Implication of Feasible Techniques for Irrigation in Hill Agriculture

Chapter · February 2016

4 authors:

Pulakabha Chowdhury
Assam Agricultural University

Lokesh Kumar Meena
Government College Bundi 27

Sanjay Kumar Ray
Indian Council of Agricultural Research

Bidyut Deka

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P. Chowdhury, K. L. Meena, Sanjay Kumar Ray and Bidyut C. Deka

1. Introduction: The aim of modern irrigation development must be to make the best use of water in conjunction with land and human resources along with other essential inputs (energy, machinery, fertilizers and pest control measures) to sustain and enhance crop production. The selection of an appropriate irrigation technology for any given combination of physical and socioeconomic condition involves complex and sometimes conflicting considerations. Where water shortage is acute, the obvious over-riding need is to raise the efficiency of water utilization. Some places, capital are short; the major requirement might be for an irrigation method with minimal dependence on capital investment or expensive equipment. In other cases, the deciding factor may be energy requirements, skill labour availability or maintenance costs and feasibility.

Since the economic considerations, along with the physical conditions and cropping patterns, are necessarily specific to each location, an irrigation system that may seem more appropriate in one country or region may not be so in another. In particular, it is a mistake to assume a prior that a modern system proved to work in an industrialized commercial economy will necessarily succeed in the context of an emerging economy. Sustainable irrigation management should be considered to achieve two objectives; sustainable irrigation to ensure food security and on the same time preserving the environment. A delicate balance exists between these two factors. Potential conflicts between the two objectives should be mitigated through appropriate irrigation practices. During the past 30 years area under irrigation has expanded considerably to feed a constantly increasing population. Water requirement of irrigation sector is highest, 70% of human water use is diverted towards agriculture.

The north eastern hilly region has large surface than groundwater resources, mainly because of its location in high rainfall area and the extensive river system. But all the water resources cannot be utilized because these are inaccessible or non-reversible. The availability of these resources has not been adequately documented and as such complete information is not available. The total surface water potential of the region is 9, 28,873 mm^3. The region, excluding Sikkim, has a total groundwater potential of 855 mm^3. As usual, all the hilly regions have low groundwater potential, the lowest being in Sikkim. The exploitable water balance is mostly concentrated in Tripura. Water application on the slopes for irrigating plantation crops poses serious problem of soil erosion.

2. Implication of Choosing an Irrigation Method: To choose an irrigation method, the farmer must know the advantages and disadvantages of the various methods. Farmers must know which method suits the local conditions better. Unfortunately, in many cases there is no single best solution: all methods have their advantages and disadvantages. Testing of the various methods - under the prevailing local conditions - provides the best basis for a sound choice of irrigation method. This chapter gives some very broad guidance and indicates several important criteria in the selection of a suitable irrigation method.

2.1. Implications for Surface, Sprinkler or Drip Irrigation: The suitability of the various irrigation methods, i.e. surface, sprinkler or drip irrigation, depends mainly on the factors like **natural** conditions, type of crop, type of technology, previous experience with irrigation, required labour inputs and costs and benefit ratio.

2.1.1. Natural Conditions: The natural conditions such as soil type, slope, climate, water quality and availability, have the following impact on the choice of an irrigation method:

Soil type: Sandy soils have a low water storage capacity and a high infiltration rate. Therefore need frequent but small irrigation applications, in particular when the sandy soil is also shallow in depth. Under these circumstances, sprinkler or drip irrigation is more suitable than the surface irrigation. On loam or clay soils all three irrigation methods can be used, but surface irrigation is more commonly found. Clay soils with low infiltration rates are ideally suited to surface irrigation. When a variety of different soil types are found within one irrigation scheme, sprinkler or drip irrigation is recommended as they will ensure a more even water distribution.
Slope: Sprinkler or drip irrigation is preferred above surface irrigation on steeper or unevenly sloping lands as they require little or no land leveling. An exception is rice grown on terraces on sloping lands.
Climate: Strong wind can disturb the spraying of water from sprinklers. Under very windy conditions, drip or surface irrigation methods are preferred. In areas of supplementary irrigation, sprinkler or drip irrigation may be more suitable than surface irrigation because of their flexibility and adaptability to varying irrigation demands on the farm.
Water availability: Water application efficiency is generally higher with sprinkler and drip irrigation than surface irrigation and so these methods are preferred when water is in short supply. However, it must be remembered that efficiency is just as much a function of the irrigator as the method used.
Water quality: Surface irrigation is preferred if the irrigation water contains much sediment. The sediments may clog the drip or sprinkler irrigation systems. If the irrigation water contains dissolved salts, drip irrigation is particularly suitable, as less water is applied to the soil than with surface methods. Sprinkler systems are more efficient that surface irrigation methods in leaching out salts.
2.1.2. Type of Crop: Surface irrigation can be used for all types of crops. Sprinkler and drip irrigation, because of their high capital investment per hectare, are mostly used for high value cash crops, such as vegetables, tea and fruit trees. They are seldom used for the lower value staple crops. Drip irrigation is suited to irrigating individual plants or trees or row crops such as vegetables and sugarcane. It is not suitable for close growing crops (e.g. rice).
2.1.3. Type of Technology: The type of technology affects the choice of irrigation method. In general, drip and sprinkler irrigation are technically more complicated methods. The purchase of equipment requires high capital investment per hectare. To maintain the equipment a high level of 'know-how' has to be available,. Also, a regular supply of fuel and spare parts must be maintained. Surface irrigation systems, particular small-scale schemes, usually require less sophisticated equipment for both construction and maintenance (unless pumps are used). The equipment needed is often easier to maintain and less dependent on the availability of foreign currency.
2.1.4. Previous Experience with Irrigation: The choice of an irrigation method also depends on the irrigation tradition within the region or country. Introducing a previously unknown method may lead to unexpected complications. It is not certain that the farmers will accept the new method. The servicing of the equipment may be problematic and the costs may be high compared to the benefits. Often it will be easier to improve the traditional irrigation method than to introduce a totally new method.
2.1.5. Required Labour Inputs: Surface irrigation often requires a much higher labour input, for the construction, operation and maintenance, than the sprinkler or drip irrigation. Surface irrigation requires accurate land leveling, regular maintenance and a high level of farmers' organization to operate the system. Sprinkler and drip irrigation require little land leveling; system operation and maintenance are less labour-intensive.
2.1.6. Costs and Benefits: Before choosing an irrigation method, an estimate must be made of the costs and benefits of the available options. On the cost side not only the construction and

installation, but also the operation and maintenance (per hectare) should be taken into account. These costs should then be compared with the expected benefits (yields). It is obvious that farmers will only be interested in implementing a certain method if they consider this economically attractive.

2.2. Implications for Basin, Furrow or Border Irrigation: This section discusses some of the important factors which should be taken into account when determining which surface irrigation method is most suitable: basin, furrow or border irrigation. Again, it is not possible to give specific guidelines leading to a single best solution; each system has its advantages and disadvantages. Factors to be taken into account which includes; natural circumstances, type of crop, the required depth of irrigation application, level of technology, previous experience with irrigation and required labour inputs.

2.2.1. Natural Circumstances: Flat lands, with a slope of 0.1% or less, are best suited for basin irrigation; little land leveling is required. If the slope is more than 1%, terraces can be constructed. Furrow irrigation can be used on flat land (short, near horizontal furrows), and on mildly sloping land with a slope of maximum 0.5%. On steeper sloping land, contour furrows can be used up to a maximum land slope of 3%. A minimum slope of 0.05% is recommended to assist drainage. Border irrigation can be used on sloping land up to 2% on sandy soil and 5% of clay soil. A minimum slope of 0.05% is recommended to ensure adequate drainage. Surface irrigation may be difficult to use on irregular slopes as considerable land levelling may be required to achieve the required land gradients.

All soil types, except coarse sand with an infiltration rate of less than 30 mm/hour, can be used for surface irrigation. If the infiltration rate is higher than 30 mm/hour, sprinkler or drip irrigation should be adopted.

2.1.2. Type of Crop: Paddy rice is always grown in basins. Similarly, the crops can stand a very wet soil for more than 12-24 hours should be grown in basins. Furrow irrigation is best used for irrigating row crops such as maize, vegetables and trees. Border irrigation is particularly suitable for close growing crops, but border irrigation can also be used for row crops and trees.

2.1.3. Required Depth of Irrigation: When the irrigation schedule has been determined it is known how much water (in mm) has to be given per irrigation It must be checked that this amount can indeed be given, with the irrigation method under consideration. Field experience has shown that more water can be applied 40-70mm per irrigation when using basin irrigation, comparatively less (30-60mm) with border irrigation and least (20-50mm) with furrow irrigation. This means that if only a little water is to be applied per application, e.g. on sandy soils and a shallow rooting crop, furrow irrigation would be most appropriate. However, none of the surface irrigation methods can be used if the sand is very coarse, i.e. if the infiltration rate is more than 30 mm/hour.

2.1.4. Level of Technology: Basin irrigation is the simplest of the surface irrigation methods. Especially if the basins are small and their operation and maintenance is simple. Furrow irrigation is having with the possible exception of short, level furrows requires accurate field grading. Borders require the highest level of sophistication. They are constructed and maintained by machines. The grading needs to be accurate. Machine operation also requires a high level of skill.

Table 1 Selection of Irrigation Methods Type of Soil and Rooting Depth of Crops

Soil type	Rooting depth	Irrigation depth (mm)	Irrigation methods
Sandy	Shallow	20-30	short furrows
	Medium	30-40	medium furrows, short borders
	Deep	40-50	long furrows, medium borders, small basins
Loamy/Medium	Shallow	30-40	medium furrows, short borders
	Medium	40-50	long furrows, medium borders, small basins
	Deep	50-60	long borders, medium basins

Clay/Heavy	Shallow	40-50	long furrows, medium borders, small basins
	Medium	50-60	long borders, medium basins
	Deep	60-70	large basins

2.2.5. Previous Experience with Irrigation: If there is no tradition in irrigation, the most simple irrigation method to introduce is basin irrigation. If irrigation is used traditionally, it is usually simpler to improve the traditional irrigation method.

2.6. Required Labour Inputs: The required labour inputs for construction and maintenance depend heavily on the extent of machinery is operated. Basin irrigation requires the least labour and the least skill. Furrow and border irrigation methods required number more labour is required combined with more skill

3. Guidelines for Installation of Drip Irrigation System on Hill Slopes:

3.1. Sample Design of a Drip System on a Slope:

Slopes create some unique problems for drip irrigation systems. These problems can be solved by designing in a following ways as shown in figure 1.

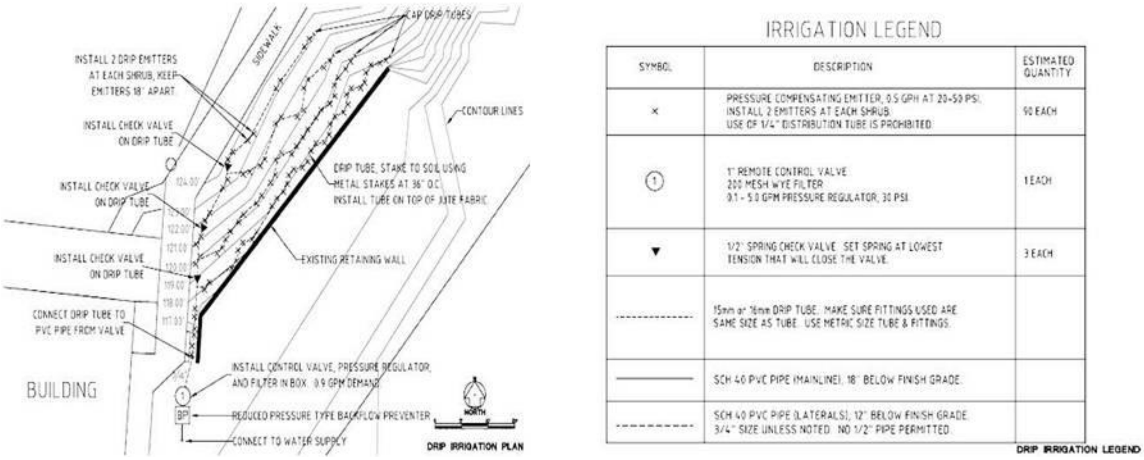

Fig. 1 Sample design of a drip system on a hilly slope.

3.2. Type of Emitters to Use: When installing drip irrigation on a slope or hillside, it is best to use pressure compensating emitters. Pressure compensating emitters apply a more uniform rate of water on slopes when compared to a standard emitter. This is because as the water is pushed in a tube or pipe up a slope the water pressure in the pipe or tube decreases. When water flows in a tube or pipe down a slope the water pressure in the tube increases. As the water pressure changes, it results in a change in the rate of water flow from the emitter. Using pressure compensating emitters solves this problem. Using a diaphragm type pressure compensating emitter is also a good option (Fig. 2).

Fig. 2. Different types of emmiters used in drip irrigation system (Source: IDE)

3.3. Drip Tube Orientation: One trick for installing drip systems on slopes is to try as much as possible to keep the drip tubes running horizontal to the slope direction. In other words, try to keep the drip tubes as level as possible. A typical design would have either a pipe or drip tube running from the control valve vertically up or down the hillside (Fig. 3). Check valves would be installed at periodic intervals on this pipe or tube. From this vertical pipe or tube, the drip tubes would branch off and run horizontally across the slope to the plants.
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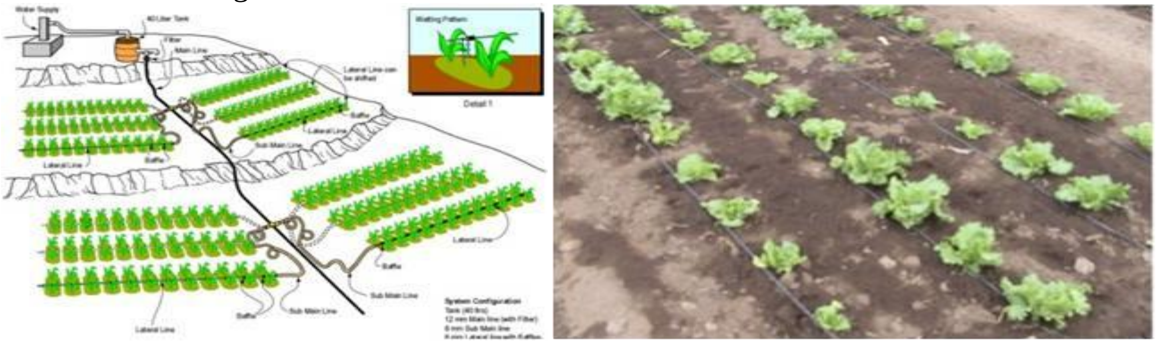

Fig. 3. Low Cost Drip Irrigation System for a Hilly Area. (Source: IDE)

3.4. Low Emitter Drainage: When a drip system is installed on a slope a problem called "low emitter drainage" occurs. Each time that the drip system is turned off the water in the tubes drains out through the lowest emitters. This causes a small puddle to form around the low emitters, and the area around these low emitters becomes saturated and over watered. Sometimes this low emitter drainage is not a problem; it just depends on where the drainage is occurring. However, most of the time the water is going to create a problem, such as a mud pit, mosquito farm, or worse. In the case of our sample design low emitter drainage would cause water to drain out of the emitters just behind the retaining wall. This would be a very bad situation, as the water could build up in the soil behind the wall and the weight of the water could push over the wall. As a general rule, if the difference between the highest and lowest elevation is 0,5 meters (1.5 feet) or less, low emitter drainage is typically not a big enough problem to worry about.

4. Traditionally Useful and Efficient Irrigation Systems for Slopy/Hill Agriculture:

4.1. *Zabo* System of Irrigation: It is a famous irrigation practice in Nagaland. The northeast region of India lies in the eastern Himalayas. Terrace farming is the important practice in the region. A forest is protected in the form of sacred grove on the hilltop. The tribal's maintain the watershed in this forest by maintenance of forests. After the rainfall, the water falls in the terraces successively and irrigates the land. A storage structure in the form of a pond is maintained in the middle terraces. The water finally flows down to paddy fields at the foothills. To get the widest coverage of irrigated land, water is also distributed in the terraces with bamboo pipes.

4.2. Bamboo Drip Irrigation in Meghalaya: This system (Fig. 4) is used by, tribes of Khasi and Jayantia, to irrigate their black pepper plantations. The water is tapped from streams and springs by using bamboo pipes. The inflow rate in the pipe at 18 to 20 m at the entrance and the outflow rate are 20-80 drops per minute. The water flows in the bamboo pipe from the hilltop to the fields at the foothills due to gravity. The intake pipe size is manipulated at various stages to control the flow of water. To fabricate the system, the internodes of the bamboo pipes are removed. The bamboo channel is smoothened by using 'Dao': a smooth axe.

Fig. 4. Bamboo drip irrigation system

4.3. Deep Pipe Irrigation System: Deep pipe irrigation system (Fig. 5) is not very common but effective means to irrigate the land. Deep pipe irrigation mainly fosters the growth of the root zone. A pipe having the diameter of 2.5 cm to 5 cm is placed vertically30-50 cm deep in the soil near tree seedling. The opening of the pipe is covered with a mesh or net to prevent the entry of animals or rodents into the pipe. A series of 1-2 mm holes, 5-7.5 mm apart, are made to supply water to the root at different levels. These holes are called as weep holes. The meshed inlet is filled using jug, hose or drip emitter (IDE).

Fig. 5. Deep pipe irrigation system

4.4. *Kuhl* System of Irrigation: Diversion channels leading directly to agricultural fields e.g. Guhls and kuhls of western Himalayas. *Kuhl* is a traditional irrigation system of Mumta Village, Gujrat India. A group of water users have association. The head of the association or the water tender is known as Kohli. His role is rebuilding the dam each spring and monitors the distribution of water among the users. A temporary headwall is created near the gorge to divert the water in the canals to the fields. The average distance of the canal to the first field is 3 Km. As the area has slope, water flows from one stream to another and finally falls into the gorge downstream. Controlling the width of outlet between two successive fields controls the flow of water. All the users assist in construction of headwall and there is a penalty for the offenders. The user if absent, is denied access to the water. During water scarcity, occasionally, the channels first lead into a storage structure so that water can be used in the subsequent dry period, too (e.g. Zings of Ladakh).

5. Conclusion: Surface irrigation is by far the most widespread irrigation method. It is normally used when conditions are favourable: mild and regular slopes, soil type with medium to low infiltration rate, and a sufficient supply of surface or groundwater. In the case of steep or irregular slopes, soils with a very high infiltration rate or scarcity of water, sprinkler and drip irrigation may be more appropriate. While introducing sprinkler and drip irrigation it must be ensured that the equipment can be maintained and targeted crops for irrigation should able to give optimum returns. Some of the traditional irrigation system is still suitable for the slope/ hill agriculture. The lost practices can be revived by encouraging tribes to conserve their remnant cultural practices. Any new method of irrigation has to be assessed thoroughly before on ground application, though the integration of modern and traditional irrigation system can bring about an absolute ideal irrigation management system for Hill Agriculture.

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