Chapter Three
Technologies for Water Conservation and Development

In HKH mountain agriculture, proper water harvesting, good management, and appropriate development are of great importance. Proper water harvesting not only increases crop production in areas with insufficient precipitation, but also controls soil erosion and recharges aquifers tapped for irrigation. Water harvesting is considered a resource-improving technique when used in combination with other modern technologies (Reijntjes et al. 1992). Changes in land use, particularly change of vegetal cover, affect turn-off and infiltration rates. Excessive overflow of water may cause severe soil erosion. Thus, water flowing through mountain terrain, particularly needs to be managed well in order to to avoid harming the resource base. Inappropriate development is like over-pumping groundwater, as is the case in many low rainfall regions where the practice is endangering sustainable agricultural production. In fact, a balance is required between the recharging groundwater reserves and the outflow by pumping or other means. The effective recharging of groundwater reserves requires parallel development and improvement in watershed areas through re-vegetation schemes and water conservation activities (Reijntjes et al. 1992).

Water conservation in the HKH belt has not yet received sufficient attention. Global climatic changes could redistribute or reduce water supplies and intensify storms, this may add to the challenge of managing a sustainable water supply (Ahmed 1996). Ahmed (1996) concluded that actual per capita water availability in the HKH region would be much less due to steep slopes and rugged terrain, and his predictions about per capita water availability indicated a declining trend (see Table 16).

Table 16: Population, Annual Renewable Fresh Water Availability and Per Capita Availability in the HKH Region

Country	Annual renewable fresh water available billion m³	Population (millions)			Per capita availability (m³)		
		1960	1990	2025	1960	1990	2025
Afghanistan	50.0	10.8	16.6	45.8	4,630	3,012	1,092
Bangladesh	2,357.0	51.4	113.7	223.3	45,856	20,730	10,555
Bhutan	95.0	0.9	1.5	3.4	105,556	63,333	27,941
China	2,799.5	657.5	1,153.5	1,539.8	4,258	2,427	1,818
India	2,085.0	442.3	846.2	1,393.9	4,714	2,464	1,496
Iran	118.0	21.6	58.3	144.6	5,463	2,024	816
Myanmar	1,082.0	21.7	41.8	75.6	49,862	25,885	14,312
Nepal	170.0	9.4	19.6	40.1	18,085	8,673	4,239
Pakistan	168.0	50.0	118.1	259.6	9,360	3,963	1,803

Source: Ahmed 1996

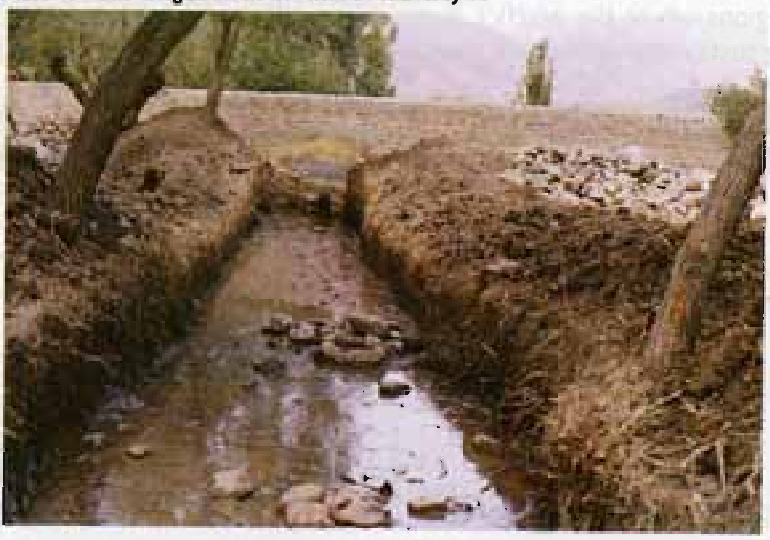
Although the water development process in the HKH region is not rapid, water conservation and development is a high priority for local people, mainly in the context of agricultural development. The governments concerned are now realising this fact and are focussing on water resource rehabilitation and management using modern knowledge. This chapter will describe several promising water-related technologies as documented in various agro-ecological zones of the HKH region. Most of these technologies are being used for managing water and irrigation for crop and orchard production. Since irrigation reduces the risk of biological failure due to drought, local farmers have traditionally designed small-scale irrigation systems. The area under irrigation is increasing day by day, as the public sector promotes various modern irrigation technologies as described in this chapter.

Kuhl Irrigation

Significance

The origin of this technology lies in the cold deserts west of the Indian Himalayas where underground saline water cannot be used for irrigated cultivation. This technology is also commonly used in the highlands of Balochistan (Pakistan), although with some minor modifications. A *kuhl* is in fact a small water channel that is built along the hill gradient for maintaining the proper gravity flow of water. The majority of the hamlets lie on the plateaux either side of the main river, and cultivated fields are found either on naturally levelled plateaux on the banks of the rivers/torrents, or on hillside terraces. The physiographic features of the terrain restrict irrigation from rivers as they flow between steep banks. In temperate areas of cold deserts, crop cultivation without irrigation is not possible because precipitation occurs mostly in the form of snow. People have taken advantage of the glacial water to perform a collective operation for effective distribution, ensuring the supply of this scarce resource. A specialised water management technology has thus been developed which is adapted to a particular topography.

Plate 1: Kuhl Irrigation in the Indian Himalayas



Components

Kuhl(s) (i.e., irrigation channels) are diverted from river tributaries/perennial torrents to a natural gradient so that the level of water is higher than that of cultivated fields. In some cases, spring water is collected in small reservoirs scattered at intervals on high uplands and is drawn down to fields whenever required through *kuhl*(s). A *kuhl* is diverted from any nearest tributary and is constructed to flow towards fields on safe sides of the terrain to avoid any danger of its being damaged by avalanches or falling rocks. Usually a spade is used for making these channels. The whole community plays an important role in the construction of the main irrigation channels as well as in the equitable distribution of water. Channels are dug in the ground to regulate the flow of water. Wherever digging is difficult or has to pass through a village track route, underground channels covered with slates are constructed. Sometimes, in this situation, wooden channels are also constructed. The wooden channels are prepared by making a deep groove in a tree trunk. Main channels are long and considerable labour is required for their annual maintenance and repair. Usually the community works together for this purpose.

Minor channels linked to the main channel irrigate all fields. Fields are generally divided into small compartments by using earthen bunds (embankments) to allow water to stand in the field for a longer time for maximum water retention. Hence the need for a second irrigation arises only after three weeks, otherwise a crop may require another irrigation within two weeks. The process of irrigating a field is begun by flooding the nearest compartment, followed by the next, and so on. For the second irrigation episode, these compartments are irrigated in reverse order, with the last compartment being flooded first, followed by the second to last, and so on. This management of water in a particular field by apportioning it to various compartments regulates proper water flow across the whole field. The reverse order of irrigating a field is used simply because irrigation is closed in that last compartment and a minor channel existed there to serve it.

Participatory management is employed for the distribution of water. The whole community is divided on the basis of the total number of farming families. Each family is assigned one full day to irrigate its fields turn-wise. For example, in the case of a total number of 20 farm families in a village, the turn of each one would come after every 20 days. However, two adjoining families may share water from each other's turn for half a day on a mutual basis, and as an internal arrangement. This arrangement allows both families to irrigate their fields after a gap of 10 days rather than 20 days. The turn of a family begins at 20:00 or 22:00h on a particular day. That day, almost all the family members are engaged in managing and distributing water in the fields.

Farmers ensure optimum irrigation to the desired soil depth by inserting a spade into the soil. If its blade is completely inserted into the soil, the field is considered properly irrigated. In a few locations, the irrigated soil is thrown upside down. If it splits into pieces, it is taken as a sign of a well-irrigated field.

Farmers have developed irrigation schedules matching the phenological stages of the cultivated crop (i.e., germination, vegetative, bloom, seed set, and harvest).

Spang Grass for Controlling Seepage Losses

Significance

Since water is transported through earthen channels, it results in huge conveyance and application losses due to seepage. The irrigation efficiency is between 50 to 60 per cent. This seepage loss is not retrievable as the water level is too deep (Ahmed 1996). Similar losses occur in the case of water stored in dug-out ponds.

Components

Spang grass is called *Pang* in Ladakh, where it grows profusely. Local people use this grass as an inner lining for water courses and ponds in order to prevent percolation losses. Spang grass has special non-permeable properties similar to that of a polythene sheet or cement lining. Farmers claim that its use in water retention gives far superior results than both polythene and cement. Its mysterious chemistry requires detailed analysis.

Karez Irrigation

Significance

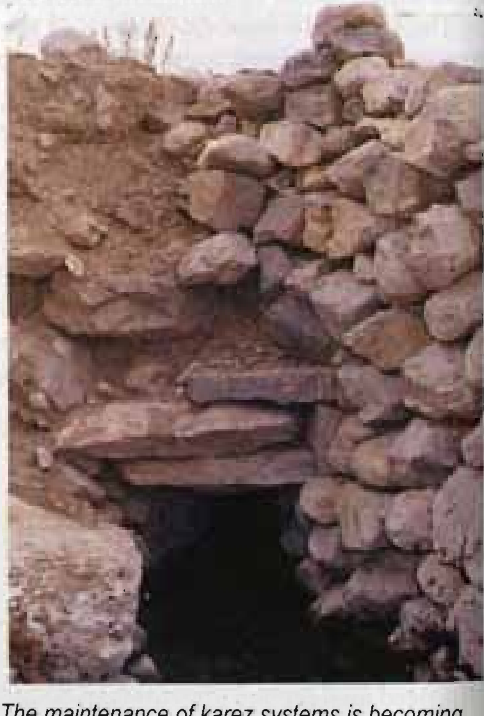
A *karez* is an underground, channelled irrigation system, an ancient technology that has played a historical role in the agricultural development of Balochistan, Pakistan. The history of the *karez* goes back thousands of years to when construction of *karez* systems was a hazardous and extremely specialised job. Amazingly, *karez* systems still exist in Balochistan. For centuries, these have been a perennial source of water for agricultural practices. Being a communal effort, water distribution rights and schedules are well settled as in the canal command areas of the Sindh and Punjab provinces of the country.

With the influx of modern technology such as tubewells, the role of the *karez* system is now gradually diminishing. However, this is still an important source of irrigation in the uplands of Balochistan.

Components

A *karez* is an underground water channel system. Lined mother wells are dug in the foothills at certain distances apart to intercept the water table high up in an alluvial fan, then water is lead to the valley floor under gravity. These mother wells are

Plate 2: Karez Irrigation System in Balochistan, Pakistan



The maintenance of karez systems is becoming very expensive. This ancient technology is being ignored because of the low rechargable capacity of underground water and the high influx of tubewells in the region. An awareness campaign may save this historical technology from becoming extinct.

connected underground through tunnels. A series of mother wells take water to cultivable lands. Sometimes, a *karez* may take perennial water flow as far as 40km.

Water is rotated from distributor to distributor and within sections of a distributor. In recent developments, concrete versions of flow dividers can be seen.

Sailaba Farming

Significance

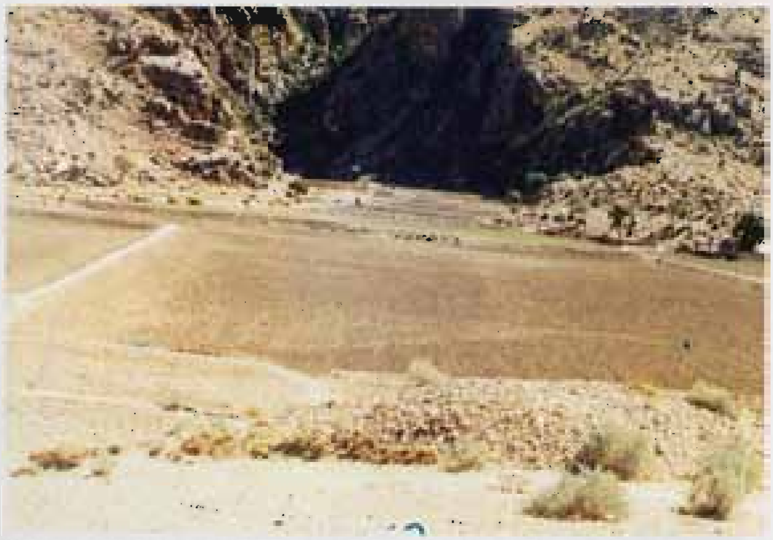
Sailaba indicates moisture conservation through flooding fields during the rainy season. *Sailaba* farming is extensive in most parts of Balochistan, Pakistan, particularly in the highlands. During the rainy season, flood water is harvested in catchments for crop production. This technology is extremely important in the kind of region where aridity prevails and mountain terrain accelerates water runoff. Most runoff is harvested for cultivation.

Components

Sailaba farming involves diversion of runoff or flood water to terraced catchments for moisture conservation. These catchments are later cultivated, generally with a mixture of crops. Farmers construct relatively level terraces, where land slope may vary between one and five per cent. The terraces usually cover a large part of the valley and are flanked by hills on either side. Each terrace will have an embankment at the sloping end to harvest water. The height of the embankment varies from one to 2.5m, and the width at the top is one metre across; the lower slopes have a gradient between 2 and 2.5:1, unless the slopes are stone pitched, in which case they are vertical. Tractors and bullocks are used to make these embankments.

Flood-water channels run along a tier of terraces and bring runoff from the surrounding hills; individual terraced fields are

Plate 3: **Sailaba Field in Balochistan**



Sailaba water harvesting is a practical method of controlling soil erosion and the movement of sediment, in addition to aiding crop cultivation. The same technology may be used effectively for conserving water on ranges and for increasing forage production by improving species' cover.

flooded sequentially. Two different systems are used to control the water movement from terrace to terrace. In the first, a stone-pitched spillway, about 2m long and 0.3 to 0.5m deep, is built at the lower left or right hand corner of the field. In the second system, flood water flows into the field from the top corner adjacent to the water supply channel. The down-stream embankment is slightly elevated for this purpose.

Pond Water

Significance

The scarcity of irrigation water is a critical constraint to improved farm productivity. A standard sized water pond is an integral component of a farm's infrastructure throughout Balochistan – for the following reasons.

- Underground water is very deep and low discharge by tubewells (wherever applicable) causes very slow and inefficient water conveyance. It may take hours to irrigate one hectare of land. The pond is used for quicker irrigation and to avoid conveyance losses.
- Irregular power supply may shut down the tubewell for many days or at any time and causes problems during peak hours. Farmers keep their ponds filled round the clock, using them as and when the need arises.
- Farmers may sell this water to neighbours for irrigation and other purposes, charging the buyer on an hourly discharge basis.
- Farmers plant timber and forage trees all around the pond to meet their domestic needs.
- It improves the underground water table.

*Plate 4: **The Water Pond is an Integral Part of the Agricultural Farm***

These water ponds are potential sites to be used for fresh water fish production and offer great scope for high returns from meagre inputs.

Components

An earthen pond measuring roughly 25m x 30m is dug at any suitable elevated site in the farm area. It is normally constructed close to the tubewell. The pond is about 1m to 1.5m deep, although the depth may vary. Tubewell water is first collected in this pond to regularise the irrigation.

Persian Wheel

Significance

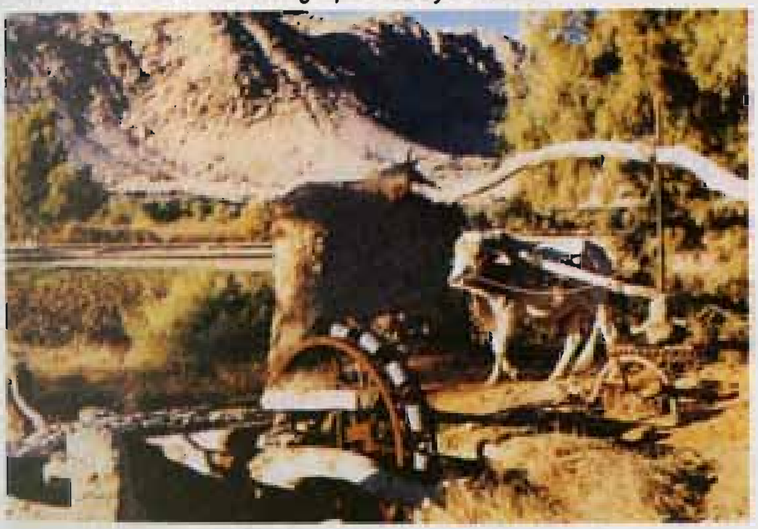
Underground water is quite deep down in most parts of the highlands. Deep wells are historically used for obtaining underground water for all purposes. The Persian wheel is a very old technology used for pulling water out of wells, mainly for irrigation. This method is in popular use in the uplands of Balochistan and in the Rod Kohi area where modern equipment, such as tubewells, is not feasible due to institutional or socioeconomic constraints.

Components

The Persian wheel is driven by a cow, bullock, or camel. The animal drives it through a wooden rod 4.5 to 6m long. The components of the Persian wheel are as follow.

- A wooden rod, 4.5 to 6m in length, with one end connected to a small iron wheel and the other end drawn by the animal.
- Two other iron wheels of different sizes, with teeth in between the wooden rod and the Persian wheel itself (only operating within the well) to pull out water. The Persian wheel is

Plate 5: ***A Persian Wheel Being Operated by a Bullock***



The role of Persian wheel technology is diminishing due to the popularity of modern tubewells among farmers. However, tubewells will not be sustainable in an arid ecosystem where the recharge rate of underground water reservoirs is very slow. Farmers will continue to depend on the Persian wheel for exploiting underground water, probably with slightly modified, more efficient equipment.

equipped with an iron necklace containing about 100 to 120 steel pots. The capacity of each pot is two to three litres and is attached to the necklace at a distance of about one ft. The length of the necklace and the total number of pots attached to it depend on the depth of the water level in the well. Approximately eight to10 pots are always within the water table.

- An animal drives the Persian wheel through a long wooden rod and an other two wheels. The Persian wheel moves the necklace within the well in an oval cycle. Water is collected in a steel channel in the centre of the Persian wheel. This steel channel takes water to the main collection site.

Trickle Irrigation

Significance

In Balochistan, irrigation methods currently followed by common farmers include the controlled flood irrigation technique on either wide border strips or basins. It is a very simple, cheap method, requiring little maintenance, yet it is also very inefficient and wastes almost 50 per cent of the precious water during conveyance from the source and by leaching from the field. Modern irrigation systems have been introduced among the more progressive farmers to control water losses and to improve the efficiency of water usage.

Components

Trickle irrigation is most commonly micro-irrigation and involves dripping water on to the soil at very low rates (4 to 24 litres/h). It is commonly used in orchards and for vine crops, it is adaptable to any farmable slope, and is applicable to a variety of soil textures.

A typical drip irrigation system is listed below.

Water source: A supply of water with adequate pressure is essential. Tubewells fitted with centrifugal electric pumps, which can pump water directly to the sys-

*Plate 6: **Trickle Irrigation System at a Government Farm***

tem with a minimum pressure of 30 Psi at the well outlet, are the most appropriate.

Control head: The control head consists of valves to regulate discharge and pressure in the entire system. A 200 litre pressurised vessel with an inlet and outlet is used to inject soluble nutrients into irrigation water with a 140 mesh screen filter to clean water from any debris and undissolved nutrients, and it includes gauges to indicate the correct pressure of the system.

Main line: Usually a locally manufactured 7.5cm dia PVC pipe (class D) that connects different sub-mains and is laid at a depth of 90cm below the ground to protect it from any damage from mechanical activities on the farm.

The sub-main: This supplies water to the laterals on one or both sides. A locally manufactured 3.75cm PVC pipe, six bars' rating, is laid at 60cm below the ground and receives water from the main line through a separate gate valve on a galvanised iron risen assembly.

The laterals: These supply water to the emitters. Usually a locally manufactured 13mm ID low-density polyethylene pipe of 1.5mm wall thickness is used. This pipe is rated at a working pressure of four bars and it is laid on the ground's surface to receive water from the sub-main via a 3.75 x 1.25 x 3.75cm MPT PVC reducing T,and a polypropylene male adapter of 13mm x 1.25cm MPT. Each lateral has a stopper flushing facility at the end.

The emitters: These are the beast of the system from which water drips at a constant low discharge from the lateral to the atmosphere. The recommended emitter is a turbo that is self cleaning, pressure compensating, self piercing, has a single outlet, and is capable of delivering a 4gph discharge at a minimum pressure of 15 Psi.

For orchard trees, the recommended drip irrigation system designs are of two types:

- drip continuous 'on the line system' and
- drip loop 'around the tree system'.

Drip Continuous 'on the line system': Recommended for newly-established plantations. Especially suitable for grapevines that are to be trained on trellises, with the aim of eventually having a continuous strip of irrigation along the row using equally spaced emitters on the lateral line that runs along the row of plants. Usually, each plant receives two emitters at plantation time, placed 0.6m apart for sandy loam to loamy sand soils and 0.8m apart for sandy clay loam to clay loam soils where the tree trunk is in the middle.

Two years later, as the plant grows, another set of two emitters are put in place, one on each side of the existing emitters at the same distance of 0.6 to 0.8m apart. Four years after plantation; emitters are added on the lateral pipe as needed, so that the distance between any two emitters always remains 0.6 to 0.8m, thus ensuring a continuous wet strip along the whole length of a row.

Drip Loop 'around the tree system': Recommended for medium-sized trees planted at moderate distances along the row (not more than 4.5m). The layout of the loop around a tree with enough equally spaced emitters should ensure that the root volume receives sufficient water. The duration of each episode of irrigation should be carefully timed to ensure that enough water is delivered to the root volume, while wetting patterns of each emitter on the loop should partially overlap. Emitters are placed around the loop 0.6m apart for sandy loam to loamy sand soils and 0.8m apart for sandy clay loam to clay loam soils where the trunk of a tree is in the centre of the loop.

Advantages

- Due to the slow rate of water application, the extent of penetration increases in problem soils.
- Water savings are made due to the application of water around the root zone, especially when trees are young.
- Frequent light water applications can maintain soil water within a narrow range, usually closer to soil field capacity, and this enhances growth and increases yields.
- Because irrigated areas are limited, weed growth is reduced.
- This system permits nutrient induction (fertigation) to the plant root zone in automatic and accurately controlled quantities.
- It allows much easier, more efficient, and economic control of weeds and pests.
- Could be used successfully on fields with great slopes where traditional surface irrigation cannot be applied.
- There is a highly efficienct water application, i.e., 90 per cent.

Disadvantages

- It is a costly system and unaffordable for small landholders.
- Most growers are reluctant to plant orchards on all of their land, and they also practice intercropping until trees start fruiting. This intercropping of certain vegetables and melons gives growers a good cash return until their orchards start bearing fruit, but it is a key constraint in the adoption of this system.
- Drip irrigation results in the accumulation of tons of salt at the outer edges of wet soil, especially in areas of low rainfall.
- The emitters are susceptible to blockage.

Bubbler Irrigation

Significance

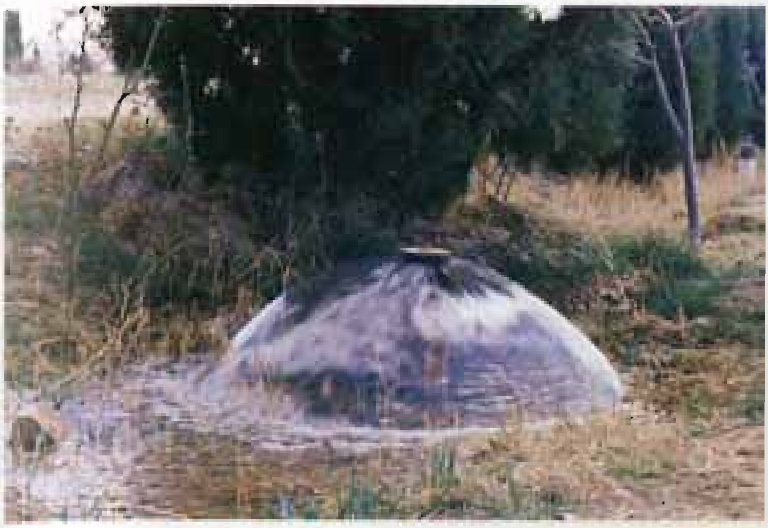
This may be defined as 'localised flood irrigation' in which each plant receives its water individually and the water is confined only to its root zone volume. This is a suitable alternative for irrigating large, widely-spaced trees which have always been irrigated by flood methods such as basin irrigation.

Components

The basic components of the system are as follow.

Water source: This should be a tubewell pumping directly into the network, if enough water is supplied to meet the high discharge of the bubblers, and a pressure

Plate 7: ***Alpha Irrigation System in Balochistan***



The popularity of this technology among farmers depends largely on its cost effectiveness. Local manufacture of equipment using indigenous materials will substantially reduce costs.

of at least three bars (45 Psi) is attainable at the well outlet before the systems' control head unit. If the above two requirements are not fulfilled, storage is necessary to collect water from the source, and a booster pump is needed to deliver water under the required pressure.

Control head: Connected either directly to the tubewell or alternatively to the booster pump, the control head consists of valves and gauges to regulate discharge and to indicate pressure. A fertilizer tank is not needed because solid fertilizers and manures can easily be spread in a basin around the tree trunk. Since the control head has a large opening outlet, a filtration component is unnecessary.

Main line: A locally manufactured 10cm UPVC pipe (class D) is used to connect different sub-mains and is laid at a depth of at least three feet below the ground.

The sub-main: Usually a locally manufactured 7.5cm UPVC pipe, 10-bar rating is laid at 0.9m below the ground. It receives water from the main line through a separate gate valve on a galvanised iron seizer assembly and supplies the laterals on one or both sides.

The laterals: A locally manufactured 2.5cm to 0.6cm UPVC pipe, six-bar rating, is laid at 0.4m below the ground and is 0.8m away from the tree trunk. These receive water from the sub-main via a 7.5 x 3 x 7.5cm all-socket PVC-reducing (T, and supply water to the risers, on which the bubbler heads are placed. Each lateral is fitted witha PVC end top and cap above the ground for flushing purposes.

The risers: The risers are 1.25cm SCH 80 UPVC pipe sections, 0.6m in length, male threaded both ends, that extend 15cm above the ground, receiving water from the laterals via a 3 x 1.25 x 3 cm MPT PVC-reducing T and have the bubbler head screwed in place on one of the ends.

The bubbler heads: These are system heads from which water is discharged in a fully circular umbrella pattern to the basin around the tree. The recommended bubbler is a pressure compensating circle, with a 1.25cm threaded female inlet.

Advantages

- Because the flow of water is under pressure in closed pipes, water conveyance efficiency from source to plant is 100 per cent.
- Since all pipes are completely buried below the ground, except the riser extending 15cm above the surface, mechanical activities on the farm are not disturbed.
- The time of irrigation is less than for other systems; thus reducing the cost of power for the system's operation.
- It permits manual spreading of fertilizers and farmyard manure on soil inside the basin around the tree.
- Due to the large outlets, the bubbler can expel solid particles of a comparatively large size, especially under higher operating pressure; thus, the bubbler outlets are not easily blocked.

The water application efficiency is high for this system - about 85 per cent almost twice the efficiency of surface irrigation methods.

Disadvantages

- The initial cost of the system is very high and thus unaffordable for small farmers.
- A high discharge rate and high pressure at the water source are the basic requirements of this system.
- If the basic requirements are not met with direct pumping from a tubewell then a field reservoir and booster pump combination are needed, adding to the total cost of the system.

Sprinkler Irrigation

Significance

Sprinkler irrigation can be used on most soils and for almost all crops except rice and jute. It is not suitable for very fine textured (heavy clay) soil where infiltration rates are less than 4mm/hr. It is well suited to sandy soils and small streams. Shallow soils and soil involving intensive land preparation can be irrigated efficiently. Land with steep slopes can be irrigated safely.

Components

In this method, water is sprayed into the air and is allowed to fall on the surface of the ground, in a manner somewhat resembling rainfall. The spray is developed by a flow of water under pressure through small orifices or nozzles.

The required pressure is usually obtained by pumping using a careful selection of nozzle sizes, operating pressures, and sprinkler spacing.

*Plate 8: **Sprinkler Irrigation is Best on Sandy Soils***

Although these modern irrigation systems are expensive, their use is necessary to stop the overexploitation of underground water resources where recharge is minimised by decreasing vegetal cover.

Advantages

- Careful application of soluble fertilizers, herbicides, and fungicides is possible (and economical) by adding them to irrigation water.
- The system is very useful for protecting crops against frost and high temperatures.
- Labour costs are less than for other methods.
- More land is available for cropping.
- Irrigation does not interfere with farm machinery.
- This method is popular in regions of water scarcity and uneven topography.

Disadvantages

- It is not useful in windy areas.
- Ripening fruit must be protected from spray.
- A stable water supply is required.
- Water must be clean and free of debris, sand, and a large amount of dissolved salts.
- It requires a high initial investment compared to surface irrigation methods.
- Power requirements are usually high since sprinklers operate at a pressure of $5N/cm^2$ to $900N/cm^2$.

Delay Action Dams (DADs)

Significance

Tillage operations in Balochistan, depend largely on irrigation using groundwater by tubewell, *karez* irrigation, and flood irrigation by spreading the flood water from

Plate 9: **DADs May Be Effective for Artificial Recharge with Good Management of Vegetal Cover in Watershed Areas**

The silting up phenomenon can be checked by proper grazing management and by constructing artificial plant communities in catchment areas. DADs have the potential to be exploited for fresh water fish production

hill torrents. In recent years, excessive groundwater exploitation by tubewells for irrigation, corresponding with rapid expansion of orchards, has caused considerable lowering of the groundwater table.

Simultaneously, a mismanagement of watershed areas followed by a sharp decline in vegetal cover is accelerating runoff with diminished natural groundwater recharge. Realising the hazard of complete exhaustion of underground water resources within a few decades, the government decided to induce artificial recharge by constructing delay action dams.

Components

The irrigation and power department of the province has promoted artificial recharge of groundwater by means of the construction of delay action dams (DADs). At present, about 110 DADs are completed or are under construction. Furthermore, 500 more DADs have been proposed. Some technical difficulties in construction and operation/maintenance of the completed DADs have been reported.

The Delay Action Dam recharges the groundwater using flood water. A DAD is constructed just within the hills where a river or creek with its flood water enters any gravelly fan. Using modern technology to construct a huge embankment, a large reservoir is created. This reservoir is located on river alluvium in transition to a fan. The stored water is supposed to infiltrate and percolate to the groundwater. Unfortunately, DADs are silting up rapidly so that the stored water tends to become finite, with water evaporating rather than infiltrating.