In situ and *Ex situ* Rainwater Conservation in *Kandi* Region of Punjab for Sustainable Agriculture

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Punjab state has been divided into six agro-climatic regions on the basis of variations in physiography, underground quality and quantity of water, amount of rainfall and moisture index. Sub-mountainous undulating region locally known as *Kandi* area has been termed as Zone I. The dictionary meaning of *Kandi* is land along the bank of river or along foothills, submontane region. The region is spread in five districts namely; Pathankot, Hoshiarpur, Shaheed Bhagat Singh Nagar, Roop Nagar and Ajitgarh (Mohali). The *Kandi* area lies between 30°21'48" to 32°30' North latitudes and 75°32' 12" to 75°56' East longitudes covering an area of approximately 0.393 m ha, which constitutes about 7.8% of 5.03 million ha geographical area of Punjab state. Geologically, the area forms a part of the Shivalik hills constituting piedmont and alluvial piedmont. The piedmonts are sited on the upper conglomerate beds mainly on a bed of clay intermixed with pebbles and cobbles and nodular concretions and in the plains, it is alluvium deposits. Fluvial action of choes, erosion and deposition are the geomorphic processes prevalent in the *Kandi* area of Punjab.

Physiography

There are two major physiographic units:-

i) Hills

Hills are present in the Pathankot, North Eastern part of Hoshiarpur and Roop Nagar districts. The hills are composed of sandstones, conglomerates and shales. The altitude varies from 300 to 600 meters above mean sea level. These hills act as medium to seasonal rivulets locally known as choes. High number of choes/seasonal rivulets originating in the hills cause severe erosion. Hills show dendritic drainage pattern and have thin to moderately dense scrub forests. Ground water potential of this hilly tract is poor.

ii) Piedmont Plain (Dissected & Rolling Land)

It forms a transitional zone between the Shivalik hills and alluvial terraces. It is 10 to 15 km wide strip and comprises parts of Pathankot, Hoshiarpur, Shahid Bhagat Singh Nagar and Roop Nagar districts. The elevation of this zone varies from 300 to 375m above the mean sea level. The land is badly dissected by seasonal streams popularly called 'Choes'. Many of these choes terminate in the area without joining any major stream/river. The fluvial action of choes erodes the soils due to which the fertility of soils is reduced.

Climate

The climate of the region varies between semi-arid to sub-humid. The average maximum temperature (41 °C) is recorded in first fortnight of June; whereas the minimum temperature (6 °C) is recorded in the month of January. The area receives average annual rainfall of 600-1500 mm with a very high coefficient of variation. The highest rainfall is recorded in the Dhar block of the region. About 80% rain occurs in *kharif* season (July-September) and rest 20% occurs in *rabi* season. Winter rains are received from late December to March. These winter rains are light and do not produce much runoff. The rains in the region are more uncertain at the time of sowing and drought occurs frequently, even during rainy season. The probability of expecting at least one dry spell of >6 days during individual months varies between 55 to 98%. The rainfall in June (pre-monsoon showers) is also quite uncertain and often delays the *kharif* sowing, resulting in decreased yields. Early withdrawal of monsoon is common in this region, resulting in severe drought during late part of the *kharif* season. It also affects the next *rabi* crop as the upper soil layer dries up by the sowing time. Sometimes, it becomes impossible to sow a *rabi* crop on residual moisture due to inadequate soil water in seed zone. Hence there is need to conserve the moisture present in the soil during the *kharif* season and to store the rainwater for its use in the *rabi* season.

Soils

Majority of the soils range from loamy sand to sandy loam and have low to medium moisture retention capacity and are highly erodible. These soils are deep, medium to light textured with low to good water retentive capacity having gentle to moderate slope. The inherent fertility of the soils of this area is very low. The soils are low in organic carbon, deficient in nitrogen, low (5-10 kg P_2O_5 ha^{-1}) to medium (11-20 kg P_2O_5 ha^{-1}) in available phosphorus and medium in K (118-280 kg K_2O ha^{-1}). Marginal lands consist of torrent-affected areas, steep slopes, highly eroded soils and excessively permeable less water retentive soils. The land in the area is undulating and has three distinct physiographic unts viz., hilly, choes (seasonal streams) and the area lying between the two which is usually cultivated. Gullies and rills are commonly found in the area.

A major portion (30-40%) of rain goes as runoff resulting in water erosion. The rain water management strategies or techniques play important part and significantly affect the crop productivity. The rainwater management strategies developed and tested under All India Coordinated Research Project on Dryland Agriculture along with the scientists of Regional

Research Station (Punjab Agricultural University), Ballowal Saunkhri have been discussed in this bulletin.

1. *IN SITU* MOISTURE CONSERVATION

To increase the moisture availability to the agricultural crops, it is necessary to adopt *in situ* moisture conservation techniques in addition to the large scale soil and moisture conservation and water harvesting structures in the watershed. The principle behind the recommendation of different practices is to increase the soil water storage by reducing the runoff, temporarily impounding the water on the soil surface to increase the infiltration opportunity time and modifying the land configuration for rainwater harvesting. Following practices are recommended for *in situ* moisture conservation:

1.1 Minor land shaping


Land Levelling

The cultivation of crops on slopes without modifying them produces higher runoff, lesser infiltration of water and more erosion. When original ground slopes are modified by forming bunds and terraces, runoff can be controlled by providing more time for the water to infiltrate in the soil. This also helps in reducing the soil erosion. These land treatment measures increase infiltration and soil water storage.

Almost whole of the arable land is divided into number of small fields by putting small bunds. The field shape, degree and length of slope vary to a great extent from place to place. Formation of bunds is an accepted method to facilitate infiltration and percolation of rain water to increase the soil water storage. Small holdings of the farmers and agricultural practices followed in the foothills of Shivaliks warrant narrow-based bunds on adjusted contours taking field boundaries and direction of slope into consideration.

Minor land shaping helps increase soil water storage in two ways:

i) Infiltration of water into the soil causes less runoff and hence reduces soil erosion.

ii) More soil water storage sustains the crop for a longer period without rain.

1.2 Tillage practices for enhancing the rain-water intake

Tillage in the rainfed areas is done for increasing and conserving soil moisture, controlling weeds and for preparation of seed-bed. Various tillage practices useful for moisture conservation are described below:

1.2.1 Pre-monsoon ploughing

Summer Ploughing

This practice includes ploughing of fields about a month before the onset of monsoon rains which makes the field surface rough and clody. This practice improves infiltration of rainwater into the soil by providing more opportunity time thereby reducing runoff and soil erosion. It also helps in killing the weeds and insect-pest harboring in the soil due to high temperature during that period.

1.2.2 Pre-sowing tillage

Pre-sowing tillage

During the *kharif* season, either there are dry spells or sometime there is heavy downpour (high intensity rainfall). Both the conditions are hazardous for the *kharif* crops. In order to avoid the crop damage due to waterlogging caused by heavy rainfalls, crops should be sown on the ridges. This method of sowing gives two advantages as the furrows helps in moisture conservation and act as channels for drainage of excess rain water thereby reducing the chances of water logging.

1.2.3 Post-sowing tillage

Post-sowing tillage operations during *kharif* such as hoeing and inter-culturing (haloding) help in pulverizing the rhizosphere for increasing infiltration of water and also control weeds. Haloding is an important practice in maize cultivation and involves ploughing with a traditional (*desi)* plough between the inter-row spaces in a month old crop. This practice checks weeds, does earthing-up and create shallow ditches between the rows. The ditches, when constructed against slope or on flat surface, intercept and detain runoff water and help store more water. Haloding helps in creating soil mulch that blocks pores and checks evaporation losses of soil moisture. Haloding makes the soil surface rough thereby reducing the rate of evaporation. In addition, the earthing up supports the plants, aerates the rooting zone and decreases resistance to growing roots, thereby creating conditions for better plant growth.

Haloding with tractor

1.2.4 Post-harvest tillage

This practice consists of repeated shallow tillage followed by planking immediately after harvesting of the *kharif* crop. Preferably, the field is ploughed in the evening and planked next morning to conserve dew drops fallen during night. Locally this practice is called as '*Gil dabna*', meaning conservation of the moisture. This practice is significantly sound. By ploughing the profile water is conserved by checking upward movement of water through breaking the continuity of capillaries towards the soil surface. This practice assumes greater significance in dryland areas where wheat is sown during the drier months of October-November and germination depends on residual profile moisture.

1.3 Mulching

Mulch cover protects the soil from the impact of rain drops and reduces the velocity of runoff and wind. Organic mulch of crop residues is known to increase soil moisture storage and maintain higher water content in the upper soil layer. Organic mulching also decreases soil temperature by providing shade. However, the residue may also pose some problems when tillage tools get clogged with the residue. It has also been observed that the termite infestation increases manifold on mulched fields. Despite these drawbacks, the effectiveness of mulching in yield increase, reducing erosion and increasing residual profile moisture has been amply demonstrated.

In *Kandi* area, the *rabi* crops are grown on moisture stored after fallow or on residual moisture left in the profile after harvesting the preceding *kharif* crops. There is relatively little rainfall during the initial growing season of the *rabi* crop and early withdrawal of monsoon results in drying out the upper soil layers comprising the seed zone. The total amount of residual or stored moisture in the profile and moisture in the seed zone is particularly critical when wheat is sown after a *kharif* crop. Therefore, to ensure proper germination of the *rabi* crop, it is necessary to conserve adequate moisture in the seed zone. The mulching is of two types as described below:

1.3.1 Brought-in mulch

This type of mulch can be applied at the rate of 4 t/ha with locally available wild shrubs viz. Basooti (*Adhatoda vasica*), Bhang (*Cannabis sativa*), Kana (*Sachharum munja*), Raya stalks (*Brassica juncea*), Nara (*Arundodonax* spp.) and Subabul (*Leucaena* sp.) in standing maize during last week of August. The application of organic mulch of green wild growing vegetation in the last week of August is effective for *in situ* moisture conservation, benefiting the standing crop of maize as well as the following wheat.

Mulching in Maize

1.3.2 In-situ raised mulch

In areas where availability of local vegetative mulch material is limited, mulching practice has not popularized among farming community at large scale. This problem can be solved by *in-situ* raised mulch by growing green manure crop of sunhemp or cowpea in between the furrows of maize. This green manure crop can be cut at an age of one month and spread in between the maize rows as mulch. This practice also reduces the weed population.

1.4 Cultivation across the slope

The soils of the *Kandi* area are generally undulating with varying degree of slope. Cultivation across the slope reduces the velocity of runoff, checks soil erosion and allows more time for water to infiltrate into the soil profile.

1.5 Vegetative barriers

Suitable grasses and bushes raised on field boundaries across the slope are the alternatives to bunding on arable lands to increase soil water storage and reduce soil erosion. These barriers when established on contours are quite effective and inexpensive. Planting of vegetative barriers is done during the rainy season and they take two to three years to become effective. The effectiveness of different vegetative barriers, such as Vetiver grass (*Vetiveria zizanoides*), Kanna grass (*Saccharum munja*), Babbar grass (*Eulaliopsis binata*) and Napier-bajra hybrid (*Pennisetum purpureum x typhoides*) was tested when planted across the slope on field boundaries for *in situ* soil and moisture conservation. The vegetative barrier of Napier -Bajra hybrid and Kanna can be raised by cuttings as well as root suckers during the month of February and July. These vegetative barriers hold the soil of the field bunds and break the flow of water which results in higher infiltration of water. This ultimately improves the soil moisture and reduces the soil erosion and runoff.

Vegetative barriers on field bunds

1.6 *In-situ* rain water harvesting and moisture conservation technologies in plantation

The V-ditch and crescent bund methods of planting for horticultural and forestry plants on sloppy lands harvest maximum *in situ* rainwater as compared to the traditional pit method of planting. In fine textured soils the plants should be placed on the upper side of the ditch to avoid water

V-ditch method of plantation

logging conditions whereas in coarse textured soils, plants should be grown in the ditch.

2 *EX-SITU* MOISTURE CONSERVATION

Despite *in situ* moisture conservation measures, the water stress does occur during long rainless periods (dry spells) even during the monsoon season. Often the monsoon recede early and winter rains are delayed, with the result the *rabi* crops are not sown in time. Because of the rolling topography of *Kandi* area, much of the monsoon rain is lost as runoff. It is estimated that 25-45% of the monsoon rain is lost as runoff in the area, depending on soil type and topography of land. This runoff water, if harvested, in excavated or impounding type reservoirs, can be effectively used for the purpose of irrigating the crop and for use by animals and raising fishery in the area. It has been observed that even after enhancing profile water storage, it was possible to collect at least 80-100 mm of runoff. The runoff coming from the upper catchments can be stored in small reservoirs by constructing earthen dams across gullies. These reserves will recharge ground water and provide water for life-saving irrigation. A substantial amount of runoff, which goes waste in cultivated land, can be collected in dug-out ponds/tanks. To check seepage loss in light soils, a lining of polythene sheet in the bottom and brick-cement on sides of tanks may be required. Inverted truncated pyramid shaped tanks having 1:1 side slopes and 5 meter depths are suitable for the region. The harvested water should be utilized efficiently through micro-irrigation systems like drip and sprinkler and may be used for establishing an orchard or for raising a fodder or grain crop. For maximum benefits, the harvested water should be applied as a pre-sowing irrigation to wheat. The design of storage structure depend on the area of catchment, the amount of runoff water to be stored, and the amount of water required for irrigation of a particular size of irrigated area.

2.1 Types of Water Harvesting Structures

The following types of Water Harvesting Structure are suitable for Kandi Region:

2.1.1 Farm Ponds

2.1.2 Earthen and Masonary Check Dams

2.1.3 Makkowal type water Harvesting

2.1.4 Micro Lift Irrigation Projects

2.1.1 Farm Ponds

Farm ponds are small tanks or reservoirs constructed for the purpose of storing water essentially from surface water. Farm ponds are useful for irrigation, water supply for the cattle, fish production, etc. Farm ponds have a significant role in areas of rainfed agriculture. They are used for storing water during the rainy season and using the same for irrigation subsequently.

2.1.1.1 Components of a Farm Pond:

The pond consists of the storage area, earthen dam, mechanical spillway and an emergency spillway. The mechanical spillway is used for letting out the excess water from the pond and also as an outlet for taking out the water for irrigation. The emergency spillway is to safeguard the farm pond from overtopping when there are inflows higher than the designed values.

2.1.1.2 Design of Farm Pond

The design of farm ponds consists of

Construction of farm pond

(1) Selection of site

(2) Determination of the capacity of the pond

(3) Design of the embankment

(4) Design of the mechanical spillway

(5) Design of the emergency spillway

(6) Providing for seepage control from the bottom

Selection of suitable site for the pond is important as the cost of

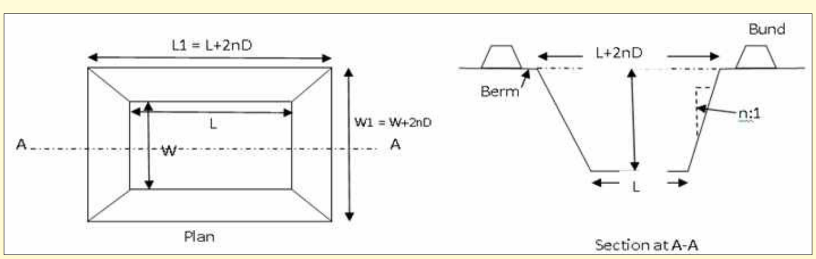

Figure: Cross section of the dug out pond construction as well as the utility of the pond depend upon the site. The site for the pond is to be selected keeping in view the following considerations:

1. The site should be such that largest storage volume is available with the least amount of earth fill. A narrow section of the valley with steep sides slopes is preferable.
2. Large areas of shallow water should be avoided as these will cause excessive evaporation losses and also cause water weeds to grow.
3. The site should not cause excessive seepage losses.
4. The pond should be located as near as possible to the area where the water will be used. When the water is to be used for irrigation, gravity flow to the areas to be irrigated is preferable.

The capacity of the pond is determined from a contour survey of the site at which the pond is to be located. From the contour plan of the site the capacity is calculated for different stages using the trapezoidal or simpson's rule.

2.1.1.3 Depth and Side Slope

The depth of the farm pond is decided by considering soil depth, soil type and equipment used in excavation. Though, the evaporation loss component can be minimized by increasing the depth but, from practical point of view the ideal depth is limited to 3 to 3.5 meter. Any depth beyond 4.0 meter will be uneconomical if human labour is employed in excavation.

Based on experience, it is observed that the side slope of the pond should not be steeper than the natural angle of repose of the excavated material. Another factor while considering the side slope is duration of standing of water in the farm pond. For higher duration, flatter side slope is recommended to avoid the slippage due to saturation particularly for unlined pond.


Farm ponds

2.1.2 Earthen and Masonary Check Dams

These are of two types i.e. the impounding type and dug-out type. In the impounding type, a retaining wall or a dam is constructed to block the flow of water into a natural storm drain, such as gully or choe. Excavated or dug-out type of water reservoirs should be located in the natural waterways if runoff can be driven into it. Earthen and masonary check dams are the most common type of manmade storage and effective and economic structures. The height of earthern structures varies from 8-15 m and of masonary structures 5-8 m with a catchment area varying between 10 to 200 ha.

The earthen dugout ponds can be constructed in Roop Nagar, Shahid Bhagat Singh Nagar and Hoshiarpur Districts where the geology varies from light textured to medium textured soils with clay bands, while masonry structures can be constructed in Dhar and Dunera blocks of Pathankot district where the hills are composed of conglomerates and shales.

Masonary check dam

2.1.3 Makkowal Type Water Harvesting

The Makkowal type water harvesting structures got its name from a remote village in district Hoshiarpur where first ever this type of structure was constructed. In this type of structure the hill seepage and the base flow is tapped in the higher hill reaches and is then delivered to the command

 

Makkowal prennial flow structure

area by gravity through a network of pipelines. The excellence of the project was widely appreciated and later on replicated at about 110 other places in the *Kandi* region. The command area in this type of projects varied from 10 hectares to 100 hectares and in a few cases even more than 200 hectares. The availability of water in this type of structures is assured for 8-9 months in a year.

2.1.4 Micro Lift Irrigation Projects

These types of structures can be constructed where the command area is at a higher level than the water source. The projects include the development of the water source through percolation wells and then lifting with centrifugal pumps to irrigate the command area. The average command area for such projects is 50 ha. About 60 such structures have been constructed by various governmental agencies and the majority of them are in hilly areas of Pathankot district.

Pumps are used to lift the water from the farm ponds and apply it to the fields. The stored water once lifted may be applied to the fields either through surface irrigation systems or through the micro-irrigation systems. The pumps need to be as close to the water as possible. Lift irrigation schemes must accomplish two main tasks: first, to carry water by means of pumps from the water source to the main delivery chamber, which is situated at the top most point in the command area. Secondly they must distribute this water to the field of the beneficiary farmers by means of a suitable and proper distribution. There is a distinct limit to the ability of a pump to create suction, so the water level can only be a maximum of 5-8 m below the pump, depending on circumstances axial flow pumps cannot create suction at all, so the pump impeller must be submerged below water level by a certain distance. In order to use the pumps for the irrigation purpose, it must be ensured that the water stored into the farm ponds is relatively clean so that the pumps are not clogged when operated.

2.2 Storage and lining requirements and materials

Poly lining of pond

About 55-90% loss of stored water occur due to seepage from the water harvesting structures and the remaining due to evaporation. It may be difficult to reduce evaporation from tanks except through reducing surface area of water. This indicates that reducing seepage losses would be highly rewarding. Efforts have been made to check seepage by the use of polyethylene sheets, bricks or plasters of various kinds. Sealing of tanks is thus considered vital to store more water in the tanks in the region. The availability, effectiveness, cost and maintenance of different sealing materials was studied. It was found that 800 gauge (200 micron) polythene sheet covered under 20 cm layer of soil was quite effective for lining tank bottoms, whereas brick and cement lining (7.5 cm thick) was found effective for lining the sides of the tank. The seepage losses through the brick lining were still above the tolerable limits. There was a gradual reduction in seepage losses over the years. Due to pervious nature of *kandi* soils seepage is the main source of water loss from earthen tanks. The evaporation losses can be reduced by decreasing surface area by increasing the depth of the tank. The shading of the water storage tank and addition of chemicals which forms protective layer on the surface to reduce evaporation is also practiced. Vegetation planted on the banks of large reservoirs improves the stability of banks, provides protection against soil erosion and enhances the quality of water for aquatic animals.

2.3 Efficient use of harvested water

Rainwater harvesting is an increasingly popular approach in those parts of the world where short periods of heavy precipitation are often followed by long stretches of dry periods. In these locations, impermeable surfaces covering sufficiently large areas are created to reduce the infiltration of rainfall into the soil. By controlling the run-off of the harvested rain, water is diverted and stored in surface ponds from where water can be extracted and used for irrigation. The water harvested in the farm ponds must be used judiciously. For this, more emphasis should be laid on micro-irrigations systems and irrigation scheduling of the crops. Irrigation is necessary when plants cannot satisfy all their water needs through natural precipitation – this practice is also called deficit irrigation. Therefore, an ideal irrigation effort aims to cover the deficit between a crop's optimal water needs and what it can take up through natural means. Because of erratic distribution of rainfall in Kandi area, irrigation is indispensible. Climatic conditions, soil type and structure, plant type, and the irrigation techniques applied are among the main factors that influence the efficiency and effectiveness of irrigation practices. For a given location and climatic and soil conditions, the efficiency of water irrigation practices can be improved by making the right decisions regarding crop type, irrigation scheduling, irrigation method, soil enhancement measures (mulching, deep ploughing, etc.) and source of water.

2.3.1 Irrigation scheduling

Irrigation scheduling helps eliminate or reduce instances where too little or too much water is applied to crops. Scheduling is performed by all growers in one way or another. However, proper irrigation scheduling involves fine-tuning the time and amount of water applied to crops based on the water content in the crop root zone, the amount of water consumed by the crop since it was last irrigated, and crop development stage. Direct measurement of soil moisture content is among the most useful methods for irrigation scheduling. The economics, and in particular the critical impact of water availability on the yield, also play a role on the uptake of advanced irrigation scheduling.

2.3.2 Micro-irrigation systems

2.3.2.1 Sprinkler Irrigation

Sprinkler irrigation systems imitate natural rainfall. Water is pumped through pipes and then sprayed onto the crops through rotating sprinkler heads. These systems are more efficient than surface irrigation, however, they are more costly to install and operate because of the need for pressurized water. Conventional sprinkler systems spray the water into the air, losing considerable amounts to evaporation. Low energy precision application (LEPA) offers a more efficient alternative. In this system the water is delivered to the crops from drop tubes that extend from the sprinkler's arm. When applied together with appropriate water-saving farming techniques, LEPA can achieve efficiencies as high as 95%. Since this method operates at low pressure, it also saves as much as 20 to 50% in energy costs compared with conventional systems.

2.3.2.2 Drip Irrigation

Drip irrigation delivers water through the use of pressurized pipes and drippers that run close to the plants and that can be placed on the soil surface or below ground. This method is highly efficient because only the immediate root zone of each plant is wetted. This system also allows precise application of water-soluble fertilizers and other agricultural chemicals. Drip irrigation is reported to help achieve yield gains of up to 100%, water savings of up to 35-50%, and associated fertilizer, pesticide, and labor savings over conventional irrigation. Drip irrigation systems can have different levels of sophistication and costs. Drip irrigation systems can also be operated with the help of solar-driven pumps.

Drip Irrigation in Kinnow

Sprinkler Irrigation in Wheat

2.4 Sustainability

The water harvesting structures can be useful, effective and sustainable with the active involvement of the community. The sustainability directly depends upon the capacity of the community in the post project operation and maintenance. The collection of user charges for generating the funds for operation and maintenance is vital. It has been observed that adequate funds are being collected by the members of the group as User charges in case of Makkowal type and Micro Lift Irrigation projects. The collection of User charges in Earthen dams is below expectations.

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