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Using Rainfall Excess for Supplemental Irrigation of Vertisols in India

J HARI KRISHNA

Farming Systems Research Programme, International Crops Research Institute for the Semi-Arid Tropics, ICRISAT Patancheru PO, AP 502324

The rainfall in India is variable in intensity, duration and distribution. High-intensity storms often result in large amounts of rainfall excess (runoff), particularly in soils such as the Vertisols where infiltration rates are low. Runoff causes large amounts of soil erosion annually, resulting in the degradation of the crop production potential of the soil resource.

Proper management of the Vertisols results in many benefits. A system of graded broadbeds and furrows has been developed at ICRISAT which improves surface drainage in the monsoon season (facilitating rainy season cropping), allows runoff to occur at non-erosive velocities and permits it to be collected in storage facilities. The broadbed-and-furrow system also facilitates reapplying the water to the crops during stress periods.

Substantial benefits were observed from the use of collected runoff during the post-rainy season, and sometimes in the monsoon season as well. On watersheds where collected runoff was applied as supplemental irrigation, increased levels of rainfall productivity were computed. It is therefore of utmost value to further explore the applicability of runoff collection and recycling to larger areas in the country.

Key Words: Runoff, Irrigation, Runoff recycling. Water harvesting

Introduction

It has been estimated that in India, about 40% of the annual rainfall results as surface runoff and flows into rivers. This rainfall excess is quite substantial considering the fact that most parts of India are classified as semi-arid." It is very likely that due to constraints imposed by topography, climatic and soil conditions as well as by flow characteristics, some surface runoff is inevitably lost, but. there-are often situations when runoff could be. collected and used economically as supplemental irrigation for crop production, and at the same time reducing the damage that is commonly experienced from flash floods.

Since about 75% of the cultivated land in India is rainfed, contributing 42% of the nation's total food production, the potential for runoff collection and reuse appears very high in these areas. The Vertisols in India cover about 60 million ha. of which about 54 million ha. are in the rainfed area (Singh 1974). It is, therefore, of great interest to study the feasibility of runoff generation;, collection and recycling on these soils and the potential impact of this technology on increasing crop production and stabilizing it over time.

Vertisols

The Vertisols are fine calcareous, montmorillonitic clays which undergo pronounced shrinkage during drying, resulting in large cracks that close only after prolonged wetting. These soils become hard when dry and sticky when wet. Drainage can be a serious problem during wet periods in the rainy season. The soils are high in bases, including calcium, magnesium and potassium, and the *p*H ranges from 7.5 to 8.6. Under semi-arid tropical conditions, the soils are low in organic matter and are usually deficient in nitrogen, phosphorus and sometimes zinc.

The Vertisol areas in India can be subdivided according to depth as :

Deep Vertisols	> 90 cm
Medium deep Vertisols	45—90 cm
Medium Vertisols	22.5—45 cm
Shallow Vertisols	< 22.5

A map of the Vertisol regions is shown in figure 1.

The saturated hydraulic conductivity of the Vertisols is very low. The initial and terminal infiltration rates of a deep Vertisols as measured at the ICRISAT Center were :

Time from start (hr)	*Infiltration rate* (mm/hr)
0-0.5	76
0.5-1.0	34
1.0-2.0	4
After 144	0.2

Due to the Vertisols' property of shrinking and swelling, large deep cracks are formed in the dry season and exist as such until sufficient wetting occurs in the monsoon season. In the early part of the rainy season, therefore' a large part of the incident rainfall can disappear into the cracks if they are allowed to remain exposed at the soil surface. The low infiltration rates of the Vertisols under moist" conditions and -the resulting runoff and erosion indicate the need for laud management techniques which allow greater opportunity time for infiltration while controlling the removal of excess water. Such systems have been developed at ICRISAT and will be discussed in a later section of this paper.

Rainfall Characteristics

The annual rainfall is highly variable in most parts of India and is concentrated in four to five months of the year. The long term weather data for Hyderabad for instance indicate that on average 86% of the annual rainfall is received between the months of June and October. Variability is evident even from the past seven *year* data at ICRISAT; while only 340 mm was- received in 1972, 1077 mm was received in 1978. The rainfall normally occurs in the form of several storms of high

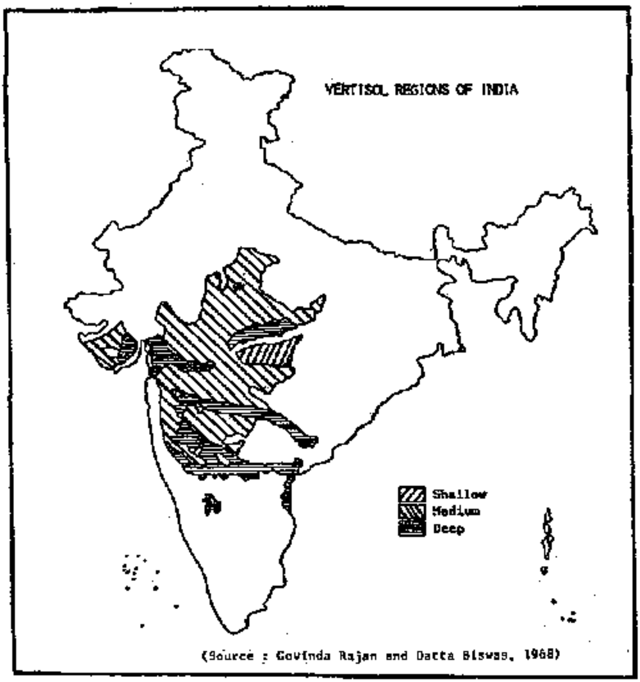

Figure 1 A map of the Vertisol regions in India

intensity and sometimes of long duration. Hudson (1971) concluded that 40% of the rainfall in the tropics occur at intensities of at least 25 mm/hr, a figure approaching the threshold value at which rainfall becomes erosive. The highest rainfall intensity measured at ICRISAT was 88 mm/hr on September 24, 1975; in four out of the past six years rainfall intensities in excess of 60 mm/hr have been recorded.

'The high rainfall intensities coupled with low infiltration rates when the soil is moist, result in large amounts of surface runoff and associated erosion on Vertisols. The variability and undependability of rainfall results in not growing a monsoon crop in low rainfall areas. In high rainfall regions, the poor drainage characteristics of the Vertisols cause difficulty in working the soil in the rainy season, under traditional management. The available rainfall has to be used in such a manner that long term stability is assured in crop production. The excess rainfall if collected and used during stress periods results in satisfactory moisture availability throughout crop growth ensuring optimum levels of production.

Rainfall-Runoff Relationships

The amount of runoff depends on rainfall intensity and duration, topography, soil characteristics and crop cover. The runoff measured on Vertisols at ICRISAT has been generally between 10 and 20% of the seasonal rainfall. Runoff rates of over 20% occurred only in monsoon fallow situations. The rainfall and runoff measured on two research watersheds at ICRISAT since 1973 are shown in table 1.

Table 1. *Rainfall (RF) and Runoff (RO) on two Vertisol watersheds at ICRISAT*

Year	*Cropped watershed*			*Monsoon fallow watershed*		
	RF (aim)	*RO (mm)*	*RO/RF* **(%)**	*RF (mm)*	*RO (mm)*	*RO/RF* **(%)**
1973	697	51	7.3	735	59	8.0
1974	810	116	14.3	807	223	27.6
1975	1042	162	15.5	1055	253	24.0
1976	687	73	10.6	710	238	33.5
1977	586	2	0.3	5S6	53	9.0
1978	1125	273	24.3	1117	410	36.7
1979	689	73	10.6	682	202	29.6
1973-1979	5636	750	13.3	5692.	1438	25.2

Moonsoon fallowing on Vertisols is still a widespread practice extending over 18 million hectares in India. It can be generalized that on the long term, approximately one-fourth of the seasonal rainfall is lost as surface runoff from these areas, while in regions cropped during the monsoon season, approximately one-sixth of the rainfall results in surface runoff. Thus, substantial runoff is generated during the monsoon reason in the Vertisol regions. In addition to the loss of precious rainwater, the problems of soil erosion due to improper management of runoff would further add to the degradation in the productive potential ofthe available cropland. To help solve these problems, a graded broadbed and furrow system of land management has been developed at ICRISAT. The moderate slopes in the furrows of approximately 0.6% allow the runoff to occur at safe velocities. These slopes also permit adequate opportunity time for infiltration particularly in the early part of the monsoon. The runoff that is generated through this system could be collected in water storage facilities and conveniently recycled to the watershed at the required time as supplemental furrow irrigation.

A parametric water balance simulation model has been developed on the basis; of hydrologic data collected from three Vertisol watersheds at ICRISAT (krishna. 1979). It has minimal input data requirements which include daily rainfall amouhts, storm duration or rainfall intensity; pan evaporation and soil moisture. A high degree of correlation was obtained between computed and measured runoff volumes in all cases. The model also simulated the soil moisture variation in the profile satisfactorily.

Runoff for Supplemental Irrigation

The collection of runoff and its reuse for supplemental irrigation has been reported from several locations in India. Verma et al. (1972) during a study conducted on deep Vertisols at Bellary found substantial increases in yield through recycling of runoff water (table 2).

Table 2 *Effect of supplementary irrigation from a farm pond on the yield of sorghum at Bellary (Verma et al. 1972)*

Treatment	*Depth of water applied (cm)*	*Yield (kg/ha) Grain*	*Straw*	*% Increase of grain yield Over control treatment*	*Per cm of water applied*
No irrigation T_1 (control)	0	527.8	2537	—	—
1 Irrig. at boot . leaf stage (T_2)	11.73	1361.1	2623	158	13.4
1 Irrig. at seed setting stage (T_3)	12.62	1722.2	3485	226	17.9
2 Irrig. at T_2 and T_3 stage (T_4)	19.37	2711.4	3719	414	21.4

With one irrigation at seedsetting stage, it was possible to increase .yields by 226%. These results indicate that the amount as well as timing, are important considerations in the application of supplemental irrigation.

Verma (197S) reported that the quality of runoff water was much better than that of well water in the Bellary area and was comparable to the excellent quality of the Tungabhadra river waters. Yield increases were also recorded with cotton by application of runoff water. A single runoff application of 10 cm of water increased the yields by upto 76% in 1972-73 and upto 47%, in 1973-74. Two applications raised the yields upto 115% in 1972-73 and upto 66% in 1973-74 (a better rainfall year). Experiments conducted at the agricultural college farm in Indore showed that upto 60% of the monthly rainfall could be collected as runoff in July while 55% was possible in August and 72% in September (Srivastava &. Varma 1975).

Chowdhury: .(1979) summarized the yield increases accruing from one application of water at various locations and for several crops in India. The data for three Vertisol stations where *rabi* sorghum is grown is given in table 3.

It can be noted that the benefits from runoff collection and reuse are quite substantial for *rabi* crops even in medium to low rainfall areas such as Bijapur and Bellary. An even greater advantage might be realized in high rainfall regions

Table 3 *Effects of "life-saving" irrigation on sorghum yield at 3 Vertisol locations (Chowdhury 1979)*

Location	*Seasons-Averaged.*	*Yield g|ha*		*% increase in yield with one irrigation*
		Without irrigation	*With one irrigation**	
Bijapur	5	16.5	23.6	43.0
Sholapur	5	9.8	13.8	91.8
Bellary	4	4.3	13.7	218.6

* Irrigation amounts not same across locations

Experience at ICRISAT

Several small watersheds on Vertisols and Alfisols at ICRISAT have been developed with systems of graded beds and furrows and grassed waterways to convey the excess rainfall safely. Small runoff collection and storage facilities (tanks) from 0.2 to 0.5 ha. m capacity have been constructed to serve some of the Vertisol watersheds. A 6.5 ha. watershed alongwith the mair waterway, and the tank is shown in figure 2.

Three tanks were constructed in 1973 using mechanical equipment; five other tanks were constructed later using manual labour and animal power. The cost of construction per ha. cm of storage has ranged between Rs. 200 and 500, depending upon the construction technique and the excavation to storage ratio at any particular location. The seepage has been very minimal (0.5-2.0 mm/day)in those tanks where the sub-soil consists of murrain haying high clay content. In other situations where sandy subsoils have been encountered, seepage rates of up to 5 cm/day have been measured; efforts at minimizing these problems are underway.

It has been observed that on tanks located on medium deep Vertisols at ICRISAT, approximately 65 to 80% of the collected water could be applied back on the land. Depending on the actual amount of runoff occurring this water in an average year would be equivalent to about 40-50. mm on the entire donor watershed. The application of water has been primarily through pumping and leading the water on the ridge from where furrow irrigation has been practiced. Aluminium pipeline may be too expensive for supplemental irrigation in dryland agriculture and therefore the feasibility of using other materials has been explored. High density polyethylene pipe of 10 cm diameter has been successfully used at ICRISAT. In addition to being flexible and light weight, it offered less flow resistance than in conventional methods and costs only a third as much.

During the past seven years, there has been ample evidence at ICRISAT to warrant further research on runoff collection and reuse. The collection of runoff during the monsoomseason and its application to post monsoon crops has been quite common on the Vertisols. On Alfisols however, there have been several occasions when moisture stress occurred even during the rainy season and collected water had to be applied fairly early in the seaspn. It is now clear that even with a

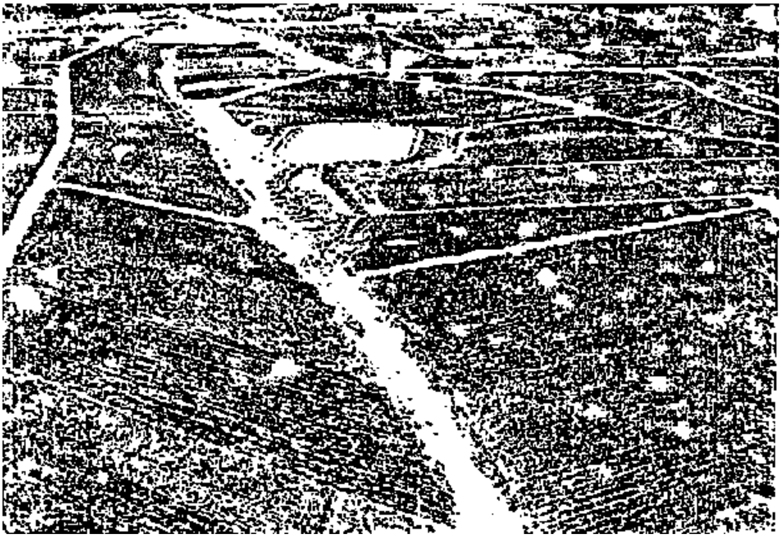

Figure 2 An ICRISAT watershed showing the grassed waterway and tank for runoff collection

single 5 cm irrigation, substantial benefit can be realized if the water is applied at the. "critical" time. In 1975, on a black soil watershed at ICRISAT, the post monsoon sorghum yield was 2570 kg/ha, without supplemental irrigation while a single 5 cm irrigation from collected runoff on a part of the watershed boosted the yields to 3570 kg/ha. The *kharif crop* of maize on the watershed yielded 4770 kg/ha and with a 3570 kg/ha yield of post monsoon sorghum the gross return at the then prevailing prices was Rs. 6493/ha. This resulted in a rainfall productivity of Rs. 62/cm of water/ha. In another year when an 8 cm irrigation was applied at planting time to chickpea in the post-monsoon season, the yields increased from 780 kg/ha. to 1310 kg/ha. In terms of rainfall productivity, the maize-chickpea sequence resulted in Rs. 63/cm of water/ha. This figure is several-fold that attained. by the traditional practice of rabi sorghum on Vertisols where a rainfall productivity of only about Rs. 10/cm of water/ha was realized.

Conclusions

Systems of runoff collection and reuse appear to have substantial potential in semi-arid tropical rainfed agriculture. The benefits will be greatest on soils of low water-holding capacity but it has been amply demonstrated that even on deep Vertisols, there can be substantial increase in the yield of post-monsoon crops by application of limited amounts of supplementary irrigation. The rainfall productivity obtained from the combination of a monsoon crop and a supplementarily irrigated post-monsoon crop under improved management can be five times higher than that under traditional farming practices.

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