<u>*Method Article*</u>

Water Harvesting, Land and Water Use Planning for Sustainable Agriculture for the Western Part of the West Bengal

Abstract

The western district of West Bengal is notorious for its water scarcity and low crop output. Having visited the sites, interacting to the farmers & officials, and studying the proposed programs there is reason to appreciate the endeavor already put and likely to put forward towards eradication of drought from the region of *Jangalmahal* area. In consideration to adverse soil, land, geographical and geological several water harvesting, agriculture, and water management strategies that have been found to be effective in the region are offered and detailed. These are (i) check dams, ponds and recharging wells in *jhor* (drainage ditch) (ii) land grading and contour bunds (iii) sub-surface dam (iv) river-bank erosion measures (v) non-conventional lined channel (vi) drip irrigation to orchards (vii) water ponds of low percolation and evaporation loss (viii) high seepage pond (ix) affluent pond (x) *jallergola* (water silo). With minimal environmental impact, successful implementation of these strategies could have a significant positive influence on drought management and agricultural development.

Key words: *jallergola*, *jhor*, check dam, chargeable battery operated pump, sub-surface dam, affluent water pond

1. Introduction

1.1 Statement of the problem

The Chota Nagpur plateau extends through Birbhum, Purulia, West Medinipore, and a large chunk of Bankura district, and is defined as a connecting link between the plains of Bengal on the east and the Choto Nagpur Plateau on the west. The highland area is significantly drier. From March through early June, a hot westerly breeze blows, with temperatures reaching over 45°C. (Goswami & Bose, 1992). Hot weather during these months, high evapotranspiration rates, steep land slopes, poor geological formation for recharging ground water and water holding capacity in the soil profile, inadequate surface water storage, lack of adoption of efficient water use practises with land and soil management, and other factors continue to make these districts one of India's most impoverished areas. However, the district's annual average rainfall is around 1400mm, and it occurs during the monsoon months of June to September, as it does in the rest of Bengal, with the majority of it quickly draining out of the area as runoff water, and the remaining months may be comparable to any desert district in India. Efficient land and water utilisation might be considered the first step toward increased agricultural yield. Identification of a suitable location and structures to be built with a primary focus on water conservation may contribute to the project's failure at times. It should be taken into account in its entirety. Water use techniques, present or prospective crop cultivation, land and soil management, finance sources, crop product marketing facilities, and other factors all need equal consideration in the pursuit of agricultural sustainability.

2. Methodology

2.1 Check dams and ponds in *Jhor* (drainage ditch)

The check dam is a solid structure made across a river to create reservoir on its upstream (Kumar & Nikhil, 2015). About 60% of the total arable land in India is rain-fed and characterized by low productivity, low income, low employment with high incidence of poverty and bulk of fragile and marginal land. Rainfall areas in these areas are highly variable both in terms of total amount and its distribution, which lead to moisture stress during critical stages of crop production and makes agriculture production vulnerable to pre and post production, risk (Kumar & Nikhil, 2015).

The *Jhor*, the natural drainage ditches of the watersheds are in good numbers in each districts of *Jangalmahal*. The runoff producing zones of these watersheds usually have high slopes, so the high velocity of runoff water and cause of top soil erosion. Bank erosion of the *Jhors* during high storms in the monsoon and the formation of gullies are observed in these watersheds, as a result the bed of the *Jhors* have widened or the process is in progress. These *Jhors* usually have no stored surface water in the month of September onwards even where there are small check dams or any other form of similar structures are made. However, some crops (mostly paddy) are grown in the bed of the *Jhors* by using available soil moisture and seepage water from the adjoining areas. In the watershed area, growing paddy or any other water loving crops have high risk. Crop damage due to want of life saving irrigation is the regular feature.

These *Jhor*s may be used for storage of surface as well as sub-surface water by constructing series of water ponds in the main water course of the *Jhor* with dug wells in the ponds where geological formation permits along with the check dams. During the monsoon these ponds will store the water as well as recharge ground water. However, examination of formation characteristics before construction of dug wells and recommended filtering norms must be followed for recharging ground water. The schematic diagrams of the *Jhor* and the proposed area under consideration for construction of ponds, path of guided storm water, check dams, etc. are shown in **Fig.1 & 2**.

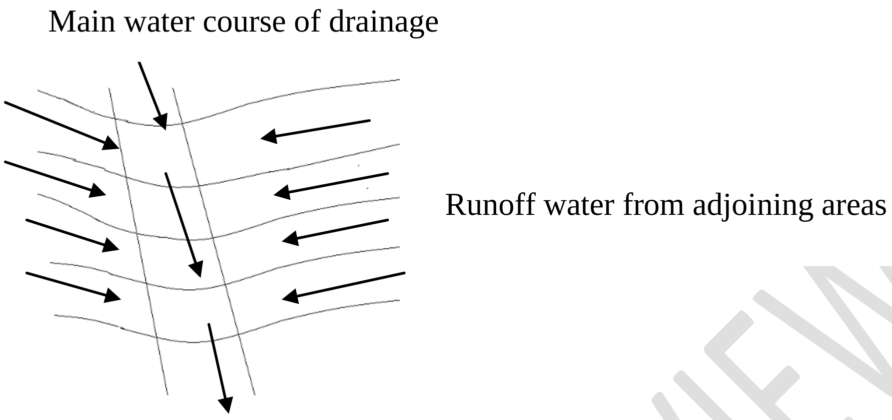

Fig.1 Schematic diagram of proposed water course in *Jhor*

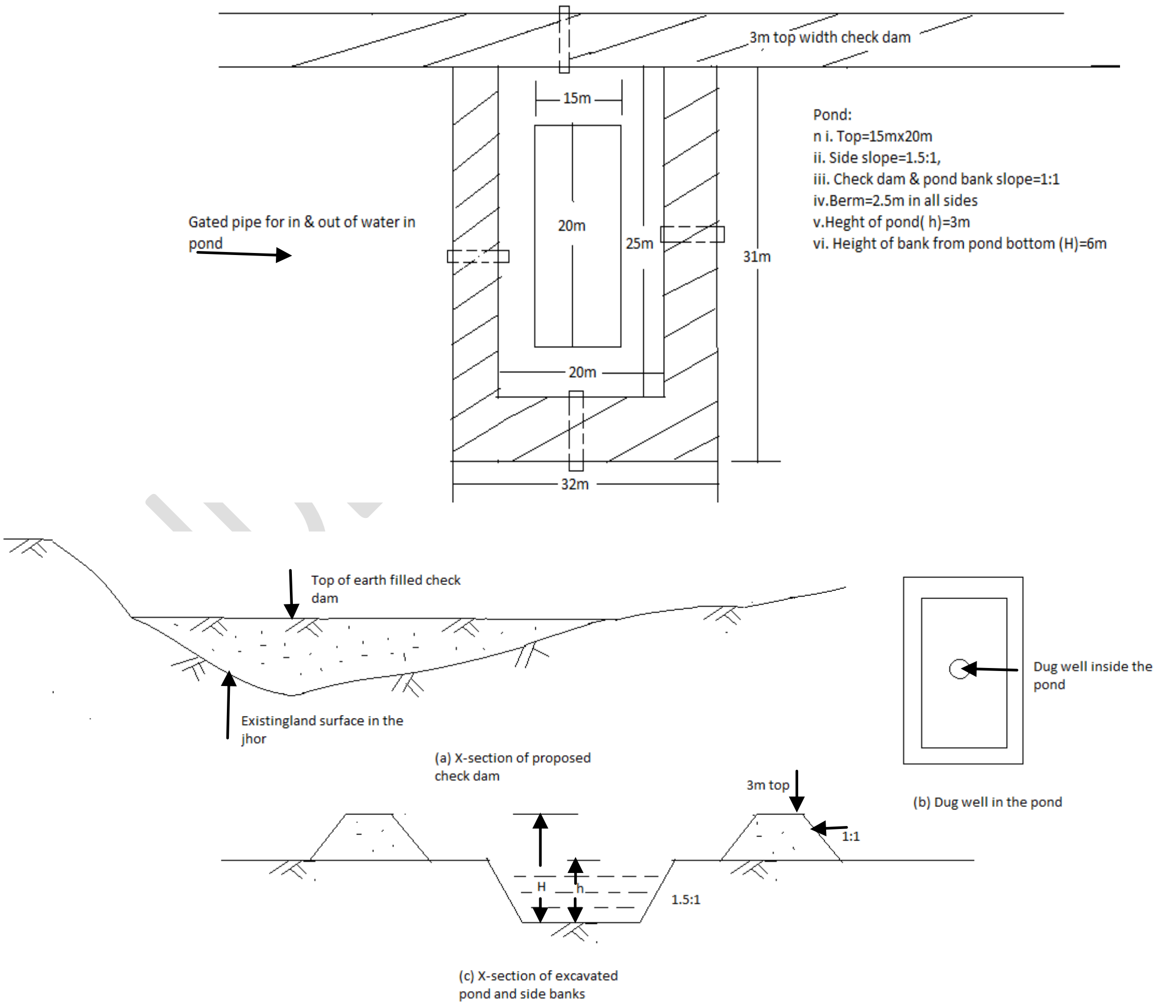

Fig.2 Check dam, ponds & dug-well sections & locations

2.2 Land levelling and contour bunds

Contour bunding is the construction of small bund across the slope of the land on a contour so that the long slope is cut into a series of small ones and each contour bund acts as a barrier to the flow of water, thus making the water to walk rather than run, at the same time impounding water against it for increasing soil moisture. (Anonymous[1]).

The runoff contributing areas of two sides of the *Jhor* have high slopes. This causes quick disposal of runoff water as well as susceptible to top soil erosion and in course of time forms gullies. This area may be leveled to flat or mild slope section to the length of runoff water. It may check erosion as well as contribute to enrich soil profile moisture. However, it involves comparatively high cost. Contour bunding may be the practical alternative.

The contour bunds at interval will impede the runoff water and divert to grass covered disposal channel for delivering it to *Jhor* where it is stored for long or allowed to held up for the period following the situation of water availability at the instant time. A sketch of contour bunding is shown in **Fig.3**.

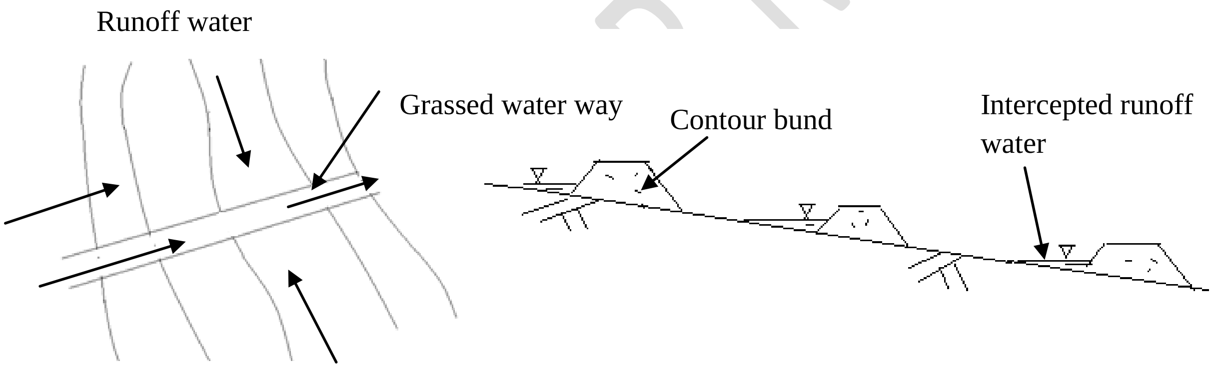

Fig.3 Contour bunds & grassed disposal channel

2.3. River lifts and sub-surface dam

Darakeswar or other rivers in this area is intermittent in nature. During the month of September onwards the rivers get dried. There is usually no surface water flow. Some water in sporadic patches is available in the bed of the river. RLI pumps are seen to operate for some time and stop till some water accumulates in these spot of patches. It is reported that in these rivers there is about 5ft depth of sand bed. Through this bed there is small flow of water which is presumed to be the contribution of sub-surface flow from adjoining areas. This water which flows through the sand bed can be held up by the sub-surface dam. Perspex or any other thick plastic sheet if inserted across the river inside the sand bed up to the depth of bottom (5ft approx.) that will create ponding of water up stream of the dam. At the dam site the RLI projects can be implemented. Such type of dam may be constructed at some interval depending on the flow of water.

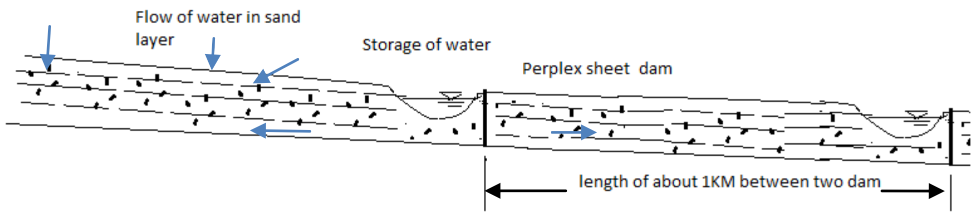

Fig.4 Sheet dam in river bed

2.4. River bank erosion

River bank erosion, is the wearing a way of bank materials of a river. River bank erosion has emerged to be one of the most dreadful environmental problems in India. The rivers Ganges, Son, Yamuna, the Brahmaputra, Chambal and Mahi, all are tough competitors when it comes to their bank erosion (Chatterjee & Mistri, 2013). Bank protection that is commonly used is made from masonry or concrete which is expensive and not natural or not environmental friendly; disagrees with spirit and soul of eco-hydraulic. In areas where tree pruning, snag removal and brush cutting must be carried out these materials can be recycled to the stream in the form of bank protection. Debris can also be used to slow the water, trap silt and sediment and permit the growth of river-edge plants (Kheiralla and Siddeg, 2015).

During the high flow in the river in the monsoon there is continuous occurrence of bank erosion. The soil of bank of these rivers is coarse to gravel mixed and therefore more susceptible to impact of wave and current. In some places it is observed that at the foot of the river bank stone boulders are being used as toe guard.

Earth filling in steps with toe guard and growing of vetiver grass may have impact on development of already eroded river bank.

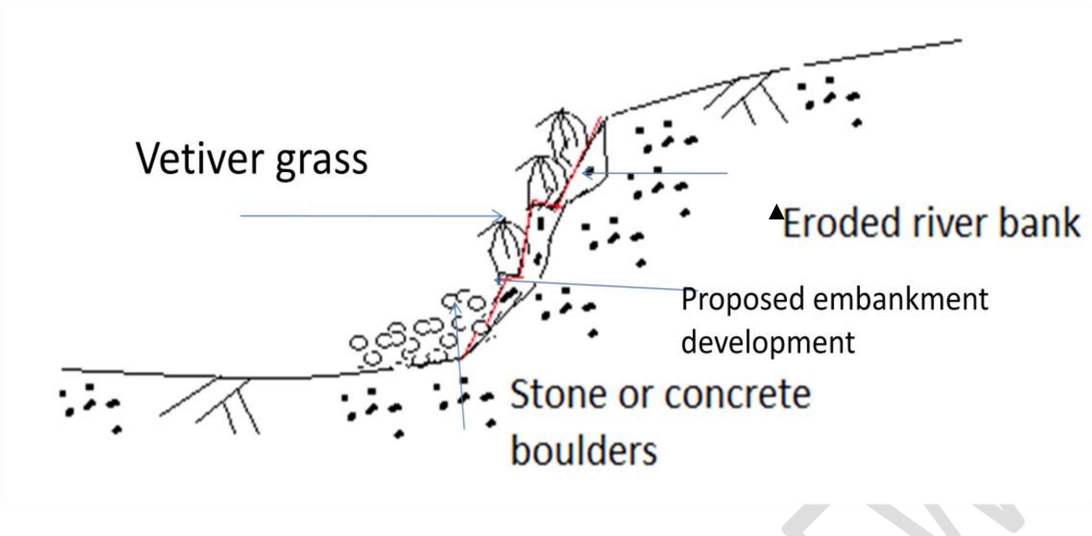

Fig.5 River bank erosion control measures

2.5. Irrigation methods

(a) Conventional

The amount of available water in the ponds or in the river or canal is being used in conventional way. The conveyance channels are earthen, zig-zag, and poorly managed. It incurs high conveyance and application losses. It can be presumed that more than 2/3rd of water diverted from the source not comes in use to the crops. These irrigation channels may be lined. Brick and concrete channels are found popular to the farmers. These are costlier. Instead of these much less costlier earthen tiles may be used to line the irrigation channels (**Fig.6).** The earthen tiles not only less costly but also eco-friendly and can be made by the local potters. It will have positive impact to local economy (Biswas, 2009). The longevity of this channel is high and loss of water through it decreases with the advancement of time in contrary to the characteristics of other lined channels.

(a) Half-round channel (b) Trapezoidal channel

Fig. 6 Half-round and trapezoidal earthen tile made channels

(b) Drip Irrigation

Drip irrigation is so far the most advance method of application of water at the plant bottom at a rate nearly equal to the consumptive use rate of the plant, thereby minimizes the conventional water losses like percolation, runoff and evaporation from soil (Biswas, 2014) (**Fig.7**). It is a process of slow application of water on, above or beneath the soil. Fertilizer can also be applied with the drip water. Emitters or applicators are placed closed to the plants and used to spray water in the form of drops, tiny streams or miniature spray. In the drip system water applied from the point source advances in all direction in the soil outward from the source. Drip irrigation is essentially a low rate, low pressure, frequent and long duration application of water in plants root zone area.

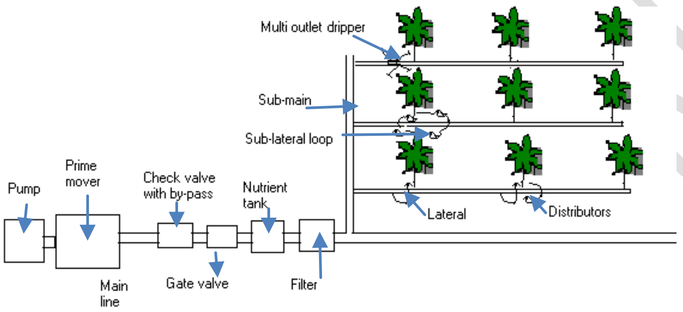

Fig.7 A schematic diagram of drip irrigation system

In consideration to the shape of the land, soil type, severe constraint in availability of water, climate, etc., there is little alternative other than to bring more area under cultivation of fruits, orchards and plantation crops and application of irrigation water to these crops through drip system. The soils in the area have low water holding capacity with higher infiltration and percolation rate. Traditional method of water application rarely be an economic proposition of water in such situation.

Use of suitable soil amendments to root zone soils to increase the water retaining ability of soil, plastic cover as mulch up to the wetted area around the plant to check the evaporation water loss and drip application of water to avoid conveyance and application losses, may be the appropriate method of cultivation practices for better water use, yield and economy (**Fig.8**).

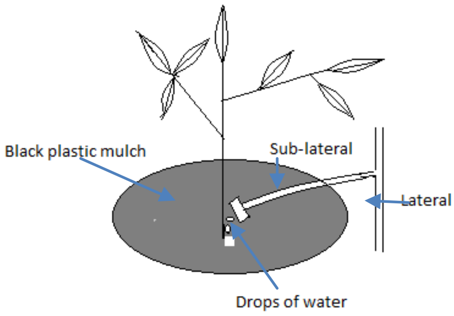

Fig.8 Drip water application with mulch at plant bottom

2.6 Farm ponds

It was suggested to store water in *jaler gola.* These are structures made of circular/rectangular underground LDPE/HDPE storage tanks. Such structures are suitable for *Jangalmahal* as also for coastal areas, affected with salinity. Seepage loss is predominant (35-40) in most of the surface irrigation schemes. Such losses may be reduced to less than 10% by using 500 micron HDPE with anti rodent adhesive food grade geo-membrane lining in canals and reservoirs. Evaporation loss may be reduced by covering 70-75% of water surface area with thermocol. Besides, eco friendly chemicals like acetyl, stearyl and fatty alcohol emulsions may be used to retard evaporation loss to the extent of 40% (Anonymous[2], 2011).

(a) Ponds with bottom and sides lining and thermocol cover

Water pond is the traditional water harvesting structure throughout the Bengal. It has got multipurpose use and available in many households. Most of the household ponds can provide little water for irrigation purpose. In the districts of *Jangalmahal* area it appears to be true due to higher evaporation and percolation or seepage losses. However, farmers prefer to have farm pond not only for storing water for irrigation purpose but also to generate scope for cultivation of fish. Such a farm pond along with the approximate volume of works and cost are stated as below.

The farm pond is designed for using the water for irrigation and with the possibility of fish culture. Thus, the lining of side walls is planned up to 2/3rd of the depth of the pond from the bottom.

The pond shall have a bottom area of 40m X 30m with 3 m depth in the middle. The side slope is to be divided into two parts, the bottom part up to 2m height with 1:1 side slope while the top 1 m is provided with 2:1 side slopes. In between these two slopes a 1.0 m wide berm is provided for supporting anchoring of geo-membrane and manual maintenance & the stability of the pond (Fig.9).

The geo-membrane will be applied only up to the 2 m height and anchored properly through the middle of the berm. The upper 1 m height with 2:1 side slopes will be compacted properly and if possible slurry of fresh cow-dung and clay mixed in 1:1 ratio has to be applied.

The size of additional catchments area should be twice of the size of the pond. The catchment area can be developed by using 200 to 250 π UV resistant LDPE film to cover the selected catchment area having a gentle slope. The transparent LDPE film can be used above the catchment area with a reasonable height that gives the farmer the scope of protected cultivation.

Estimated cost (at site)

1.	Excavation –	4439 cum - @ Rs. 73/cum	= Rs. 3,24,047=00
2.	500μ HDPE film (upto 2m)-	2000 sqm - @ Rs.100/sqm	= Rs. 2,00,000=00
3.	Fixing charges -	2000 sqm - @ Rs. 30/sqm	= Rs. 60,000=00
4.	200μ LDPE film for catchment-	4000 sqm - @ Rs. 29/sqm	= Rs. 1,16,000=00

Total = Rs. 7, 00,047=00

Expected yield

It can be expected that the pond will be 90% filled with harvested rain-water (about $4000m^3$), which includes the interim use of water. However it can be expected that about $2700m^3$ water will be there for off-season use.

To avoid evaporation loss, any non-decaying material like 'Thermocol' may be floated on the surface of the pond covering about 70% of surface area for favouring seasonal fish culture with supplement food. For cultivation under drip irrigation, the maximum water requirement is about 18cm. Therefore, $2700m^3$ water irrigates = 2700/0.18 =$15000m^2$ = 1.5ha

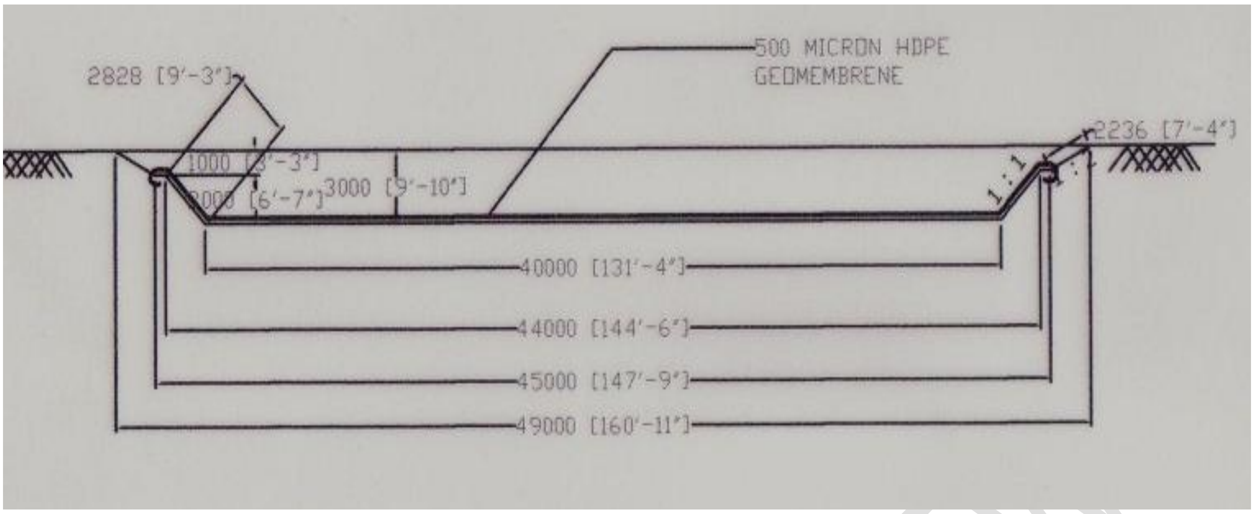

Fig.9 Design section of farm pond

(b) Ponds with bentonite layer bottom and top cover with creepers

Bentonite has got the good characteristics of poor conductivity of water. If it is used at the bottom of the pond in layer of 10cm thick it may check considerable amount of percolation loss of water particularly in a newly excavated pond up to a coarse zone. At the sides of the ponds cow dung and rice husks mixed with mud may also check the seepage losses to a good extent. The top of the pond may be covered by growing creepers like cucumber, bottle gourd, etc. over the *mancha* (platform) **(Fig.10**). In additional to creation of scope of cultivation of crops this practice will help to reduce the evaporation loss of water due to lower surface temperature of pond water by the crop cover.

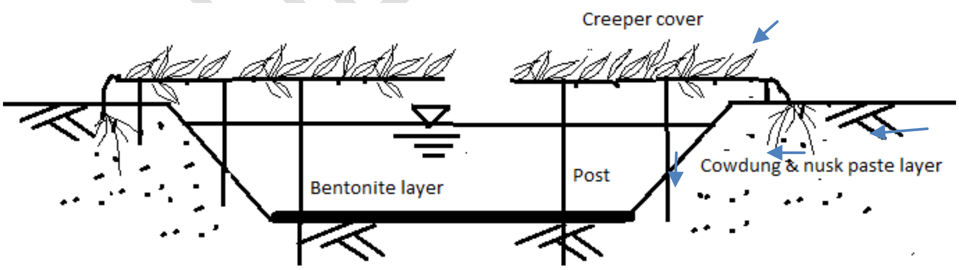

Fig.10 Section of pond with bentonite bottom and top covered by creepers

(c) Pond with high seepage water towards down stream

It is observed that at the upstream of a watershed there are some old pond re-excavated in recent time to increase the storing capacity. This pond has got the character of constant seepage contribution to the down slope. Water of this pond is found in use partly by managing this seepage water and partly diverting directly to the down side through pipe outlet. It has been reported by the villagers that the expert personnel did the geological and soil survey of the area and they found these pond sites as the best ones. From this information it may be presumed that below the bottom of the pond within short distance there might have an impermeable layer which restricts the percolation loss of water and the coarse soil of pond bank permits high rate of seepage flow. The situation is described by the **Fig.11.**

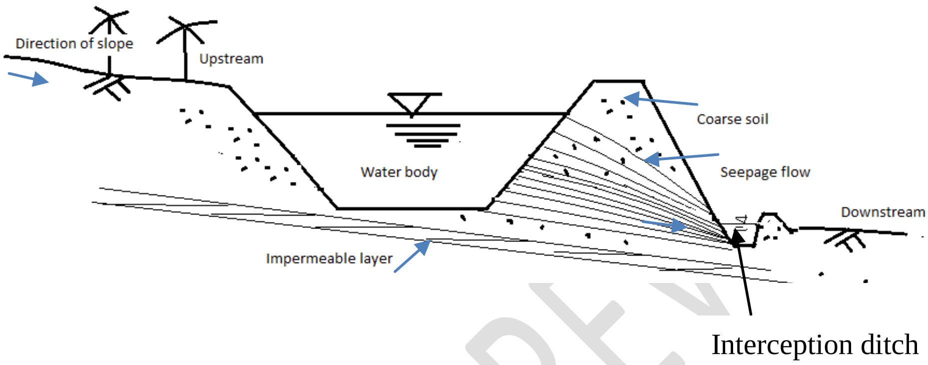

Fig.11 Sectional view of pond with high seepage to down stream

Selection of this type of sites for pond may give the benefit of much controlled loss of water through percolation and the seepage water can be beneficially used for crop production.

(iv) Pond with sub-surface inflow in it (affluent pond)

Underground dams provide a valuable source of water for consumption of drought season. However, the contaminant levels of the water need to be monitored to ensure that they did exceed standard limits (Fakharinia *et al.*, 2012).

It has been reported that in some places if ponds are excavated it gain water due to contribution of sub-surface flow in it in the season and off season as well. In fact the sub-surface flow is intercepted by this pond which comes across to the sub-surface flow path of water. Thus, the capacity of water storage of this pond is become much more as apparently created. With the support of a schematic diagram such situation is explained in **Fig.12**.

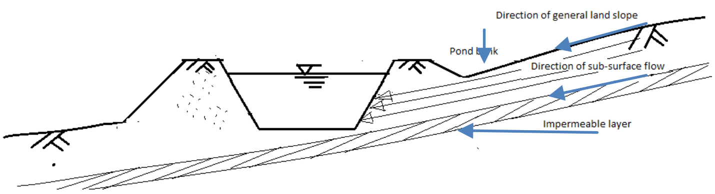

Fig.12 Pond with sub-surface flow in it

To find out the suitable site for such type of pond the soil profile study is required. The catchment of upstream to the pond and seepage flow characteristics need to be known for better selection of site as well as to have an idea of availability of water through sub-surface flow other than surface runoff water.

2.7. *Jallergola* (water silo) & battery powered drip system cultivation practice

(a) Circular

The different diameter flexible LDPE/HDPE (500π) is available in the market. Getting it one end closed and another end open the water containing structure could be made. Also by using suitable gauge poly sheet, the required diameter poly tube can be made by jointing through appropriate welding. The plastic sheets of adequate thickness can also be used to construct rectangular shape structure. The pits in the land to be excavated across the slope and it may be little bit larger in size such that it can comfortably accommodate the water-filled poly bag or sac placed in it. This may be called as *jallergola* and can be made in series by providing earthen partition walls in between the two *jallergola.* The *jallergola* to be filled up with water by allowing the incoming runoff water from upstream within the plot guided through small bunds to enter in the *jallergola.* These are now covered with some straw over bamboo sticks made net to protect it from natural calamities and human or cattle interferences. These are placed preferably in between the plant rows so that no land is lost for use.

Dimension of *jallergola* = Diameter 2m & depth 3m

Capacity of *jallergola* = 9.42m^3 ≈ 9m^3 (say) or equivalent 3m x 2m x1.5m rectangular *jallergola*

Cost of each *jallergola*

Polythene bag = 25m^2 polythenexRs.100/m^2=Rs.2,500

Excavation of earth = 9.42m^3xRs.40/m^3=Rs.376.8≈Rs.380

Cover of straw under bamboo sticks made net= Rs.50

Misc =Rs.70

Total = **Rs.3, 000**

Unit cost of water

Assuming the longevity 5 years & maintenance of Rs.200/year, the cost of per liter water=3000/ (9x1000x5) +200/ (9x1000) =0.066+0.02=0.088≈Rs0.09= **9 paisa**

The cultivation is proposed under drip irrigation. In consideration to average pan evaporation during the irrigation days (2.5, 2.75, 3.00, 5.5, 6.5 and 7.0 mm/day during December to May respectively), crops (horticultural/fruits/vegetables), crop coefficient (0.9), pan factor (0.8), wetting area (30%), the irrigation water requirement = **1815m^3**

This number of *Jallergola* required for 1ha area = 1815/9 =201.66≈ **200**

(b) Rectangular

For **0.2ha** field, the trench may be excavated by 3m width x 2m depth x 31m length of 2 numbers. The polythene is to be placed along the sides & bottoms of the trenches and anchored properly on the bank as shown in **Fig.13**. The top is covered with polythene attached to bamboo sticks made net. This polythene also anchored properly in soil to stop movement of air over water in trench. However, some portion may be kept open if specialized (air breathing or such type) fish culture is done with supplement feeding.

Fig.13 Rectangular *Jallergola*

Cost:

i) Excavation=3x2x31x2=372m^3@Rs.40/m^3=Rs.14,880

ii) Plastic(500µ)=(31+3)x2x2+(3x31)2 +(31+3)x2x0.6=244.8m≈250m^2@Rs.100/m^2=Rs.25,000

iii) Polythene= (3x21x2)x1.1=126≈135m^2@Rs.10/m^2=Rs.1,350

iv) Bamboo stick net = Rs.1,500

v) Misc=Rs.270

Total=Rs.35, 835≈**Rs.43, 000/-**

Cost/ha=Rs.2,15,000/-

For **0.2ha** area the water requirement = 1,815m^3/5 = **363m^3**

Volume of water/*Jallergola* = 3 x2x31 = **186m^3**

Volume of water in 2 numbers of *Jallergola* = 186x2 =**$372m^3$**> **$363m^3$**

Unit cost of water:

Assuming the longevity 5 years & maintenance of Rs.2, 000/year, the cost of per litre water= (43,000x2)/ (363x1000x5) +2,000/ (363x1000) =0.047+0.0055=0.0229≈Rs.0.052=**5 paisa**

2.8 Drip system

The drip system is considered for portable battery powered water pump of 0.1HP capacity able to irrigate 0.2ha of land at 1000l/h discharge and 12m head. The battery is 12V of 90A.This pump set can works 3.5-4 hours at a stretch .In fact; 0.027HP pump set is required to irrigate 0.2ha land at a time @ 400lph discharge for 4 hours. Therefore, if the land size is doubled that also can be irrigated by the 0.1HP pump set at a time with little less uniformity of coefficients of emitter flows. This pump set can cover an area of 1ha if operated for 16-17 hours in a day in peak time. Thus, this pump set capacity may be said 1 ha.

3. Discussions and conclusions

Due to lack of organic compound in soil, most of the water goes away as runoff during the storm in the western part of West Bengal. The drainage ditch (jhor) may be used for storage of water by the proper construction of dug wells. However, examination of formation characteristics are required before construction of dug wells and recommended filtering norms must be followed for recharging ground water. The contour bunds at interval will impede the runoff water and divert to grass covered disposal channel for delivering it to jhor where it is stored for long or allowed to hold up for the period following the situation of water availability at the instant time. Bank protection materials commonly used are made of masonry or concrete which is expensive and not natural or environmental friendly .It disagrees with the spirit and soul of eco-hydraulic. Plantation of vetiver grass at river bank may be a good alternative to control the erosion. It has been found that earthen tiles are the eco-friendly and less costly material which can control the water losses much more effectively over the conventional earthen irrigation channels. Drip irrigation is a low pressure, low volume irrigation system which is very much suitable for high value crops such as fruits and vegetables. If managed properly, drip irrigation can increase yield and decrease the use of water, fertilizer and labour. However, it needs power to operate the system. The area here in under consideration is so under developed that most of the villages have not access the electricity to run the pump set. The use of diesel pump is costlier. The farmers of these areas are mostly scheduled caste and tribes having small land holdings presumably unable to afford power operated drip irrigation unless provided with free of cost or subsidized considerably.

As a suitable alternative to diesel or electrically operated pump set, the solar photovoltaic and chargeable battery water pump set may be tried.

The water silo may be an economically suitable and technically feasible practice of water storage in adverse geological and geographical area. It may be constructed at water scarce western part of West Bengal and tested its applicability in combination with pump driven by chargeable battery or solar power to operate the drip system. The successful implementation of these programs may have the considerable positive impact on drought management and agricultural development as well at the minimal deterioration to environment.

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