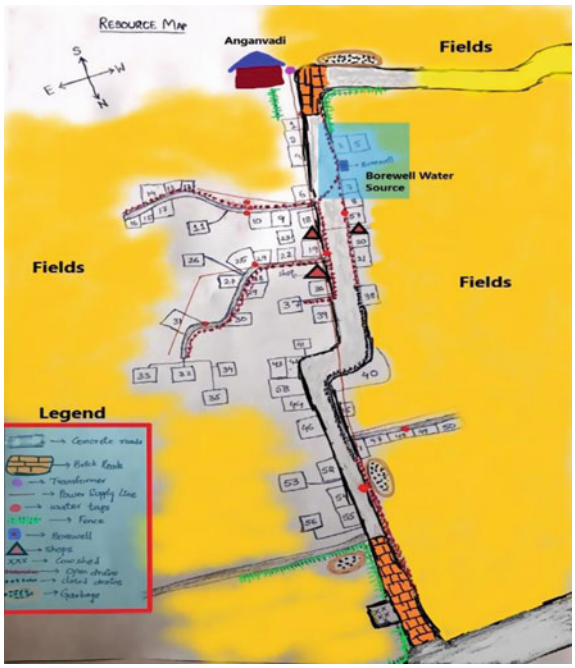


**Fig. 2.** Resource map

observe using the frameworks and write down and describe what it is that we encountered from the very first footstep to the very last step. It depicts the micro level of land use and how the people use that land (Fig. 3).

The Transects have been made of the village based on the properties of type of drains, type of roads and water availability.

### 4.3 Seasonal Routine, Income-Expenditure, Inflow-Outflow Analysis

The next step in PRA is to identify how the daily routine of villagers change from season to season. This helps us in understanding the lives and needs of people seasonally in a better manner.

The wealth of any village depends on the income and expenditure of each and every day, which should be considered and analyzed in various aspects such as energy, agriculture, skill development etc.

The necessities which go into the village (inflow) and products that come out of village (outflow) decide how independent/dependent the village is, indicators such as the amount of energy, water, waste management, skill development, livelihood generation, health, education, infrastructure, agriculture, sanitation etc. (Fig. 4).

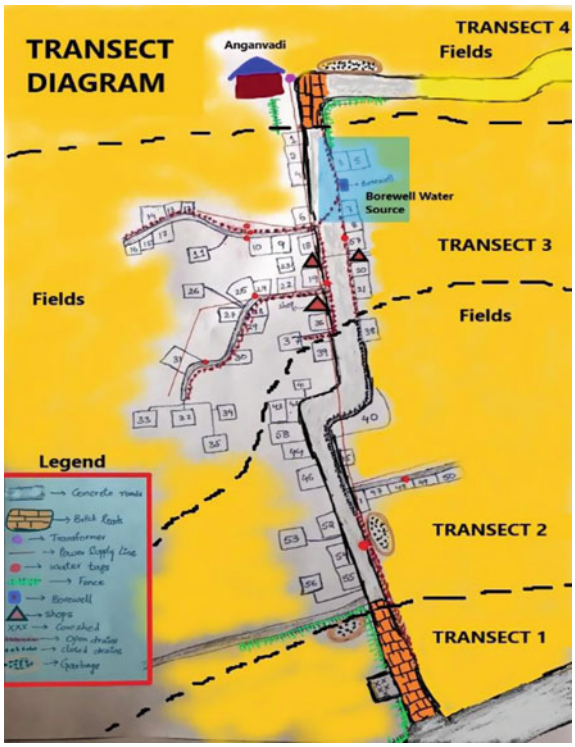


**Fig. 3.** Transect diagram


**Fig. 4.** Economic factors

### 4.4 The Problem Tree

The Problem tree is used to list down all the causes and effects of the major problems that have been cornered down onto in the village. It is then used to compare all the indicators and identify the major challenge and set the most prevalent challenge as the

thematic working area. In our case, we had 3 separate Problem trees for 3 different major challenges. Out of this, the chosen thematic area was **Water Management** as it clearly had more effects on the community than the others.

### 4.5 The Venn Diagram and the Brainstorming Session

The Venn diagram helps us to know different types of communities' present in the village, as well as the villagers' view of their importance in the community and also indicates the proximity of the contact and cooperation between those communities/groups.

Finally, the Brainstorming tool is inclusive of a session with the opinion leaders in the village to understand how deeply roots the chosen problem is in the village.

Post the extensive PRA sessions, the major challenge was found to be "**Water Management**". As a result of this find, the data was collected accordingly such as water storage capacity in each house, type of storage, amount of water being pumped to the village, no. of people use water motor, amount of water drawn from underground and impurity test. We calculated the flow rates of water from each pipe in the village during water being supplied includes bore water and Tharyal water. By this, we came to know how the water is managed throughout the village and we noticed that flow rates are different in different sectors, this is a supporting point for the mismanagement of water. And such mismanagement was the direct cause of the water stress within the village. This caused the people to use the bore well water illegally as the legal Tharyal supply was not enough for them.

### 4.6 The Interviews

After narrowing down on our thematic area with the help of PRA, the team conducted a series of interviews through the village to affirm the team's PRA result. The subjects of the interviews taken by the team were spread throughout the whole village. As Dodeneer was a small village with only about 58 houses. The people we interviewed ranged from all age groups from children to older people, both male and female. The team took interviews from 46 houses and received a lot of similar information on the water challenge in the village.

A few notable questions asked during the interviews were:

1. How many times do you fetch water daily?
2. How much water do you need on a daily basis?
3. What is the amount of storage you have in your house?
4. Do you adopt rain water harvesting methods?
5. What are the alternative water sources you have?

### 4.7 Creating Personas

Based on the responses of these interviews, the team coagulated common responses and began the task of creating personas of people in the village. A persona is a way of creating a fictional character who is a representation of the issues faced by a set of

common people due to a common challenge. The team created personas of a teenage girl, a daily wage labourer and a housewife—The most common people in the village.

The category of housewives in the village is represented by Conscientious Kumari, our persona 1. She is a calm-headed, responsible, hard-working woman who spends most of her time doing household chores. She wishes she could earn more money to support her family and provide her children with a better lifestyle. She goes to a nearby village for household work, but is often late for work because of the irregular/inconsistent arrival of water. This persona sheds light on the difficult life of a housewife in the village that is further aggravated by the persisting water shortage.

The category of labourers is depicted by our second persona, Hard worker Harish. A hardworking man who is fed up of the administration's apathy towards the people in the village, Harish is among the 95% of the men in the village who are directly dependent on skilled/unskilled seasonal labour to feed the mouths at home. This sect of people is not employed throughout the year, much owing to the fact that most of them don't study higher after grade 12 in order to get a well-paid, stable job. They are often delayed to their work places which are outside the village, due to the water woes in Dodeneer. These people often have to go to nearby villages in order to collect water from the houses of rich landlords, and are often subject to harsh, demeaning treatment at these places.

The final category of personas is represented by Perseverant Rampyari, a teenage girl. She is smart, energetic and never complaining about her personal issues due to the water shortage in the village. She fetches water from neighbouring villages for the family even when it's her time of the month. In spite of being in unbearable pain, she still has to perform the excruciating task of walking almost 2 kms with 2 buckets of water, at least twice a day. She never talks about it to anyone and silently bears it, just like all her other friends do.

The limitations to the course of study have been specified in Sect. 8 (Fig. 5).

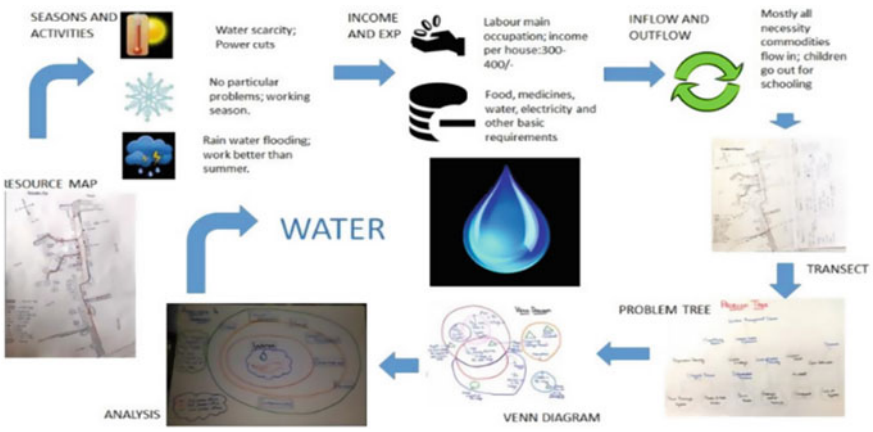


**Fig. 5.** PRA

## 5 Result 1

The narrowing down to the area of focus was through a thorough analysis of all the tools in the Participatory Rural Appraisal. Each of these tools gave a new idea of approach into the challenge. The conclusion of the PRA was found to be that, the village was facing a major challenge in the management of water, a challenge that arose due to the lack of uniform distribution of water throughout the village. Figure 2 is the flowchart that outlines the whole PRA process conducted by the team in the village of Dodeneer.

### 5.1 Medium of Water Storage

"How do the villagers store their water?", the importance of this question was that it helps identify the amount of water each house in the village consumes per day. The data we got from the families coupled with the measurements of the capacity of the buckets and cans taken by the team helps come up with a pretty much accurate figure of the amount of water consumed by the village on a particular day according to the villagers. The following are the pre-study measures taken by the team:

**Capacity of Tank**: 300/350/500/1000 L

**Capacity of a Bucket**: 20 L

**Capacity of a Can**: 50 L

**Capacity of a Sump**: Around 4000–5000 L (the actual sump has a much larger capacity, but only about this much amount is filled in the two sumps in the village).

The total consumption of water in liters by the village in a day for 47 houses (11 houses were data deficient, i.e. no tenant existed during the time of study) is 17,336 and since 47 of 58 accounts for about 81% of the whole village, this data can be used as a good parameter to make our following calculations. This is an average of 368.85 L of water per house. Now, consider that after including some reasonable data for the missing houses through observational methods, we can roughly estimate that the missing houses also average at 368.85 L of water. So, doing the math we get 21,393.3 L (estimate after including both the sources Tharyal and bore well) of water consumed per day in the village. (including the missing 11 houses). Considering the fact that the unauthorized usage of the bore well is susceptible to termination at any point of time by the government, the supply of water from Tharyal only can be taken as the legal source of water and it takes place only for a couple of hours per day on an average (since supply duration varies). Thus, bringing us down to the realization that the total water received by the people of the village is much below 50% of the calculated value. Forcing the research to consider the major challenge faced by the village is water distribution (Fig. 6).

After the challenge faced by the village was identified, a small survey was conducted in the village pertaining to the method of storage of water and the capacity of water stored, the number of people in each house, if there is the usage of a motor in that house and also if their source of water was the Tharyal source or the bore well source. The study involved the team going from door to door and asking questions to each household that pertained to water challenges. The responses given by the households were recorded, quantified, analysed and interpreted. A quantifiable dataset was created that housed 47 entries (houses) with 11 fields (questions).

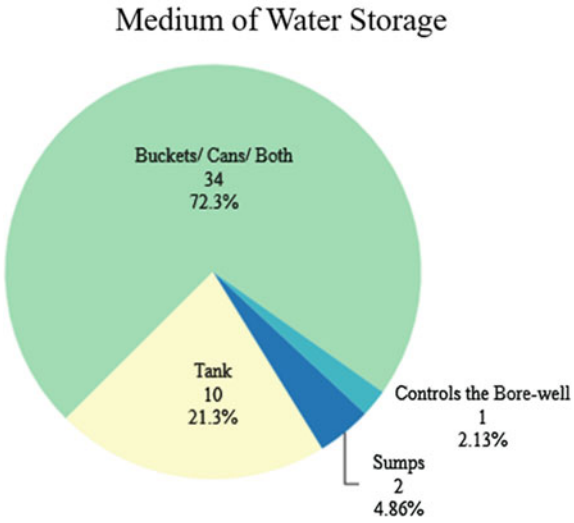


**Fig. 6.** Medium of water stortage

The whole study covered 47 houses i.e. 81% of the houses in the village. A few insights that were gathered were:

- There were no houses that practised rainwater harvesting.
- The storage units used were 50 L cans, 20 L buckets and 350–500 L tanks and 2 houses used underground sumps.
- 11 houses in the village used motors.

The figure below shows on how about 50% of the village does not get the average amount of water per capita per day as suggested by WHO. And the remaining percentage of the village acquires water at least four times that, from the data and the statistics obtained. Thus, proving the inconsistency in the distribution of water across the village providing an illusionary effect of scarcity.

**Table 1.** Water distribution survey

| | | | | | |
|---|---|---|---|---|---|
| Total number of houses | 58 (47 data collected) | | Number of people | | 307 (approx.) |
| Source of water | Bore well | | Tharyal | | Both |
| | 18 | | 34 | | 8 |
| Number of houses with motor | | | 11 | | |
| Type of storage (Cans: 50; Bucket: 20 L) | Cans + Buckets | Sump | Buckets | Cans | Tanks |
| | 5 | 2 | 27 | 2 | 10 |
| Number of houses with <120 L of water | | | | 21 | |

**Table 2.** The last column represents the number of liters for day

| Bore well water | Diameter (cm) | Base area ($cm^2$) | Height (cm) | Flow rate ($cm^3$/min) | Water (in liters) for 3 h/day |
|---|---|---|---|---|---|
| Tap1 | 26.5 | 551.5458602 | 8 | 4412.366882 | 794.2260388 |
| Tap2 | 26.5 | 551.548602 | 7 | 3860.821022 | 694.9477839 |
| Tap3 | 26.5 | 551.548602 | 12 | 6618.550323 | 1191.339058 |
| Tap4 | 26.5 | 551.548602 | 7 | 3860.821022 | 694.9477839 |
| Tap5 | 26.5 | 551.548602 | 5.8 | 3198.965989 | 575.8138781 |
| Total water into the village on each day (in liters) | | | 3951.275453 (around 4000 L) | | |

## 5.2 Flow Rates in the Taps

The flow rates obtained in each of the taps coming from the bore well as well as Tharyal was measured and observed to be varying. This gives a varying ratio of the number of buckets filled to the tap. This gives a clear picture of how non-uniformity plays a major role in the village. The experiment conducted was for one minute on a bucket of the base area of around 552 $cm^2$ resulting in varying heights. By using the actual discharge formula of $Q = Ax/t$, where Q is the discharge, A is the base area of the measuring bucket, x is the height of water achieved in a minute and the time is taken (60 s in our case) the flow rates of each pipe was observed. Table 1 gives us the flow rates of the bore well taps and Table 2 gives us the flow rates of Tharyal taps (Table 3).

**Table 3.** The total volume in the table represents the water being supplied to the village through Tharyal taps

| Bore well water | Diameter (cm) | Base area ($cm^2$) | Height (cm) | Flow rate (liters/min) | Water (in liters) for 2 h/day |
|---|---|---|---|---|---|
| Tap1 | 19 | 283.528737 | 17 | 4.819988529 | 578.3986235 |
| Tap2 | 19 | 283.528737 | 3.5 | 0.9923505795 | 119.0820695 |
| Tap3 | 19 | 283.528737 | 11.5 | 3.260580475 | 391.269657 |
| Tap4 | 19 | 283.528737 | 10.5 | 2.977051738 | 357.2462086 |
| Total water supplied into the village on each day (in liters) | | | | 1445.996559 | |

## 5.3 Water Supply to Each House

The village has predominantly 2 sources of water, the one from Tharyal as well as the Borewell in the village. Some houses use only Tharyal water while some use only the Borewell water. There also a few houses that use both the Tharyal and the Borewell water (Fig. 7).

As the above pie chart dictates, we see that the larger part of the village has the Tharyal water supply as their only source of water (54%). This is followed by the houses with the only bore well as a water source (28.6%). The houses that have both Bore well and Tharyal water supply are another 12.7%. These are all the direct

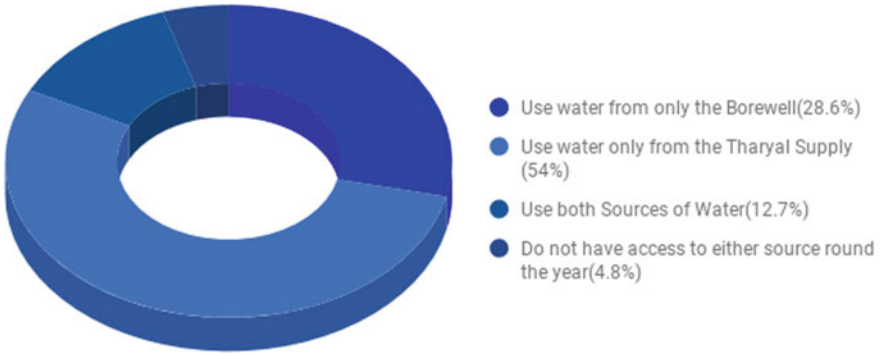


**Fig. 7.** Water sources in Dodeneer-1

connections i.e. there is a pipe in the house compound. But there are also 3 houses that have no direct connection of water into the house. These are called indirect connections. And they constitute 4.8% of the whole (Fig. 8).

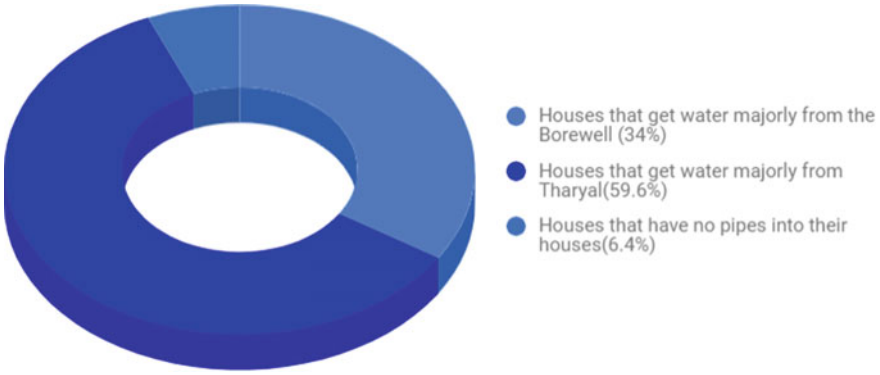


**Fig. 8.** Water sources in Dodeneer-2

The above graphs, tables and figures are the outcomes of the village visit, observations, analysis, brainstorming and documentation.

## 6 Result 2

On the basis of the in-depth analysis (both primary and secondary) conducted in the village, the team with the help of its brainstorming sessions with the Live-in-Labs® team reasoned out a few solutions that were believed to be viable in solving the water crisis in the village.

The first step however was to identify what defined the problem statement we have talked about in this paper. So, the 5 factors that defined our problem statement were:

- The different flow rates for the 3 different Tharyal water outlets in the village.
- The houses accessible/tap ratio varied significantly across the 3 outlets.
- The use of motors by a few houses.
- Lack of transparency in the water arrival timings.
- The issue of a direct pipe connection into a house.
- With these 5 factors sorted, the next plan was to identify which of our proposed solutions was the most effective in clearing out these 5 intrinsic ambiguities. The solutions that we initially proposed were:
- A **Radial Water Distribution System** to effectively distribute water uniformly in the village.
- A **Leakage Detecting mechanism** to identify whether water leakage was happening in the village.
- **Water Recycling** to reuse grey water.
- **Rain Water Harvesting** to use the runoff rainwater as domestic water and also prevent the roads from flooding.
- **Fog Catcher**, a not very common method which dwells on capturing moisture present in fog, condensing it to water and then using it.
- A **Common Storage Tank**, which is more or less a lesser case of the Radial Water Distribution System.
- **Affixing Water Faucets**, a solution that has to be definitely used along with any other solution chosen (Table 4).

**Table 4.** Solution ranking matrix

| Solutions | C1 | C2 | C3 | C4 | C5 | Total |
|---|---|---|---|---|---|---|
| Radial water distribution system | 1 | 1 | 1 | 1 | 1 | 5 |
| Leakage detector | 0 | 0 | 0 | 0 | 0 | 0 |
| Water recycling | 0 | 0.5 | 0 | 0 | 0 | 0.5 |
| Rain water harvesting | 0 | 0.5 | 0 | 0 | 0 | 0.5 |
| Fog catcher | 0 | 0.5 | 0 | 0 | 0 | 0.5 |
| Common storage tank | 1 | 0 | 0.5 | 1 | 1 | 3.5 |
| Fixing water faucets | 1 | 0.5 | 0 | 0 | 0 | 1.5 |
| *Key* | | | | | | |
| C1: different flow rate for 3 outlets | C2: people/ tap varies across 3 outlets | | C3: use of motor by some houses | | C4: transparency of water arrival timing | C5: direct pipe connection (just 1 house) |

Water distribution system [9] is used to describe collectively the facilities used to supply water from its source to the point of usage. The sole purpose of a distribution system is to deliver water to the consumer with appropriate quality, quantity and pressure. Only a good water distribution system could suffice the above purposes.

A good distribution system involves the uniformity in the supply throughout the area and should not fall low in its pressure head. The quality of water should also not deteriorate during the distribution through the pipes. Hygiene is also one such factor contributing to the quality of the distribution system. Thus, the distribution pipes are to be laid preferably 1 m away from the sewer lines. The distribution pipes should be fairly resistant to leakage so as to avoid losses of the resource. Sustainability factors to be considered for the water distribution systems [11]. Distribution system is to be laid across the entire area without being a hindrance to the population, thus one of the best possible ways would be by following the road layouts beneath or above the pavements.

Distribution system is broadly classified into four major types, namely,

- Ring System
- Dead End System
- Grid Iron System
- Radial System.

Since the area of research was of an irregular shape, the best possible method of distribution was found to be the radial system of distribution. In this system, the whole area is divided into small distribution districts or zones and an individual distribution reservoir is provided for each zone. It is generally preferred type of reservoir is of the elevated type. From this reservoir the pipelines are laid radially to the surrounding streets (Fig. 9).

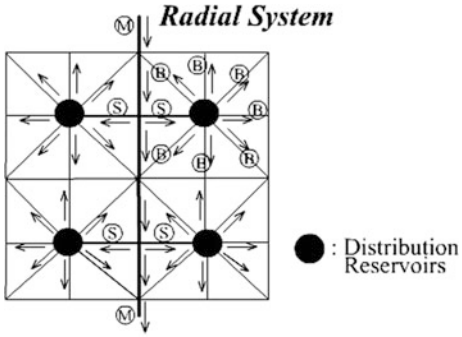


**Fig. 9.** Schematic diagram for radial system

The **Radial Water Distribution System** was found to be the most effective of all solutions proposed for the village because of its ability to solve the 5 issues that defined our problem statement (mentioned above).

- The flow rates across the 3 Tharyal taps can be equalized using the unified water distribution system
- Careful planning in setting up the central reservoirs can normalize the houses accessible/tap ratio

- A system as efficient as this can cause the people from giving up the use of illegal motors to pull up groundwater
- The Tharyal water is directly stored into the reservoirs first when it arrives. This simplifies the task of people having to wait for the water to come. Thus, the irregular water timings would not pose an issue anymore
- The direct pipe connection can also be avoided once this system is deployed in the village.

## 7 Conclusion

From the observation and the analysis in the due course of the research it is found that the village does not lack the resource water, but requires an instant deliberation on the distribution of the resource across the village. It was also observed that the village did not have any kind of knowledge in the concept of water conservation. There has to be steps taken to bring awareness in the rural areas of the country to conserve and maintain a moderate usage of the depleting resource. The self-help groups (SHG) can take the initiative of bringing awareness in the village. Also, implementation of Nature Based Solution to manage water utilization can be done by the government to ensure sustainability.

Through the substantial research methods executed in the study, that gave relatable data and results of the village Dodeneer, it is determined that some challenges as mention across the paper are existent in Rural India. Steps need to be taken by the government or any private organizations in order to build a sustainable economy and help lead India to being a developed country.

## 8 Limitations of the Study

The study conducted was subject to several limitations like the following:

- People at times were hesitant to give out their personal details like their income, assets, saving details.
- The men in the families were not present during the hours of study as they had their jobs under the MGNREGA scheme.
- The lack of opinion leaders in the village further limited the study.
- All the people in the village belonged to the particular community and due to this, it was difficult to identify a different perspective of the same issue.

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