CP 017

Symposium on Rainwater and Dryland Agriculture, pp 1-9
1982, *Indian National Science Academy, New Delhi*

Rainwater and Dryland Agriculture—An Overview*

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Management of rain water is the key to success in dryland agriculture as most of the cultivated areas in India as well as in the entire world depends on rainfed farming. An integrated approach for the management of rain water consists of increasing moisture storage in the soil, optimum use of this moisture through efficient cropping systems, harvesting a portion of the runoff water for "life saving" irrigation, and reorientating the concepts and organization of irrigation, including that from tanks, to enhance productivity per unit of rain water.

The development of water resource within small watersheds in which a farmer or a group of farmers may be operating can bring about a chain reaction leading to the development of a more efficient and highly productive agriculture. The management of rainwater can increase agricultural productivity of the drylands many times, reduce the flood hazards, and alleviate the misery of droughts. Intensive studies and innovative development approaches are needed to make it possible for the resource-poor farmer to use the technology for the management of rainwater. Also the feasibility of the use of solar energy for lifting water needs consideration.

National policies should aim at and encourage the efficient use of rainwater in situ. Investments may be considered a price for social justice; they will facilitate agricultural development, after centuries of stagnant agriculture, in the semi-arid areas.

Key Words: Rainwater management

According to some estimates out of 370 million ha meters of rain water which falls on 329 million ha of land in 2 to 5 months in a year, 170 million ha meters runs off in rivers and streams and hardly 80 million ha meters seems to be entering the soil system. One hundred and twenty million ha meters is lost in evaporation. It is only a fraction of the runoff water which is being used for irrigation. How can we; change this distribution and improve dryland agriculture is the main question. ln

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* Submitted as C.P. No. 17 by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

India about 25% of the cultivated area is under irrigation. For various reasons that are beyond the scope of today's discussion, hardly l/5th of the potential of these irrigated lands is presently being realised.

These irrigated areas alone could feed the entire nation and produce enough to spare but we cannot ignore half the population of the country which lives in the non-irrigated areas and has no other employment except agriculture.

No doubt irrigation is given the highest priority in our national planning and the country hopes to extend irrigation to as much as 50 per cent of the total cultivated area. But even after this expansion, half of the cultivated area in the country will still remain dependent on natural rainfall for farming. Thus, the key to equitable agricultural development and the solution to the problem of poverty lies in the drylands.

Rainfall is our natural asset. It is an everlasting resource and we have it in good measure, else we would not have been 600 million[6]. Average rainfall in India is 1125 mm[4]. If the rainfall that India receives were well distributed in time and space throughout the country, there would be no problems of droughts and floods. Unfortunately, this is not the case. The important question is whether it is possible to affect some changes in nature's distribution of rain through weather modification. Some researches on weather modification have been done in the past, but whether this approach offers any promise of practical application needs critical study.

Nearly two-thirds of the area of the country receives less than the average rainfall. Moreover, the rainfall is unpredictable and uncontrollable. Thus, management of rainwater is a key factor in the development of the Indian agriculture.

The rainfed farming areas of India can be divided into three groups[9].

.1.	*Humid and sub-humid (mostly wet/dry semi-arid tropics)	With 4.5 to 7 humid months and the remaining months dry	20.7%
2.	Dry semi-arid tropics	With 2 to 4.5 humid months and the remaining months dry	60.0%
3.	Arid tropics	With less than 2 humid months and the remaining months dry	19.3%

Most of the irrigation in the past has been confined to the arid and semi-arid areas of the country, particularly those which are geographically so located as to take advantage of major river systems (i.e., in the Indo-Gangetic alluvial plains and the deltaic areas of South India).

Most of the semi-arid areas of the country on both sides of the Vindhyas are unirrigated and depend on natural rainfall for cropping. Monsoon season *(kharif)* cropping is dominant, though some areas grow only rabi crops. In a limited area

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* This also includes a small percentage of area with more than 7 humid months and most of the areas which according to Troll's classification are wet/dry semi-arid tropics with 4.5 to 7 humid months and the rest of the months dry.

two crops are grown but their yields are low. The rainfall of all these areas is variable in intensity, amount, and distribution in time as well as in space. In most of these areas the southwest monsoons produce the rains. Some areas in South India have a biomodel rainfall pattern and receive more rain from the northeast monsoons. Since there is only a short period when precipitation exceeds evapo-transpiration, it is the management of rainwater during this period on which the fate of agriculture depends.

Strategy for Making the Best Use of Rainwater

Our approach should aim at: (i) making the best use of the rain for successful cropping during the rainy or post-rainy season by adopting cropping systems that fit into the water availability period, (ii) Harvesting and storing of some of the runoff water in small tanks nearby, when the rain exceeds the storage capacity of the soil, and (iii) Utilizing the natural drainage and runoff water through surface and groundwater irrigation systems. It is beyond the scope of today's symposium to discuss the third aspect, which is receiving attention of many engineers and planners. It is the other two approaches that will be discussed in this paper.

Humid and Sub-humid Areas

The humid and semi-humid regions of India are considered as areas of assured rainfall and a favourable moisture status for cropping. However, even in these areas, periods of moisture stress occur and assured rainfall is a myth. They grow upland paddy and maize and show greatest fluctuation' in yield. They also contribute largely to surface runoff of water, erosion and floods. They are the main sources of seasonal and perennial rivers and streams. The topography of some of this region is such that retention of the excess water in situ may be difficult, except through engineering works. Hence, the main strategy is to drain this excess water and to reduce soil erosion through better soil-conservation practices. There are a few million hectares 6f land in this region particularly in the Sivaliks and outer Himalayas in north, where harvesting and ponding of water in situ is possible and can revolutionise agriculture of the region. Drs. Tejwani, Prihar, Murthy, Misra and Bhumbla will provide enough evidence of the possibility of harvesting water in situ in this region. I consider this area as most neglected and critical for rainwater management and control of floods and erosions in north India. Every participants' experience in this region has a lot of element of location specificity, but this is good as this technology can be transferred on small watersheds of a few hectares to a few hundred hectares, provided the locations are carefully chosen. What can be done in Kandi area of Punjab, Sukhumajri (Chandigarh) Dehra Dun, Tehri Gasipul in UP Hills, Bilaspur in Himachal Pradesh, can certainly be repeated on thousands of small watersheds all along this belt. The most rewarding thing is that it enthuses farmers and ensures their willing participation. What authoritarian laws could not enforce, the spectacular production gains and elimination of risk hazards have done. I leave this topic now for the participants to develop.

Dry Semi-Arid Tropics

It is an area of greatest concern. It is an area of great instability and uncertainty of production. It grows upland paddy, dryland wheat and most of the sorghum, millets, pulses and oilseeds. It is no wonder that the production of these crops has so much fluctuation. Water is the main limiting factor in this region but because of the ill-distribution of rain both in space and time and the great variation in intensity of individual rain showers, there is a considerable loss of water as runoff (10 to 25%). This excess water besides being a serious loss to the agriculture of the region, poses a drainage problem and becomes a flood hazard elsewhere. Estimates show that about 10 per cent of the rainfall is lost as runoff from rainy season cropped black soils (deep Vertisols) and about 25% from red soils (Alfisols) under Hyderabad conditions. Most of the runoff occurs in a few storms of high intensity. Models are now available that can predict the runoff loss under a given soil, climate, crop cover, and management system[2].

The questions are: should this runoff be encouraged? reduced? or maintained? If the runoff water is locally stored, one must know how best to use it for productive agriculture. Part of the answer to the first question lies in the nature of the soil and the local cropping system and management. Kampen[5] feels that the first effort should be to retain as much rainwater in the soil on which it falls, so as to provide a favourable moisture regime to the crop.

If the rainfall intensity and amount exceed the infiltration and storage capacity of the soil, the excess water may be harvested nearby in the same field or at another convenient point in the same watershed.

Drs Kampen, Harikrishna, Venkateswarlu, Sivanappan, and Havange who have experience of this region will be presenting the specific concepts, and techniques of rainwater management in Black and Red soil zones of Peninsular India. These approaches offer considerable promise in SAT. The harvested water can be used for "life saving" irrigation so as to maximize production per unit water and stabilising agriculture. This concept is different from the one used in conventional irrigation which is based on transported water.

It is unfortunate that the small tanks and farm ponds which were most appropriate devices for harvesting runoff water in situ have receded in the background in the last few decades. At one time these formed the backbone of agriculture in the Indian SAT, particularly on the Deccan plateau. The major factors responsible for the decline of tank irrigation have been the deforestation, overgrazing, accelerated erosion, and encroachment on the catchments of the tanks which seriously affected the capacity and efficiency of these systems. Moreover, traditional tank systems have the inherent weakness that the farmers on the donor watersheds do not get irrigation. The water is used for irrigating paddy through gravity flow in the command area below. In the context of the growing population pressure, new concepts and technologies have to be introduced[8]. Improvement of tank irrigation systems need be given high priority in many states, particularly Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra, Madhya Pradesh and even some parts of Uttar Pradesh, Rajasthan, Gujarat and Orissa. The whole philosophy, technology, organization and administration of tanks for water harvesting and irrigation should be reoriented. It is gratifying to note that some work on the redesigning of tanks and the introduction of new cropping systems and irrigation techniques for less water requiring crops like sorghum, maize, groundnut, pulses, etc., has been initialed in Andhra Pradesh. However, in national planning, the development of water resources through small systems benefitting local farmers needs to be given greater importance.

The use of runoff water to charge aquifers and to recapture water in underground reserves is well understood. Unfortunately much of the runoff water does not enter the aquifers and is lost. In recent years, systems of percolation tanks are being tried in Maharashtra; the technical, social and economic efficiency of such systems requires a critical evaluation.

I restrict my comments to a few basic aspects which are:

(1) Encouragement of water-resource development on a small watershed basis so as to provide a standby water source to a farmer or group of farmers for life-saving irrigation. Availability of even a small amount of irrigation water will dramatically change the outlook of subsistent farmers through providing greater certainty. Water is an agent of change.

(2) Construction of new tanks and farm ponds and remodelling and improving the existing ones to introduce controlled irrigation using lift systems where needed so as to extend the benefits of the harvested water also to the donor watersheds is considered an act of social justice for the eradication of poverty. For this purpose the consolidation of holdings on a watershed basis, where possible and practicable, is worth attempting.

(3) Making cheaper sources of energy or devices available for lifting water for "life saving" irrigation is critical to the practical success of runoff collection and use systems. Let us not forget that besides technology, one factor which made green revolution possible in Punjab is cheap electric power for water lifting. I believe the same can be done for tank irrigation system.

(4) Suitable implements, machinery, and inputs to facilitate the adoption of efficient land and water management systems is required.

(5) Technology with higher payoffs, and better incentives for increasing production, and facilities for marketing of produce must be available;

(7) Development of water resources in dryland areas should be considered as a long-term investment for stabilisation of agriculture and for catalysing a highly productive farming system.

The strategy, based on water harvesting in situ, may be considered as an investment in small farm water resource development. It is the price of social justice and a necessary prerequisite for breaking centuries' old agricultural stagnation in these dry ureas. If a part of the huge sums that arc spent in fighting droughts, famines, floods, calamities and emergencies are used for development of on-farm water resources, the problems of drylands will be largely solved. If we can spend 20 to 25 thousand rupees for irrigating a hectare of land with these new irrigation projects, the similar consideration could be given to the small watershed based projects. The country has put much effort in irrigation based on transported water. It is high time that some attention should be paid to the management of rainwater in situ i.e. indigenous water.

It may be argued that there will not be enough runoff water available in -extreme drought years. It may be remembered that it is not the total rainfall but its distribution and high-intensity storms that determine the quantum of runoff. Even one high-intensity storm may yield enough water for storage for supplemental irrigation. If there is a provision for making use of such an opportunity, it can provide greater stabilities in the productivity of drylands and reduce the misery of drought prone areas. Experience of Sukhomajri, Dehra Dun and Bilaspur in North and of ICRISAT and AICRPDA in the South provides sufficient evidence for it. If water is applied through gravity, availability of energy may not be a constraint but if it is to be lifted the energy can be a constraint. For such situations the availability of solar energy or wind power may provide a solution. How these forms of energy can be brought within the grasp of poor farmers is a real challenge to the scientists and the planners.

Rainwater-Harvesting in Arid Lands

In the arid lands, the rainfall being low, the main strategy of rainwater management is through efficient dry farming practices. However, sometimes in the arid lands also considerable runoff occurs. This is how droughts and floods are common phenomena in many of these regions. Therefore in these arid zones also there are some possibilities for increasing the efficiency of rainwater management for increasing the productivity. Dr Singh has discussed these possibilities (see page 84-91). The collection of runoff water to provide drinking water for cattle and to meet human needs has been a tradition in this area; it needs to be improved.

Solar energy and wind energy for lifting water offers great scope in arid as well as semi-arid areas. Teams of scientists from CSIR and ICAR must urgently work together to make it feasible for fanners to use these sources of energy for lifting water. The recharging of aquifers through runoff water and its exploitation at suitable locations is getting some attention. However, this strategy should also be critically examined so as to extend benefits to the largest number of farmers.

Rainwater-Harvesting in Alkali Soils.

In the experience of scientists of the Central Soil Salinity Research Institute (CSSRI) the vast stretches of alkali soils of North India that cover more than 2.5 million hectares offer excellent opportunities for harvesting runoff water[1]. Great potential exists in western UP, Haryana, Rajasthan, and Punjab. These lands produce excessive runoff because of their low infiltration rates. A three-tier system is proposed by Dhruvanarayana and his colleagues (i) store in Paddy fields, (ii) store runoff in dug out ponds, and (iii) store the rest in bigger reservoirs. This technique can provide a means for reclamation of these deteriorated lands,. recharging the aquifers, and reducing flood damage to crops in surrounding areas.

Use of Harvested Rainwater for Agriculture in Drylands

It hardly needs to be emphasised that the harvested rainwater is a scarce commodity and should be used sparingly only for "life saving" irrigation at the most critical stages of crop growth or for extending the cropping season, thus making inter-or sequential cropping possible. This approach is different from the conventional concept of irrigated farming, which is based on an adequate supply of water for the crop to maximize yields per unit area.

Data recorded on red soils (Alfisols) of ICRISAT show that on these soils about 25% of the seasonal rains runoff. The water thus harvested could be used for increasing the yield of *kharif* crops by application at critical times. Some of it was available for supporting double cropping on a small area. In case of the deep black soils (Vertisols) which when cropped allow much less runoff than the red soils because of the greater moisture-storage capacity, there generally is enough moisture to mature a *kharif* crop successfully. However, there may not be adequate moisture in the surface layers to allow the establishment of a *rabi* crop successfully. This is often true even when there is plenty of moisture in deeper layers of the soil to support the crop once the roots make contact with these layers. In this situation, a small amount of harvested water from the *kharif* season may be used for moistening the surface soil to facilitate good *rabi* crop establishment and providing more dependable double cropping opportunity. Numerous examples of the application of these concepts under semi-arid as well as arid conditions can now be given[2,6].

Methods of Irrigation

Most of the soils of the semi-arid India have a sloping topography and are not suitable for conventional basin-type irrigation. However, under such Situations the furrow system of irrigation may be feasible. Even more sophisticated trickle irrigation or drip irrigation systems seem promising, however, their costs are presently prohibitive. Likewise, plastic pipes for distribution of water are another costly item that deserves the attention of engineers for bringing these systems within the reach of small farmers. The possibilities for reducing such costs need to be discussed at this forum.

Seepage Losses

Another problem associated with storing water in farm ponds is seepage losses. Many techniques of reducing this loss have been tried. The participants of this symposium have presented their views[3]. Suffice to say that we are still looking for cheaper methods for reducing seepage losses. There is considerable location specificity in this. For instance the Sukhomajri experience is not replicable in the Kandi area of the Siwaliks where soils are very porous, but it can be followed in the Ghaggar catchments with heavy clays.

Efficient Use of Rainwater Through Storage in the Soil, Better Moisture Conservation and Efficient Cropping

The whole research programme on dry farming must be based on the philosophy of increasing the stored water in the root profile and increasing its efficiency. The most rewarding practices that result in greater efficiency of rainwater use are:

(1) Use of less water requiring crops and their varieties.

(2) The tailoring of varieties to fit with the favourable period of moisture availability (9). Based on the probability of rainfall and the moisture storage capacity of different soils one can develop conceptual models indicating the most favourable duration of a crop and variety for a given situation.

(3) Improve fertility management and rainwater management for dryland' agriculture.

(4) Synergistic effect of soil and water management and crop management system.

Groundwater Resource Assessment

Another aspect that I would like to emphasise is that we should think of water as a costly input and value it on the basis of its productive efficiency. "How much food per unit of water can be produced?" The surface water and underground water resources should be correctly measured and regularly monitored. Conjuctive use of surface and underground water is necessary to improve the efficiency of use of rainwater. More sophisticated techniques such as remote sensing for determining the magnitude of water resources and the use of nonconventional energy resources such as nuclear energy for tapping the fossil water resources also need attention.

I am convinced that through better management of rainwater our drylands can produce many times more food than they are doing now. This also offers hope for a better quality of life for the people of rainfed lands. Rainfall may be somewhat unpredictable but not uncontrollable with modern technology. We can predict its. behaviour, harness it for useful purposes, and reduce its damaging effect caused through floods, droughts, and erosion.

To sum up best rainwater management system should aim at its better storage in soil, harvesting runoff in situ, and recycling for stabilising and improving production. The philosophy and techniques of ponds, tanks and wells as means of water sources for catalysing agriculture needs critical examination. Small water resource development is much more suitable for people's participation than large irrigation works. The scope for development in semi-humid and semi-arid areas is tremendous. If the rainwater is tackled on the ground where it falls, it can become a blessing and if allowed to runoff, it has the potential of becoming a menace.

National policies should aim at and encourage the efficient use of rainwater in situ. Investments may be considered a price for social justice, for centuries stagnant agriculture in rainfed agriculture in India.

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