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Improved Water Management Under Rainfed Agriculture With Special Reference to Coastal Ecosystem - A Computer Simulation Modeling[1]

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ABSTRACT

Rainwater conservation forms the core of the improved watershed management approach suited particularly to the small land holdings in coastal ecosystem. It is an integrated approach on rainwater management, dealing with on-farm harvest and storage of excess rainwater during monsoon, and recycling the same for irrigation for dry season (deficit water period) crops, with the objective to introduce multicropping in the otherwise predominantly monocropped areas. We present below, in this paper, the salient aspects of the comprehensive works done at CSSRI, Regional station Canning for the Sundarbans area of West Bengal.

1. The analysis shows that the region has an average (1963-92) annual rainfall of 1768 mm ranging from 1030 mm to 2462 mm . It also indicates that the month of July and August are the wettest and there is probability of severe damage to the crop in these months. The water balance analysis shows considerable scope for conservation of excess rainwater in on-farm reservoirs.

2. A soil water balance model for rainfed rice cultivated in humid, deltaic lowland was developed to estimate the excess rainwater availability. It was recommended to convert 20 per cent of the watershed area into OFR to harvest excess rainwater. The optimal design of OFR was suggested which should be of great use for developmental agency as a ready-design reckoner.

   Design of On-Farm Reservoir (OFR) suggests that the parameters are shape, size, depth, side slope, capacity and location. The dug-out type of OFR are most common in flat topography. The prevailing trapezoidal OFR with and without *bund* were considered to determine optimal size of OFR.

3. Probability analyses of weather data including rainfall and evaporation, as a measure of crop water demands, has been used to propose an optimal planting schedule for rainfed rice for different farming situations in order to minimize the climatic hazards. Based on monsoon and dry season planting schedule and crop suitability in the region, a crop calendar for optimal farming operations was prepared with the objectives of stabilizing production and minimizing recurrent production losses due to uncertain weather. Similar studies can be made for crop planning in rainfed areas of different agro-ecological conditions to cope up the problems of climatic hazards.

4. In rainfed humid lowlands, improvement in surface drainage is possible through rainwater harvesting in OFR. Improvement in weekly surface waterlogging was simulated by providing the optimum size of an OFR in a unit watershed area. It was estimated that rainwater storage in OFR improves surface drainage to the extent of 75 per cent and thus provides the scope for cultivation of high yielding rice varieties in rainfed humid lowlands.

5. A simple linear programming model was used to propose an optimal land allocation for dry season (winter and summer) cultivation under various limitations of land and water to arrive at a contingency

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plan for maximization of profit. Economics of the data generated in farmer's field under OFR with and without *bund* under various constraints have been worked out.

A software on computer simulation model has been developed on **RAINSIM** for the benefit of the users. The software is user-friendly and tested for a wide range of situations for its versatility. It may be used for all situations related to rainfed agriculture.

India has a 8,129 km long coastline. Its peninsular region is bounded by the Arabian Sea on the west, the Bay of Bengal on the east and Indian Ocean to its south. It has two distinct major island ecosystems, the Andaman and Nicobar Islands in the Bay of Bengal and the Lakshadweep Islands in the Arabian Sea. The hinterland of the coastline has varied geomorphic and topographical features of mountains, valleys, coastal plains, riverine systems, climatic conditions, soil conditions and water budgets, and a wide range of cultivated crops.

Coastal areas, mostly saline in nature, are different from inland areas in that the latter are formed due to secondary salinization through high water table conditions caused by the introduction of irrigation in arid and semi-arid areas, whereas salinity problems in coastal soils is caused during the process of their formation under marine influence and subsequently due to periodical inundation with tidal water, and, in case of lowlands having proximity to the sea, due to the high water table with high concentration of salts in it. The coastal soils exhibit a great deal of diversity in terms of climate, physiography and physical characteristics, as well as in terms of generally a rich stock of flora and fauna.

The coastal zone may thus be defined as representing transition from terrestial to marine influences and vice versa. It comprises not only shoreline ecosystems, but also the upland watersheds draining into coastal waters, and the nearshore sub-littoral ecosystems influenced by land-based activities. Functionally, it is a broad interface between land and sea that is strongly influenced by both.

Drainage embankments

All major rivers and drainage lines terminate in the coastal zone. The silt load carried alongwith the river flow increases the drainage congestion, leading to flooding of the agricultural field. It has been suggested that earthen embankments, preferably brick-pitched, having side slope of 3:1 on the river side and 2:1 on the country side, with 1 m free board above the high tidal level, are appropriate for protection against flooding. To effect drainage from such embanked areas, one-way sluice gates are provided in the embankments. A suitable shelter with trees or grasses will further strengthen the embankment from tidal wave action. For protection against shifting coastal sand dunes, planting of wind break may be beneficial.

It has been observed that only in a few irrigation commands field drainage is now being provided by the Command Area Development Authorities. For improving the field drainage system, it is suggested to construct peripheral *bunds* to clearly demarcate the catchment and also the various fields, so that inflow of excess water from outside the area into the catchment and the flow from one zone to another is regulated.

Watershed management

Watershed management aims at an integrated use of land and water resource, on the one hand, and higher productivity and sustainability, on the other, depending upon the local conditions. It helps reduce erosion, runoff and other degradation processes, and augments availability of food, fuel, fodder, and other products. Majority of watersheds in coastal ecosystem fall in the rainfed area of low to medium range where agriculture has low productivity and stability. Watershed management in the West and East coast receiving high rainfall, and characterized by topographical setting of hill slopes in the West, as well as plain areas, beside some areas lying below the sea level in Kerala, is also of paramount significance. Integrated watershed management at macro and micro scale, the latter being of specific significance for the coastal areas having poor land holding, in general, with focus on drainage, irrigation, and crop improvement practices has, therefore, a vast scope.

Rainwater conservation

This forms the core of the improved watershed management approach suited particularly to the small land holdings in coastal ecosystem. It is an integrated approach on rainwater management, dealing with on-farm harvest and storage of excess rainwater during monsoon, and recycling the same for irrigation for dry season (deficit water period) crops, with the objective to introduce multicropping in the otherwise predominantly monocropped areas. We present below, in this paper, the salient aspects of the comprehensive works done at CSSRI, Regional station Canning for the Sundarbans area of West Bengal (Sen *et al.* 1998a,b; Ambast *et al.* 1998a,b,c; Ambast and Sen 1996, 1998).

1. The analysis shows that the region has an average (1963-92) annual rainfall of 1768 mm ranging from 1030 mm to 2462 mm. It also indicates that the month of July and August are the wettest and there is probability of severe damage to the crop in these months. The water balance analysis shows considerable scope for conservation of excess rainwater in on-farm reservoirs. It was also estimated that, on an average, about five week drought may occur during the monsoon and about three week continuous drought is expected during the ripening stage of rainfed rice crop.

2. Estimates of excess rainwater availability are important for designing an on-farm reservoir (OFR) to provide supplemental and life-saving irrigation, and to improve surface drainage. A soil water balance model for rainfed rice cultivated in humid, deltaic lowland was developed to estimate the excess rainwater availability. It was recommended to convert 20 per cent of the watershed area into OFR to harvest excess rainwater. The optimal design of OFR was suggested which should be of great use for developmental agency as a ready-design reckoner. The procedure suggested may be used for optimal design of on-farm reservoir in different agro-ecological conditions.

Design of On-Farm Reservoir (OFR)

The design parameters are shape, size, depth, side slope, capacity and location. The dug-out type of OFR are most common in flat topography. The prevailing trapezoidal OFR with and without *bund* were considered to determine optimal size of OFR. The length-width ratio of OFR was taken 1:1 as it is having the minimum parameter, and therefore attains maximum storage. As ground water is at shallow depth and saline in nature, the depth of OFR with and without *bund* was taken as 2 m and 3 m respectively. The side slope for silty clay loam soil was kept as 1:1.

Probable weekly rainfall values at 2 year return period were used for design of OFR. The initial size of OFR was kept at 40 per cent of the farm area. The location of OFR was varied to allow runoff from 10 to 100 per cent of farm area. If OFR was found empty a negative increment to size of OFR was provided for further computation. When OFR got filled, the size was considered as optimal and the process was terminated. Computations were made at percolation losses of 3,4,5 mm d^{-1}.

A monograph has been developed to determine the hydrologic and hydraulic features of OFR in unit farm area for various combinations. It represents three types of curves, i.e. the design dimension curve, OFR capacity curves, and rainwater availability curves. Since OFR was considered square in shape the design dimension curve represents the equal length and width of the selected size of OFR. The OFR capacity curves give the information on total volume that can be stored in the OFR of different sizes. The capacity curves were plotted for OFR with and without *bund* with 2 and 3 m depths respectively. The rainwater availability curves for different sizes of OFR, i.e. 10, 20, 30 and 40 per cent of farm area were generated for construction of OFR at different locations, i.e. 10, 50 and 100 per cent below farm area which contribute runoff from 10, 50 and 100 per cent farm area, respectively. Further, rainwater availability for different percolation losses, as mentioned earlier, were generated.

3. Probability analyses of weather data including rainfall and evaporation, as a measure of crop water demands, has been used to propose an optimal planting schedule for rainfed rice for different farming situations in order to minimize the climatic hazards. Based on monsoon and dry season planting schedule and crop suitability in the region, a crop calendar for optimal farming operations was prepared with the objectives of stabilizing production and minimizing recurrent production losses due to uncertain weather. Similar studies can be made for crop planning in rainfed areas of different agro-ecological conditions to cope up the problems of climatic hazards.

4. In rainfed humid lowlands, improvement in surface drainage is possible through rainwater harvesting in OFR. Improvement in weekly surface waterlogging was simulated by providing the optimum size of an OFR in a unit watershed area. It was estimated that rainwater storage in OFR improves surface drainage to the extent of 75 per cent and thus provides the scope for cultivation of high yielding rice varieties in rainfed humid lowlands. Therefore, construction of OFR not only provides water for irrigation, but also improves surface drainage, and thus makes it possible to grow HYV of rice in the lowlands.

5. A simple linear programming model was used to propose an optimal land allocation for dry season (winter and summer) cultivation under various limitations of land and water to arrive at a contingency plan for maximization of profit. Economics of the data generated in farmer's field under OFR with and without *bund* under various constraints have been worked out. In normal years of rainfall, it was proposed that rice should be grown in 20 per cent area, and 80 per cent area should be cultivated with non-rice crops in case of OFR with *bund*. Whereas, it was 40 and 60 per cent, respectively for OFR without *bund*. The study also indicates the benefit-cost ratio around 2 (excluding income from pisciculture and horticulture) for both *bunded* and *unbunded* OFR, which thus justifies the investment in OFR.

Efficacy of such technology on water harvesting and recycling, has been tested for waterlogged and salt-affected coastal soils in Orissa (Panda and Rath, 1991). In the coastal area of Maharashtra, pumping out of water from the dug-out pond helped in leaching of salts from surrounding areas. Pumping only once before the onset of monsoon helped leaching of salts upto a radial distance of 27.0 m (Chavan *et al*., 1985). Sharma and Helweg (1982) used optimization techniques for designing a tank system in the semi-arid tropics of India. Palanisami and Flinn (1989) studied the direct and indirect impact of varying water supplies on rice yield for a set of tank irrigation system in South India. Verma and Sarma (1990) developed a computer-based procedure for designing storage tanks and computing cost and volume of water available at the time of irrigation for planning water harvesting tank system in the *Kandi* dry farming belts of Northern Punjab. Paul and Tiwari (1994) studied the feasibility of small farm ponds for rainwater storage at Hazaribagh. The cost-benefit ratio for an unlined tank was reported as 1:4 and lining cost as US$ 135 per 100 m^2. Mayya and Prasad (1989) developed a linear programme model to optimize the net profit from tank irrigation system and to determine the optimal cropping pattern. Same model was employed by Prasad and Mayya (1989) with additional constraints for delayed start and water deficit condition. It was observed that through delayed start of agricultural operation facilities to bring more area under irrigation, grain yield was reduced due to unfavourable climatic conditions during flowering and grain formation stage. Adoption of deficit irrigation in the initial period of crop season was reported to be more advantageous, as the overall net profit of the system increased. Rao *et al*. (1988) developed a dated water production function to evaluate the effects of alternative combinations of crop water deficits at various crop growth stages for determining optimal water allocation using dynamic programming approach.

Another improved technology to utilize the surface water is life-saving irrigation by digging

Doruvus, which is a conical pit dug to collect seeped-in water. In this method, suitable particularly for sandy loam soil, fresh water floating over saline groundwater may be skimmed horizontally through tile drains at the rate of 18 lps, which would be sufficient for operating six sprinklers continuously. The technology has been tested in Andhra Pradesh.

A software on computer simulation model has been developed on **RAINSIM** for the benefit of the users. The software is user-friendly and tested for a wide range of situations for its versatility. It may be used for all situations related to rainfed agriculture.

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