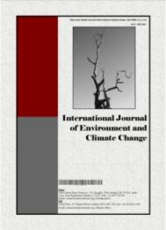

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Gravity Fed Micro Irrigation System for Small Landholders and Its Impact on Livelihood - A Review

T. S. Sherpa [a*], G. T. Patle [a] and K. V. R. Rao [b]

[a] College of Agricultural Engineering and Post Harvest Technology, Central Agricultural University, Gangtok, Sikkim, India.
[b] ICAR-Central Institute of Agricultural Engineering, Bhopal, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Worldwide pressurized micro irrigation technologies have remarkably shown its effectiveness in water saving and increasing the crop yield with several other benefits. Although among the small land holder farmers, adoption of pressurized micro irrigation system is minimal mainly due to the small land holding and more system cost. Gravity micro irrigation is one of the best alternatives for the small land holder farmers with almost all benefits derived by the pressurized micro irrigation. Gravity fed drip irrigation has enormous capability for water and nutrient conservation. This review paper explains design, layout, features of gravity fed micro irrigation system, its suitability and benefits to the small farmers for achieving more yield per drop of water. The comprehensive attempt in the current review analysis is to enhance a most favourable methodology and technology to magnify and intensify the operation of gravity fed drip irrigation system in extensive cultivation and production. Further to accomplish the efficient utilization of available water resources for growing horticultural crops in hilly region of India, gravity-fed micro irrigation should be integrated with water harvesting system.

Keywords: Drip; gravity fed; micro irrigation; livelihood; hilly; north east; topography.

**Corresponding author: E-mail: tsheringsangmosherpa@gmail.com;*

1. INTRODUCTION

Water is an important entity required in the sustainable crop production system. Water signifies one of the basic needs for agriculture and economic growth of any country. Nearly 80% of exploitable water in the world is utilized by agriculture sectors. This consumption of water is increasing day by day due to growth of globalization and population. Changing climate is also influencing the water demand in agriculture sector [1]. Rainfall is the basic source of water on the earth and temporal and spatial variation the rainfall pattern, amount and rainfall intensity are also affecting the crop production process. Many areas of the country are experiencing the water scarcity due to large scale exploitation of the fresh water resources. Although the creation and development of irrigation facilities in many parts of the country helped to increase the productivity and production of the major crops but water losses during conveyance and field application are found as major drawbacks.

Advancement in the pressurized micro irrigation technologies has resulted to achieve more yields per unit area and saving of precious water [2]. As compared to traditional irrigation, micro-irrigation has been proven to be a cost-effective, energy-efficient way to use less water and increase water efficiency. This is because micro-irrigation only uses up to 35% to 40% of the water it needs. There are many factors that affect drip irrigation management, such as soil properties, crop and growth stage, environmental factors, and more [3]. It also cuts down on the amount of underground water that is used in surface irrigation. The results of these things can be combined to make a practical, organised system that decides how much and when to use drip irrigation system. Gravity fed drip irrigation [4,5] is similar to pressurized drip irrigation having additional advantage of energy saving also directly manages the quantity of water emitted from each emitter nozzle in each sector during the irrigation process without requiring to control the flow rate or the duration of the irrigation event [6]. Gravity-fed drip irrigation system use synonymous to drip irrigation system in case of water application but gravity-fed drip system having advantage of energy saving [7].

2. TYPES OF IRRIGATION TECHNIQUES

Water can be obtained from various sources in different irrigation techniques. But the ultimate objective is to distribute water uniformly to the complete field, to such extent that every plant receives fair quantity of water it [8].

2.1 Surface Irrigation

In surface irrigation systems, water moves above and across the field easily by gravity so that it can wet and penetrate the soil. Surface irrigation can be further divided into furrow irrigation, border irrigation, and basin irrigation. It is often called flood irrigation when the irrigation results in flooding or close to flooding of the cultivated land [9,10].

2.2 Drip Irrigation

Drip irrigation is also called as trickle irrigation. Drip irrigation is a type of irrigation where water is delivered to the root zone of plants drop by drop. If this technique is used correctly, it can be the most water-efficient method of irrigation, because evaporation and runoff are cut down. In modern agriculture, drip irrigation is usually combined with organic or inorganic (plastic) mulches which have additional advantages such as decreasing evaporation rate, increase in soil temperature control of weeds etc [11,12,13].

2.3 Sprinkler Irrigation

In sprinkler, also known as overhead irrigation, where water is piped to one or many central locations inside the cultivable land and distributed by overhead high-pressure sprinklers or guns [14,15]. The use of sprinklers, sprays, or guns on permanently installed risers is commonly referred to as a "solid-set" irrigation method. As the name suggests, rotor sprinklers are driven by a ball drive, gear drive or impact mechanism [16].

2.4 Sub-surface Drip Irrigation

Sub-surface drip irrigation has been used for many years in agricultural field and in regions with higher water tables [17]. In sub-surface drip irrigation laterals with drippers are buried into the soil. Water is applied slowly below the soil surface through emitters with discharge rates in the same range as that of surface drip system [18]. This system is mostly used for close growing row crops but can be used on small fruit crops. The main advantage of this method is to reduce evaporation losses, little interference with cultivation or cultural practices and possibility of longer operation life [18,19].

3. DEVELOPMENT AND JOURNEY OF MICRO IRRIGATION IN INDIA

Journey and development in micro irrigation in India is represented in figure 1. To promote the use of plastic products in agriculture, the Indian government launched a centrally sponsored programme in 1992. Rural infrastructure funds were established in the year 1995. The overall goal was to improve agricultural water use efficiency by promoting technological interventions. It was in 2006 that a government-sponsored micro irrigation programme was launched to promote the widespread use of drip and sprinkler irrigation and to encourage farmers to use water-conserving technologies. The National Mission on Micro Irrigation was established in 2010 as a result of a centrally sponsored micro irrigation programme. This programme lasted through the 2013-14 fiscal year. To date, the National Mission on Sustainable Agriculture has implemented the National Mission on Micro Irrigation, which was incorporated into the National Mission on Micro Irrigation in April, 2014. "As of April 1, 2015, the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) included the Micro Irrigation component of on-farm water management under the slogan of "Har Khet Ko Paani". Micro-irrigation is being widely adopted in India in order to ensure a 'per drop-more crop'.

3.1 Advantages of Drip Irrigation

Drip irrigation has capability to make use of water in most efficient way to yield more crops and vegetables [20]. According to Schwankl et al., (1996) drip irrigation system has the potential to use very less amount of water to the roots of plant and reduces the water loss due to evaporation and also increase irrigation uniformity [21]. Phene (1990) performed the comparison of surface irrigation, sub-surface drip irrigation and reported decreased amount of water loss because of reduced evaporation, deep percolation, zero surface runoff [22]. The drip irrigation system also increases yield as well as quality [6], it also has higher efficiency in nutrition. Whereas sub-surface drip irrigation supplies water beneath the surface of the soil by making use of buried drip tapes [23].

4. GRAVITY FED DRIP IRRIGATION SYSTEM AND METHODOLOGY

The concept of more crops per drop can be brought to realization only through effective and proper management of irrigation water sector consuming lions share. Micro-irrigation systems are the most efficient methods, but the adherence of these technologies is under threat due to some reasons or other. Gravity-fed drip irrigation system is one of the creativeness of these technologies where the pumping cost is nullified and can be brought under practice in undulating topography [5,6]. It is a low-cost irrigation technology operated through gravitational force and applicable for small land. Water can be tapped either from perennial springs or harvested at the mid hills using some lining material in a small reservoir [24].

Various micro-irrigation companies have started the production of gravity-based drip kits especially for small-scale fields. This system does not include use of pump for building pressure in water for easy flow, instead potential head due to high elevation of water is used for

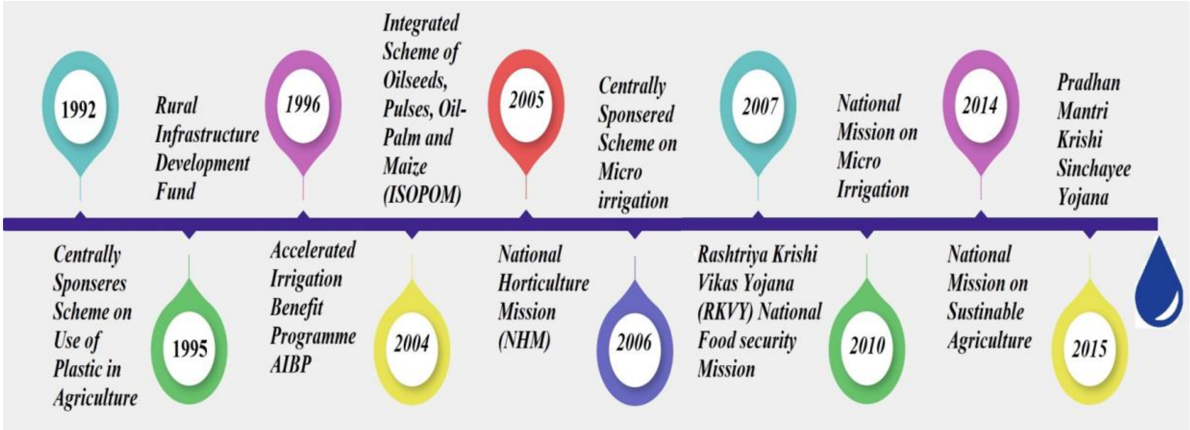

Fig. 1. Journey of micro irrigation and development

functioning of dripper in order to reach the crop water requirement. Usually, a water tank is placed at some elevated position, which results in creation of pressure for easy flow of water in the drip lines. Screen filter and valves are placed after the water tank. Sand filter or hydro-cyclone filter are not included in the system therefore, clean water is to be provided to the tank for avoiding clogging of the system. A farmer can be able to utilize this gravity-based drip irrigation system for irrigating land up to 2000 m^2 area according to type of crop planted. This method of irrigation system helps farmers to produce high value crops with little cost and energy as their input as compared to any other traditional methods. Most of the regularly accessible long path turbulent flow emitters need an operating water pressure head of 10 m or more for perfect discharge of water. Also pressure head is required to meet the friction losses in different components of the system, whereas the elevation difference between two adjacent terraces mostly ranges between 0.5 and 5.0 m. It was found that the mentioned pressure was not sufficient to operate the system by using turbulent flow emitters [25]. Take-apart button emitters and a pressure head of 4.0–6.5 m resulted in low emission uniformity (64–72%). Micro tubes 1.0 mm in diameter, on the other hand, increased emission uniformity to 94% to 98% for the same conditions. Other challenges include large differences in discharge from emitters due to system placement on multiple terraces with various elevations, sizes, and slopes as well as irregular shapes

Different features in the design of drip irrigation systems were considered in by [26,27,28] assessed the drip irrigation system for the relative effects of hydraulic design, manufacturer’s variation, grouping of emitters, and plugging. But, these designs are developed for plain fields or land and the high-water pressure is boosted up by using electric pumps or manual pump. Few alterations for designing standards are necessary to design drip irrigation systems especially on hilly terraces.

Kumar et al., 2009 shows the study done in NW Himalaya, India. This paper discusses on how hill and mountain agro-ecosystem is identified by very low irrigated land and difficult terrain. And terrace cultivation in this type of region lays out abundant scope for gravity-fed MIS. The MIS (drip tape) operated through gravity head achieved hydraulic parameters of 26.54%, 86.29% and 87.46%, respectively for emitter flow variation rate; CUC and Du. The system provided 41.4% and 33.3% saving in irrigation water, respectively, for garden pea and French bean. The saving was resulted due to an increase in water use efficiency by 70% and 35%, respectively, in case of garden pea and French bean under MIS. The savings were realised as a result of an increase in water use efficiency of 70% and 35%, respectively, in the case of garden pea and French bean under MIS.

The savings were realised as a result of an increase in water use efficiency of 70% and 35%, respectively, in the case of garden pea and French bean under MIS. Despite the fact that the study was conducted on terraced land in the NW Himalaya, this simple gravity-fed low pressure irrigation system could effectively address the most important issue of water management and increasing the area under irrigation in the world's hill and mountain agro-ecosystems [17].

Very few researchers have conducted the experimental study at field level on gravity fed drip irrigation and assessed its impact on different aspects namely system evaluation, water saving increase in crop yield cost effectiveness etc. and presented in Table 1.

5. CONCEPT AND METHODOLOGY OF GRAVITY DRIP IRRIGATION SYSTEM

The concept of more crops per drop can be brought to realization only through effective and proper management of irrigation water sector consuming lions share. Micro-irrigation systems are the most efficient methods, but the adherence of these technologies is under threat due to some reasons or other.

Gravity-fed drip irrigation system is the energy saving method in which the water is channelized and distributed through network of small diameter PVC pipes through gravity and directly applied in the root zone of crop, through emitting device at a low pressure. Gravity-fed drip irrigation system is one of the improvisations of these technologies where the pumping cost is nullified and can be brought under practice in undulating topography. It is a low-cost irrigation technology operated through gravitational force and applicable for small patches of land. Water can be tapped either from perennial springs or harvested at the mid hills using some lining material in a small reservoir.

Table 1. Work done on gravity fed drip irrigation its impact analysis at field level

Sl. No	Authors	Study Performed / System	Salient findings	Reference
1.	Bhatnagar and Srivastava 2003	Gravity-fed drip irrigation	• Field emission uniformity above 90%. • Total head loss was 0.17 m.	[25]
2.	Lazarovitch et al., 2006	Soil Hydraulics Properties on Gravity-fed drip irrigation.	• Discharge variability along the lateral depends on the dripper discharge rate, dripper spacing and pressure compensating drippers.	[9]
3.	Prakash & Kumar 2006	Gravity-fed irrigation for Vegetable pea and French bean.	• Flow rate variation was 26.5%. • Christiansen uniformity coefficient was 86.3%. • Distribution uniformity was 87.5%. • The system saved 41.1% and 33.3% irrigation water. • Benefit Cost Ratio was 1.78. • Internal Rate of Return was 12.2%. • Payback period was 3.8 years. • The system provided 41.4% and 33.3% saving in irrigation water. • Increase in water use efficiency by 70% and 35%.	[29]
4.	Rigve et al., 2018	Gravity-fed low head drip irrigation.	• At 3 m and 2.5 m heads, 6 lateral lines each of 30 m length, 8 laterals each of 25 m length and 10 laterals of 20 m and 15 m length provided fair uniformity EU>70%. • 4 number of laterals each of 20 m or 15 m had fair uniformity EU>90%.	[18]
5.	Ayare Thoka 2018	Gravity-fed in line drip irrigation for cashew plantation.	• Emission uniformity was found to be 85%. • Co-efficient variation of emitters was 0.071. • Logarithmic relationship of wetted depths with wetted radius was found to be 0.9672.	[30]
6.	Karlberg et al., 2007	Low- cost drip irrigation system for tomatoes with different salinity level of water.	• Average yield of 10 Mg ha^{-1} Low- cost drip irrigation system with plastic mulch was observed.	[31]
7.	Singh et al., 2007	Drip irrigation for spring sunflower.	• Final results were, 80% RDF with 80%. ETc drip irrigation. • Higher energy. • Water productivity. • Economically feasible.	[32]

Sl. No	Authors	Study Performed / System	Salient findings	Reference
8.	Gimeno et al., 2018	Drip irrigation for citrus orchard.	• Average of 23% of water savings was accomplished in treatments Sub- surface drip irrigation. • Better plant status was observed with treatments with a higher number of emitters each plant.	[33]
9.	Albaji et al., 2015	Comparative analysis of different irrigation Methods for Jaizan Plain of Iran.	Concluded that drip and sprinkler irrigation methods of irrigation were better suitable, effective and efficient as compared to surface irrigation technique.	[34]
10.	Biswasi et al., 2017	Gravity-fed drip irrigation for Pomegranate Orchard.	• Emission efficiency was >90 %. • Discharge variation along the lateral length was <20 %. • Better water management system. • Reduction in the cost was 18.8 % as compared to conventional drip irrigation system.	[35]
11.	Carstens et al., 2020	Hydraulic Capacity of a Gravity-Fed Irrigation System.	• Dissolved oxygen was found out as concentration above 7mg l−1 in the upper regions, and declining to 2mg l−1 in the deeper zones. • Manganese ranged from <5 µg l−1 near the surface to >8,000 µg l−1 near the water-sediment interface. • Reduction in hydraulic capacity in the system	[24]
12.	Ezekiel et al., 2017	Gravity-Fed Irrigation System for Maize Crop.	• Eight treatments replicated three times. • Variation of the emitter flow rate was 19.7%. • Emission uniformity was 92 %. • Distribution uniformity was 91.9 %. • Discharge coefficient of variation was 6.34% • Efficiency of the system was 92.2 %.	[12]
13.	Oiganji et al., 2017	Drip Irrigation System.	• Water saving up to 27.0%. • Improved the rice yield by 28.9%.	[36]
14.	Jamrey et al., 2018	Drip Irrigation System for Naturally Ventilated Poly-House	• Uniformity coefficient (CU) was 93.63%. • Distribution uniformity (DU) was 89.69%. • Distribution characteristic (DC) 54.06%. • Emission uniformity (EU) 89.99%.	[37]
15.	Raphael et al., 2018	Gravity- fed Drip Irrigation System for sloped	• With 5.34 % slope results were: • The values of Cv, Us, EU and Uc were quite high for the two	[5]

Sl. No	Authors	Study Performed / System	Salient findings	Reference
		greenhouse.	sections. • Proper flushing and site selection will affect the water application uniformity of gravity fed surface irrigation system.	
16.	Sarker et al., 2019	Low-Pressure gravity Drip-Irrigation System for Eggplant.	• System found better for a 2 m operating head with a 0% and 1% slope. • Uniformity of water application >80%.	[19]

5.1 Basic Components of a Gravity Drip Irrigation System

Conventional drip irrigation system consists essentially of a pumping system, main line, submain, lateral, and emitters, The ancillary components include a valve, pressure regulator, filters, pressure gauge, fertilizer application component, whereas major components of gravity drip irrigation system consists of water source and storage tank: Water is carried to the storage tank through gravity fed PVC pipes from spring stored in plastic or concrete tank; Water distribution system: It consists of main line/sub main and laterals; Control valve: mostly ball valve, air release valve, flush valve; Filtration unit: Screen filter, Mesh filter, Disc filter etc. type and quality of filter depends the quality of water, and water flow in the system; Water application devices known as emitter/dripper.

The pipe that conveys water from the water source to the sub-main is the mainline and the sub-main conveys water from the mainline to the laterals. Mainline and sub-main are normally made of PVC. All main line and sub-main should be provided with a manual valve. Lateral pipe, which actually conveys the water that would be distributed on-to the field and emitters are connected to it. It is made from black polyvinyl chloride tubes. Emitter is that part of the drip system that actually delivers water to plant root zone. Generally, it has smaller passages for discharging water and is prone to physical, chemical and biologically induced clogging as compared to bubble or micro sprinkler. Most point source emitters might be on-line or in-line and it can also be classified as long path, pressure compensating emitters. The line source emitters are porous pipe, which discharge water along its entire length. Mono-walled and bi-walled perforated polyethylene pipe are commonly used line source emitters. Filter: Its function is to purify water for irrigation from suspended impurities prevent blockage of the pipes and hole of the drip nozzles (emitter). End cap helps to prevent water from running out at the end of the drip tubes. Fig. 1 shows various components of a gravity- fed drip irrigation system designed for the terrace fields of hilly region and drip irrigation layout for the plain field is shown in Fig. 2.

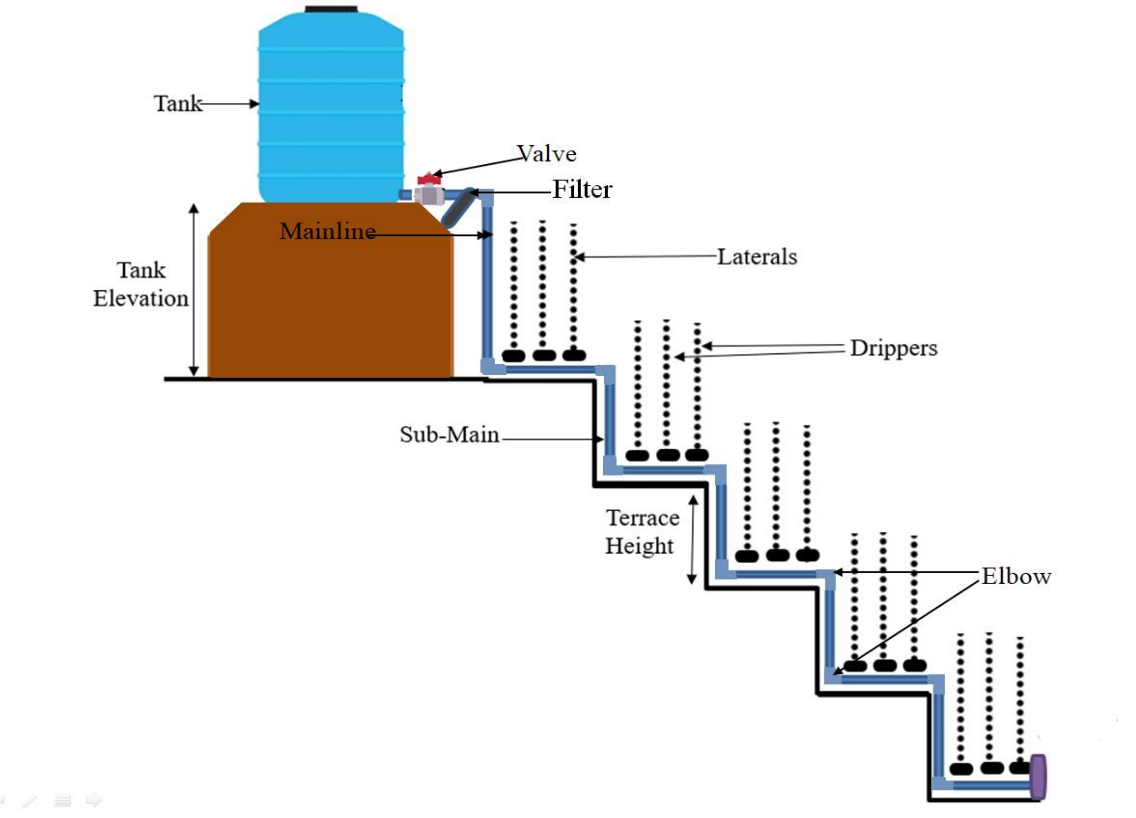

Fig. 1. Basic set-up design for Gravity- Fed drip irrigation system for the terrace field
(Source: Patle, 2020)

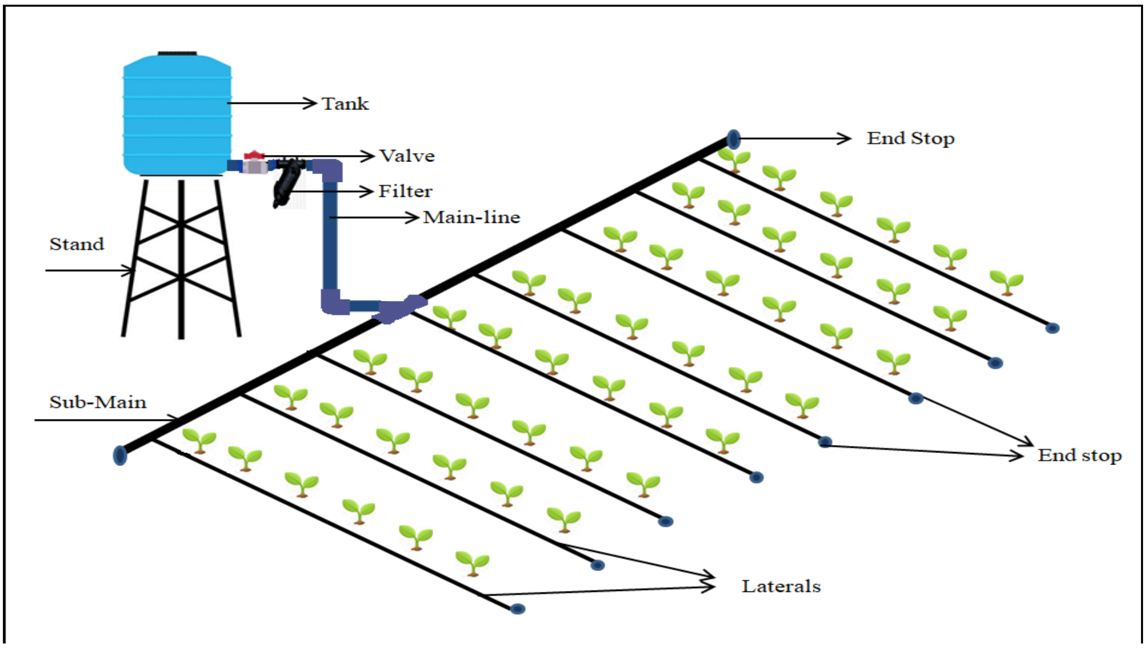

Fig. 2. Drip irrigation layout for the level field area

5.2 Basic Information Required for Design

1. Survey of land: Depending upon the topology of the land, for checking the sustainability of the system [39].
2. Type of crop: General layout of the system and especially lateral an emitter spacing will depend upon the type of crop to be grown in that area different crops have different plant spacing and irrigation requirement.
3. Soil type: The texture and structure of soil, infiltration rate, water holding capacity and bulk density of soil must be known before installation of system.
4. Land slope: General land slope must be known before designing the irrigation system to determine the location of lateral, main and sub-main. Example in case of hilly terrain the lateral should be laid along the contour and main and long the contour sub-main should be perpendicular to the contour.
5. Climatic records: From the climatic record it will be possible to know the crop water demand and it is also useful to know when and how much irrigation should be needed in various seasons of the year.
6. Source of water and water quality: The type of filter will depend upon the source and quality of water. With the well or tank as a water source, only screen or disc filter will be sufficient, otherwise when the area is large with river or streams as a water source, then combination of sand and screen or sand and disk filters is essential [40].

5.3 Estimation of Crop Water Requirement

As the first step in the proper design of irrigation system, it is required to know the crop water requirement. In general, the term crop water requirement is equal to the rate of evapotranspiration necessary to sustain optimum crop growth. Various factors should be measured like evaporation rate, transpiration rate, Crop evapotranspiration (ET_c) Evaporation, Reference evapotranspiration (ET_0) and Water requirement (W.R.). The design of drip irrigation system differs from crop to crop, soil to soil and climatic conditions. Steps involved in design of gravity drip irrigation system are almost similar to the conventional drip irrigation system [41]. In general following are the basic steps

1. Selection of crop
2. Crop water requirement
3. Topography details
4. Selection of dripper (emitter)
5. Calculation of irrigation time
6. Selection and design of lateral
7. Selection and design of sub-main

8. Selection and design of main line
9. Materials and cost Estimation

1. Selection of crop and crop coefficient: Suitable crop and crop coefficients need to be selected and water requirement of crop is estimated using equation given below.

Water requirement can be calculated by following formula:

$$Peakwater\ requirement = \frac{Crop\ areaxPE\ x\ Pc\ x\ Kc}{Eu}$$

Where,

Crop area = row to row spacing (m) x plant to plant spacing (m) of the crop,

PE= Maximum pan evaporation of the region, mm/day

P_c = Pan Coefficient, approximately taken as 0.7 to 0.8.

K_c = Crop Coefficient, the value of which for any crop depends upon foliage characteristics, stage of growth of crop, environment and geographical location.

Wetted area= It is the area which is shaded due to its canopy cover when sun is overhead, which depends upon stage of growth of plant. Generally, it is assumed that the area occupied by the roots is same as that occupied by the canopy. Percentage wetted area of crop varies in between 1/3 to 2/3 of the area of the plant. Table 2. shows wetted area of various crops in drip irrigation system [41] .

Table 2. Wetted area of various Crops considered in Drip irrigation [41]

Crop	Wetted area (%)
Pomegranate	20
Lime	20
Oranges	30
Grapes	50 to 60
Banana	50 to 60
Vegetables	60 to 70
Sugarcane	60 to 70
Chilly	75

2. Topography details need to be collected including land slope, length and width of the terrace/level fields etc.
3. The selection of dripper: Number of drippers per plant and selection of dripper depends on peak water requirement of the crop and the infiltration rate of the soil. The emitter must supply enough water to the plant root zone to meet the crop water requirement. However, if the percentage wetted area becomes too large, many of the advantages of drip irrigation are lost. The wetted soil volume depends on emitter flow rate, irrigation duration and emitter spacing and soil. Normally the emitters are located near the plant or the areas of high root concentration. Emitter can be on single lateral with equal spacing, double laterals, laterals with loops or other configurations [41].
4. Calculation of irrigation time:

   i. Irrigation time for tree crops(hrs)
   $$\frac{Water\ Requirement\ (liters/day/tree)}{Discharge\ rate\ of\ dripper\ per\ tree(liters/hour)}$$

   ii. Irrigation time for row crops(hours)
   $$\frac{Water\ Requirement\ (liters/day/unit\ area\ )}{Discharge\ rate\ of\ dripper\ per\ unit\ area(liters/hour)}$$

Where discharge rate per unit area is calculated as lateral line discharge rate divided by row spacing.

5. Selection and design of lateral: Lateral carries water from sub-main and feeds to the individual drippers. Generally, one lateral for each row or orchard plant and one lateral for two rows of sugar-cane or vegetables are used. The size and length of lateral is decided by the discharge of the drippers and number of dripper on one lateral. The laterals are small diameter flexible pipes or tubes made up of low-density polyethylene (LDPE) or linear low-density polyethylene (LLDPE) of 12 mm, 16 mm and 20 mm diameter. There colour is black to avoid the algae growth and the effect of ultraviolet radiation. They can withstand the maximum pressure of 2.5 to 4 kg/cm^2. They are connected to the sub-main by using grommet and take off as per row spacing of the crop. On slopping ground the laterals are placed along the contour with 1% extra length for sagging purpose [41].

Calculation of lateral flow rate: Flow rate of lateral is the function of emitter discharge and number of emitters along the lateral.

$Q_l = K.n_e.q_a$

Where, Q_l = Total flow rate in one lateral, l/sec
n_e= Number of emitters on one lateral

q_a= Average emitter discharge, l/h
K= Constant, 1/3600

Lateral length (L_l): It depends on the number of drippers along lateral's length and distance between them, that is,

$L_l= n_e.l$
L_l=Length of lateral
l= Spacing between two emitters
n_e= Number of emitters in on lateral.

Lateral head loss calculations: The diameter of lateral is usually selected such that the difference in the discharge between two extreme emitters operating simultaneously should not exceed 10%. Friction factor of pipe material is given in table 3.

The William-Hazen formula used for calculation of head loss is given as:

$$\Delta H_l = K(\frac{Q_l}{C})^{1.852} * D_l^{-4.871} * L * F$$

Where, ΔH_l= the head loss in pipe, m
K= Constant, $1.21x\ 10^{10}$
Q_l= Flow rate in lateral pipe; l/sec
C= the friction coefficient for continuous section of the pipe material.
D_l= the inside diameter of lateral, mm
L= the length of lateral, m
F= Outlet factor

Table 3. Friction Factor of pipe material

Material	Friction factor
Aluminium	130
Brass	135
Cast Iron	130
Concrete	120
Galvanised iron	120
PVC	150
Smooth pipes	140
Steel	145
Wrought iron	100

6. Selection and design of sub-main:Sub-main is generally made up of PVC (poly-vinyl-chloride) pipes of 32 mm, 40 mm, 50 mm, 63 mm and 75 mm in diameter

The design of sub-main is based on both capacity and uniformity. Capacity means the sub-main size should be large enough to deliver the required amount of water to irrigate the subsequent part of the field. Uniformity means the sub-main should be designed to maintain an allowable pressure variation, so that flow into all lateral lines taking from it will have little variation. Sub-main supplies water to individual lateral. Design of sub-main is similar to that of lateral, however it differs in that the spacing between outlets is greater and larger flow rates are involved. The size and length of sub-main is determined by number of laterals and distance between the laterals. Usually in a plain field, the position of the sub-main should be located at the center of the plot. On sloping field, the lateral lines should be laid along the contour and the sub-main along the slope, as far as possible [41].

7. Selection and design of mainline:

Generally, the size of main line is one size higher than submain. The size of main line is decided by flow rate of all the submains. The sizes of main line are 40 mm, 50 mm, 63 mm, 75 mm, 90 mm and 110 mm etc.

The William-Hazen formula used for calculation of frictional head loss is given as:

$$\Delta H_m= K(\frac{Q_m}{C})^{1.852} * D_m{}^{-4.871} * L_m * F$$

Where, ΔH_m= the frictional head loss in pipe, m
K= Constant, $1.21x\ 10^{10}$
Q_m= Flow rate in pipe; l/sec
C= the friction coefficient for continuous section of the pipe material.
D_m= the inside diameter of Sub-main, mm
L_m= the length of Sub-main, m
F= Outlet factor

6. IMPORTANCE OF GRAVITY FED DRIP IRRIGATION SYSTEM FOR IMPROVED LIVELIHOOD OF HILL FARMERS

The Himalayan region of India has 14% of land area holds up 6% of total population of India. In spite of low population, the people of hilly regions struggle in meeting the demand of crops. The average farmer’s family produces only 5–8 months of food from their cultivated terraces fields [29]. Negi et al. (2006) listed ecological and economical aspects responsible for non-sustainable agriculture system [38]. Which includes rain-fed cultivation, small and much fractured holdings scattered above very rough terrain, insufficient crop yield and limited scope to adopt intensive agriculture. Shortages of land and low productivity are the causes for cultivation of steep and unstable hill slopes.

The method of gravity- fed micro-irrigation system (MIS) has an advantage of greater water efficiency and cut back on problems related to traditional irrigation methods for the hilly regions [39]. Agro- ecosystem of hilly regions hardly has land for irrigation because of difficult and rough terrains. One of the advantages of having terrace cultivation is that these lands have great opportunity for gravity-fed micro irrigation system [25]. It not only reduces the fuel/electricity energy but also escalates profit.

Water is becoming scarce commodity in several parts of India and worldwide [42]. Global warming and climate change also affecting the spatio-temporal variation of rainfall in several parts of India including the north eastern hill regions [43]. With increase in water crisis, efficient use of water is necessary. Topographical constraints are posing the constraints for the creation of large water storage structures. Under such circumstances gravity fed drip irrigation can be adopted as the climate water smart water saving technology for the hill agriculture [44]. Available hill slope can create the sufficient pressure for the water flow in piped and operating the emitters. The gravity-fed drip irrigation system is a low-cost irrigation system, mostly suitable for hilly topography, where an irrigation system can be operated without any external power requirement [45]. It is suitably for small areas such irrigation system is suitable for small land holding. Farmers can easily operate and maintained the gravity drip irrigation system and grow variety of crops with a small quantity of water.

7. CONCLUSION

From the brief review illustrated above, it can be concluded that Gravity- fed drip Irrigation system has a major role in water and nutrient conservation. Elaborative discussion on the effect of gravity- fed drip irrigation on economic factors, productivity, water saving and irrigation scheduling conclude the bright future of gravity-fed drip irrigation system technology in agricultural sector. The future of Gravity- fed drip irrigation is because of the sustainable approach with maximum environmental conservation. Current review shows huge scope of research and improvement in the field of gravity fed drip irrigation. It is very helpful to nature and society especially for the small land holders in hilly states of the country. The overall effort in the current review analysis was aimed to develop an optimum methodology and technology to enhance the use of gravity-fed drip irrigation in large scale cultivation and production. This minimizes the fuel-based energy or electricity requirement in operation of gravity fed drip irrigation system which further increases profitability.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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