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Rainwater management in high rainfall rainfed areas

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The basic objective of water harvesting in high rainfall areas is to allow maximum possible rainwater to be stored in soil profile in-situ, and the excess runoff to be collected, stored and used in the same area or other areas. So, rainwater management in high rainfall areas involves creating a saturated soil profile, and storing water in ponds, ditches, streams and river beds. This helps in mitigating the water needs during dry spells in kharif season. Harvesting potential can be enhanced by integrating the check dams with ponds, and multi stage harvest with ponds. In high rainfall areas, the water storage structures are usually refilled in the same season with the subsequent rainfall, stream flow, spring water, or seepage water. The stored water in the soil profile and also in storage structures should be used judiciously by early sowing and promoting early growth, using crops with low water demand and deep rooting system, zero tillage or reduced tillage, residue recycling, and mulching. Rainwater productivity of the harvested water can be further enhanced by multiple use of water, and integration of water harvesting with seepage and evaporation management practices. Enhanced rainwater productivity due to water harvesting has associated benefits of groundwater recharge and biodiversity promotion

Keywords: Check dams, Evaporation, Mulching, Multiple use, Ponds, Water harvesting

'WATER is life, water is food. Leave no one behind', the theme for the World Food Day 2023, indicates the importance of water. Around 68% of global freshwater withdrawals and consumption is used in agriculture (www.undp.org). India has the highest irrigated area (112 M ha) as well as the highest area under groundwater irrigation. However, groundwater use has several demerits like depletion in water level and the need for recharge, shift in well sites due to water level depletion, accidents in abandoned wells, water quality issues (salinity, iron, nitrate, fluoride, arsenic, few toxic metal ions), salinity intrusion in coastal areas, and land subsistence. Use of canal water has problems like secondary salinization, waterlogging, need of huge fund and land for developing reservoir and canal networks, and strong opposition by environmentalists and ecologists. Harvesting and use of rainwater largely avoids such issues. In high rainfall areas (exceeding 1,000 mm), potential exists to harvest and create sufficient water resource. Rainfed area with more than 1,000 mm annual rainfall is about 23.2 M ha covering 270 districts.

The basic objective of water harvesting in high rainfall areas is to allow maximum possible rainwater to be stored in soil profile *in-situ*, and the excess runoff to be collected, stored and used in the same area or other areas. Surplus water should be stored *ex-situ* in reservoirs, tanks, ponds and aquifers as minor storage systems. For maximum returns from harvested water, it should be applied at an early stress stage of the crop as the stored water in tank reduces with passage of time due to seepage and evaporation losses. The objective is quite different for semi-arid and sub-humid regions, in which the main aim is to conserve maximum rainwater *in-situ* in the root zone of soil profile. In contrast, for arid regions, the main objective of water harvesting is to induce more runoff (by modifying ground surface) in uncultivated areas for its collection and use in cultivated areas. Rainfall in high rainfall areas is usually sufficient to meet the water demand of current season crops. However, aberration in spatial and temporal distribution leads to water shortage during the cropping season. So, proper conservation and management of excess rainwater is needed to overcome water shortages during dry spells in rainy season. Also, in good rainfall years, with the harvested water, a second season crop is often feasible. Efficient rainwater management can bridge the yield gap between rainfed and irrigated agriculture.

Rainwater harvesting and management

Field bunds and management: In uplands, graded bunds should be provided across the slope, so that these act as a series of miniature barriers to check the loss of water and soil through runoff. The bund height should gradually increase from ~ 5-15 cm from upper reach to lower reach for rice crop. Previous studies reported that for medium lands, the optimum bund height is 20-25 cm for rice crop. Further, the runoff loss reduced substantially with 22 cm bund and with an increase in bund height, number of irrigations of 6 cm each during dry spells also reduced (Table 1). Bund management in terms of sealing in each season is required to check free flow through holes in bunds and additional return may be obtained from field bunds by growing crops such as pigeon pea, black gram, maize and yam in flood free areas.

Table 1. Bund height (cm) and number of irrigations for rice crop in a medium land

Bund height (cm)	Irrigation number (6 cm each)
6	4
10-14	3
18	2

Check dams: Temporary check dams are usually made from rocks, sandbags, concrete blocks, or wood. Permanent check dams are masonry structures and are very common. Sometimes, the masonry head wall of a permanent check dam is replaced with high quality folded rubber sheets anchored to masonry base which can be inflated and deflated to check and flush out sediments, respectively.

ICAR-Flexi check dam: ICAR-flexi check dam or rubber dam is an inflatable structure built across a stream and used for water conservation, flood control and regulating flow of water in the stream. When it is inflated, it serves as a check dam/weir, while when deflated, it functions for flood mitigation and sediment flushing. Such flexi dams with a height from 0.5-1 m were tested across stream widths ranging from 2-5 m. The water stored in the upstream side of the dam extends to a length of 0.8-1.7 km. The additional volume of water stored in the upstream side varies between 4,800-10,000 m^3 during monsoon season. In case the stored water is used for irrigation in dry spell, it gets continuously filled up by the water flowing from the upper catchment during monsoon. Harvesting potential can be enhanced by integrating the check dams with ponds in the storage area of the upstream side. In *kharif* season, when paddy crop suffers from dry spell, the flexi check dam helps in diverting water to fields and increasing paddy yield up to 62%. Also, stored water helps to grow *rabi* pulses, oilseeds and vegetables.

Water harvesting farm ponds: In rainfed agriculture, supplemental irrigation from rainwater harvesting ponds avoids the risk of total crop failure during dry spells. Rainwater harvesting permits smallholder farmers for crop diversification. Fields with clayey subsoil should

A flexi check dam across the water stream (water flowing over inflated rubber)

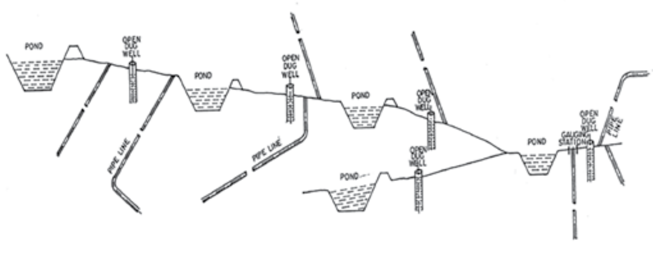
be prioritized due to low seepage percolation rate (<5 mm/day). The ratio of catchment area: command area for such soils is 3-5 with storage volume of 1750 m^3/ha (Table 2). For soils with high seepage percolation rate (>10 mm/day), pond lining is must. However, poly lining increases the cost of water harvesting by 50% and hence, the harvested water must be used judiciously using sprinkler or drip irrigation, and also for growing high value crops.

Table 2. Catchment: command area for soils with different seepage rate

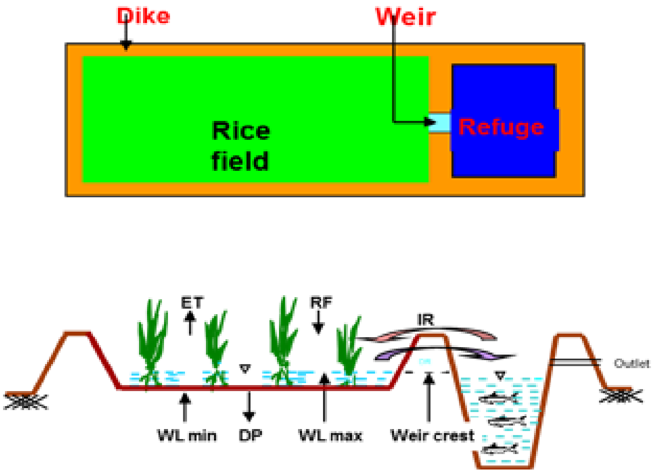
Seepage rate (mm/day)	Catchment : command area	Pond capacity (m^3/ha)
< 6	3 to 5	1750
6-10	>5	1750
>10	Pond lining	As per need

Tank-cum-well system: This technology developed by ICAR-Indian Institute of Water Management is useful for micro level water resource development and use in plateau areas with 2 - 5% slope. The well is constructed 100 - 300 m downstream of the tank along the drainage line in a watershed to tap the seepage water from tank. Fifteen pairs of such tank and well need to be constructed for a catchment of 500 ha to ensure successful crop in *kharif* season against the dry spells. In addition, harvested water in such system have potential to irrigate 60 ha area in *rabi* season.

Two-stage rainwater harvest in rainfed lowlands of plateau areas: Two-stage *in-situ* rainwater conservation technology is developed by ICAR-IIWM for multiple use and enhancing rainwater productivity in medium and shallow lowlands. In the first stage, rainwater is harvested in the rice field by providing 20 cm high weir in the downstream side just before the refuge pond. In



Tank-cum-well system at Dabarchua, Keonjhar the second stage, runoff water from rice field (spilled over the weir) is collected in the refuge pond. The harvested water is used for growing fish and providing supplemental irrigation to rice crop during dry spell. After harvest of rice in main field, light duty *rabi* crops can be grown using lifesaving irrigation from the refuge pond.

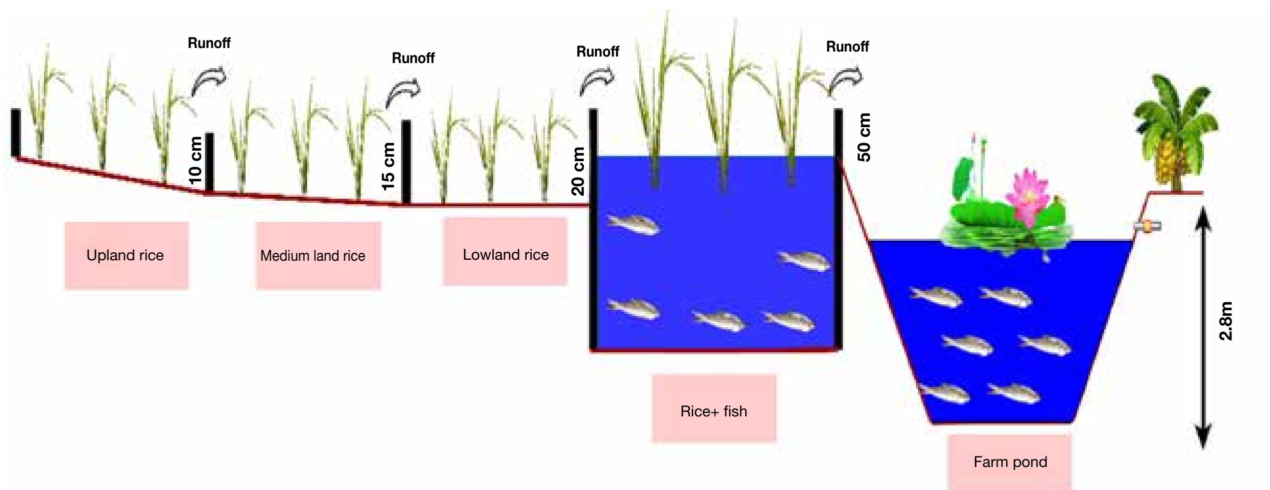


Two stage rainwater harvest

Multi-stage rainwater harvest and multiple use of harvested water: Multistage rainwater harvest in a landscape and multiple use of harvested water in farm ponds is required to overcome the problems related to climate variability and the growing water scarcity. A bund height of 10 cm in uplands, 15 cm in medium lands and 20 cm in lowlands for rice cultivation in sequence with the topography is useful. The surplus water from lowland rice field is collected in a deep water rice field for rice-fish cultivation with the provision of strong dyke of 50 cm at the downside. Surplus water from rice-fish field entered into the water harvesting farm pond using a weir. The harvested water is used for multiple uses such as fish and lotus cultivation, drip irrigation to dyke crops in the dry season, supplemental irrigation to rice crops during dry spell, and early irrigation to dry season short duration field crops. The surplus water from water harvesting farm pond is allowed through a PVC pipe placed at 2.8 m height (about 0.4 m below the dyke). Such provision helps to contain occasional rise in water level exceeding the drainage capacity through the PVC pipe. Also, the water supply by capillary rise to dyke crops (papaya and banana) is optimum in *kharif* season. The surplus water from pond is allowed to the natural drain in downstream for meeting the ecosystem services.

Dyke crops papaya and banana in *kharif* season

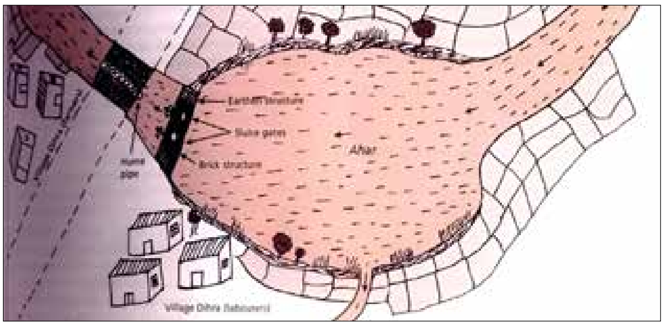
Integrated rice-fish-horticulture-duck system: In saucer shaped lowlands, rainwater and flood water from the surrounding area accumulates. Drainage is often not feasible, and semi-deep and deep water rice varieties are grown with low productivity. Productivity of such lands can be increased by 2 - 3 times by land modification to integrated rice-fish-horticulture-duck system. A strong dyke (1 m high, 2 m wide at top and 4 m wide at bottom) around the system is useful to prevent flood water and wild fish, and to check the escape of cultivated fish. Dyke height is ~ 0.4 m higher than the normally expected maximum water level. One outlet using PVC pipe (0.4 m dia) is provided in the down corner at 0.8 m below the dyke for draining excess water under gravity, when feasible. The outlet should have fine-meshed net to prevent escape of fish from pond refuge and entry of wild fish from outside. The field, pond refuge and side trenches are interconnected for water harvesting and synergistic interaction among rice, fish and dyke crops. The pond refuge (12 m width and 2 m



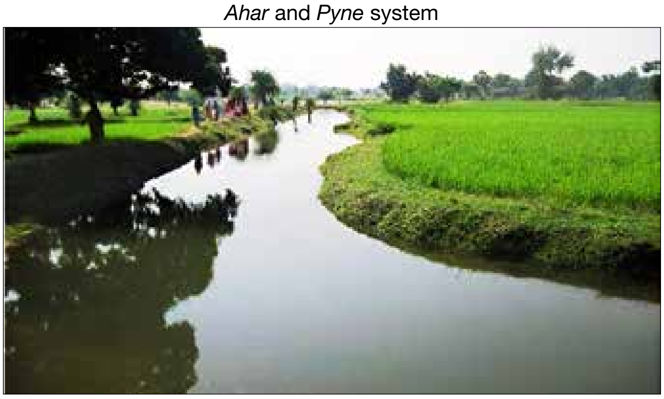
Multi-stage rainwater harvest and multiple use of water deep) is constructed at the down end of the field. Two side trenches of 2.5 m width are constructed adjacent to the dykes along the longitudinal side of the field and are connected to the pond refuge. The trench bottom should have a gentle slope of 0.75% towards the pond refuge. About 60% area is used for the undisturbed field, 23% for dykes on 4 sides, 7% for the pond refuge, and 10% for two side trenches.

Rice-fish-horticulture system in rainfed semi-deep water area

Ahar and pyne system: The traditional system of *ahar* and *pyne* is one prominent practice in South Bihar. *Ahar* is the water harvesting structure and *pyne* is the diversion channel carrying the water to crop fields. Some *pynes* can be created by erecting embankment in the river beds. During dry spell, irrigation water for paddy crop is drawn out from *Ahars* by opening pipe outlets made at different heights in the embankment. Beds of *ahar* and *pyne* can used to grow a *rabi* crop using the residual moisture, especially in drought years in which the water level recedes fast. The system is also useful in groundwater recharge. Average area that can be irrigated from *Ahar* during *kharif* season is 57 ha and can go up to 400 ha.



Ahar and *Pyne* system



Ahar and *Pyne* system prevalent in Southern Bihar

Evaporation management

The prominent management options include early sowing, mulching, residue recycling, and zero tillage or reduced tillage.

Early sowing and promoting early growth: The rate of evaporation is low (2 to 3 mm per day) during the colder months of December and January, and increases progressively in subsequent months and reaches a peak in May-June. Early sowing and promoting early growth of suitable cold loving crops helps in utilization of profile moisture, early harvest, and evading the period of high evapotranspiration rate.

Mulching: Mulching with dry leaves, weeds and other bio-wastes help in lowering the soil temperature in summer and checking evaporation losses. Also, the weeds are controlled. In winter, mulching improves the soil temperature for fast sprouting of tubers, germination of seeds and increases the crop yield. Mulching when integrated with surface drip irrigation for close spaced row crops, it saves water by checking evaporation loss. Further water saving is possible by integration of mulching and micro-irrigation with the application time limited to critical crop growth stages only.

Use of crop residue: Leaving behind crop residues on field over long period is effective at field level to promote infiltration, reduce evaporation loss and facilitate water availability to plant by maintaining pore size distribution, bio pore creation, and microbial aggregation. For significant reduction in evaporation, at least 50% of crop residues should remain on soil surface.

Avoid on-season tillage: One on-season tillage operation leads to loss of about 0.5-inch water (1.27 lakh litres/ha) as evaporation. Zero tillage and reduced tillage can be practiced for sowing followed by spreading crop residues and mulch, so that the needs of on-season tillage can be avoided with a reduced evaporative loss.

SUMMARY

Rainwater management in high rainfall areas is to allow maximum possible rainwater to be stored in soil profile and harvest excess runoff, store it and use it in the same area or nearby areas. Harvesting potential can be enhanced by integrating the check dams with ponds, and multi stage harvest with ponds. ICAR-Flexi check dam or rubber dam is an inflatable structure built across a stream and used for water conservation, flood control and regulating flow of water in the stream. Tank-cum-well system, a technology developed by ICAR-IIWM is also useful for micro level water resource development and use in plateau areas with 2 - 5% slope. Integrated rice-fish-horticulture-duck system is very useful in saucer shaped lowlands, where rainwater and flood water from the surrounding area accumulates. The prominent evaporation management options include early sowing, mulching, residue recycling, and zero tillage or reduced tillage. Enhanced rainwater productivity due to water harvesting has associated benefits of groundwater recharge and biodiversity promotion.

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