Converting Rain into Grain: Opportunities for Realizing the Potential of Rain-fed Agriculture in India

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Introduction

Rain-fed agriculture is practiced on 80 % of the world's agricultural land area, and generates 65-70 % of the world's staple foods, but it also produces most of the food for the poor communities in developing countries and least favored areas. The low and variable productivity of these lands is the major cause of poverty for 70 % of the world's poor inhabiting these lands. The largest challenges of poverty-related undernutrition are found in arid, semi-arid and dry-humid, rain-fed regions of the developing countries (Falkenmark and Rockstrom 1993). The distinct feature of rain-fed agriculture in these developing countries is that both productivity improvement and expansion has been slower relative to irrigated agriculture (Rosegrant et. al. 2002). But, as Pretty and Hine (2001) suggest, there is a 100 % yield increase potential in rain-fed agriculture in the developing countries, compared to only 10 % for irrigated crops. This calls for increased efforts to upgrade rain-fed systems globally and, especially in developing countries to provide sufficient and affordable food and nutrition to the vast populations.

India ranks first among the rain-fed agricultural countries of the world in terms of both extent (86 M ha) and value of produce. Due to little alternative opportunities available outside the agricultural sector, the high population of landless households and agricultural laborers, and low land and labor productivity, most of the poverty is concentrated in rain-fed regions (Singh 2001). At the same time, there is growing evidence to suggest that agriculture continues to play a key role in economic development and poverty reduction in these regions ((World Bank 2005; Irez and Roe 2000). Some of the available estimates suggest that 1 % increase in agricultural productivity translates to 0.6 –1.2 % decline in the percentage of rural poor (Thirtle et al. 2002). The only silver lining in the scenario is that there appears to exist a significant potential for raising productivity in rain-fed systems. Yield gap analyses, undertaken by the Comprehensive Assessment, for major rain-fed crops found farmers' yield to be a factor of 2-4 times lower than the achievable yields and offering substantive opportunities for realizing the potential of rain-fed agriculture (Molden 2007).

Rain-fed Agriculture Scenario in India

Rain-fed areas in India are highly diverse, ranging from resource-rich areas with good agricultural potential to resource-constrained areas with much more constrained potential. It is in the rain-fed regions where cultivation of nutritious (coarse) cereals (91 %), pulses (91 %), oilseeds (80 %) and cotton (65 %) predominates. Rosegrant et al. (2002) employing the IMPACT model have estimated that even by 2025, one-third of India's cereal production shall be contributed by rain-fed areas (Table 1). Rain-fed agriculture supports 40 % of India's population. Earlier, the rain-fed farming systems, because of its risky nature, were dependent upon locally available inputs and grew traditional drought-resistant crops. But over-time cropping systems have changed (Kanwar 2001), and farmers have started cultivating high-value (but vulnerable) crops requiring intensive use of costly inputs.

Table 1. Rain-fed and irrigated cereal area, yield and production in 1995 (actual) and 2025 (computed), and fraction of rain-fed area and production for India.

Parameters		1995 (actual)	2025 (computed with IMPACT model)
Irrigated	Area, M ha	37.8	46.7
	Yield, t/ha	2.65	3.81
	Production, M tonnes	100.3	177.7
Rain-fed	Area, M ha	62.3	49.8
	Yield, t/ha	1.20	1.63
	Production, M tonnes	74.6	81.4
Rain-fed area, %		62.2	51.6
Rain-fed production, %		42.7	31.4

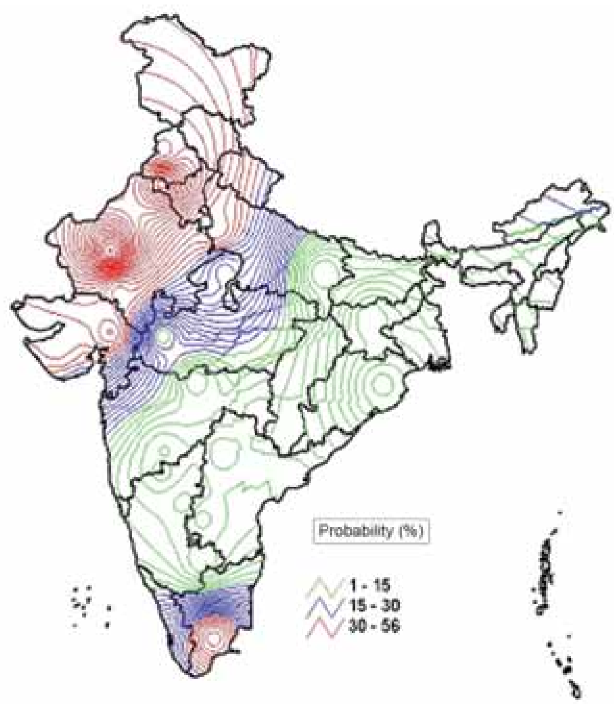
Source: Adapted from Rosegrant et al. (2002).

The last 4 decades of Indian agriculture, which registered overall impressive gains in food production, food security and rural poverty reduction in better-endowed 'Green Revolution' areas, by-passed the less-favored rain-fed areas, which were not partners in this process of agricultural transformation. Particularly, the last decade has witnessed serious distress among the more enterprising small and marginal farmers in the rain-fed regions who opted to replace, with little success, traditional low-value crops with high-value (but more vulnerable) and input-intensive crops through borrowed resources. As an extreme desperate step, over 25,000 farmers, mainly from rain-fed regions, committed suicide during the past 9 years—every 8 hours a farmer took his life (Lobo 2007). Besides several other factors related to agriculture sector as a whole, e.g., adverse meteorological conditions resulting in long dry spells and droughts, unseasonal rains and extended moisture-stress periods with no mechanisms of storing and conserving the surplus rain to tide over the scarcity/deficit periods, were the major causes for non-remunerative yields and heightened distress. It is only recently that the Government of India has constituted a National Rain-fed Area Authority (2006) to address these issues and develop and implement a comprehensive single-window program for the development of rain-fed areas in the country.

Constraints of Rain-fed Agriculture

Rainfall is a truly random factor in the rain-fed production system, and its variation and uncertainty is high in areas of low rainfall. Semi-arid regions, however, may receive enough annual rainfall to support crops but it is distributed so unevenly in time and/ or space that rain-fed agriculture becomes unviable (Reij et al. 1988). Rockstrom and Falkenmark (2000) note that due to high rainfall variation in semi-arid regions, a decrease of one standard deviation from the mean annual rainfall often leads to the complete loss of a crop. Whereas in the arid zones (< 300 mm/annum) absolute water scarcity constitutes the major limiting factor in agriculture; in the semi-arid and dry sub-humid tropical regions managing extreme rainfall variability in time and space is the greatest water challenge. Dry spells, which generally are 2-4 weeks of no rainfall during critical growth stages causing partial or complete crop failures, often occur in every cropping season. The probability of deficient rainfall (deficiency in rainfall numerically equal to or greater than 25% of the normal) in India during the southwest monsoon period is: once in 2.5 years in West Rajasthan; once in 3 years in Gujarat, east Rajasthan, western Uttar Pradesh, Tamil Nadu, Jammu and Kash-mir, Rayalaseema and Telangana; once in 4 years in the south interior Karnataka, eastern Uttar Pradesh and Vidarbha; once in 5 years in West Bengal, Madhya Pradesh, Chattisgarh, Konkan, Coastal Andhra Pradesh, Bihar, Jharkhand and Orissa; and once in 15 years in Assam (very rare) and Kerala. Even dry sub-humid regions, where rainfall varies between 750-1,200 mm, experience contingent drought

Figure 1. Probability of occurrence of terminal droughts in India—consecutive 3 dry weeks from second week of September.



situations due to a break in monsoon conditions. Based on its time of occurrence, such rainless periods/ agricultural drought may be termed as early season drought, mid-season drought and terminal drought. While early season drought can be mitigated through replacement with short-duration varieties or change in the cropping pattern, droughts at the latter two stages have potential to cause serious damages to crop production (Figure1). Terminal droughts are more critical as the final grain yield is strongly related to water availability during the reproductive stage. Apart from these short-duration droughts (dry spells), in the low to medium rainfall regions, the rainfall amount and distribution may be sufficient to raise only a low water requiring hardy crop but not a sensitive crop with high water requirements. Introduction of such a crop for economic reasons leads to the early appearance of drought conditions and crop failures.

Though water deficiency at critical crop growth stages is the major constraint of rain-fed agriculture, water itself may not always be the primary limiting factor for food production even on the so-called 'drylands'. Analysis of farmers' participatory field trials in more than 300 villages, showed that the existing practices of rain-fed agriculture has depleted soils not only in organic matter and macro-nutrients but also in micro- and secondary nutrients, and substantial gains (70 to 120%) are observed when crops were supplied with adequate quantities of these nutrients (Wani et al. 2005; Rego et al. 2005).

Effect of Irrigation Intensity on Crop Yields

Most research studies on the impact of irrigation on crop yields are conducted under high input use and on small plots, and thus fail to capture the scale impacts at district/ regional level and depict a high effect of irrigation. But, under actual farming conditions in developing countries like India, the exogenously supplied inputs show a great deal of spatial variation and impact the overall gains at the district/ regional level. An exercise based on district level secondary statistics to assess the effect of 'irrigation' and 'no irrigation' for the various crops in the 16 major states of India (where the rainfall is less than 1,500 mm/annum) revealed that:

i. productivity increase due to irrigation varies between 7-74 %, except for soybeans (0 %) and rabi rice (550 %);

ii. achievable yields are much higher than productivity levels achieved through irrigation and improved practices at the district level;

iii. productivity enhancement due to irrigation is less than 30 % among oilseed crops, except for castor (52 %) and sunflower (47 %); and

iv. among cereals, millets (pearl millet and finger millet), maize and barley recorded less than 30 % increase in productivity due to irrigation.

Yield differences between irrigated and rain-fed areas are more pronounced when the crop is grown under a variety of agro-ecological regions, compared to its concentration in few and similar districts. Though the effect of irrigation on crop yields suggest low gains for few crops, on-farm trials and evaluation reports of watershed projects (Joshi et al. 2004; Sastry et al. 2004) suggest that the effect of supplementary irrigation on rain-fed crop yields is considerably higher (Table 2). Therefore, an assessment was made to identify opportunities for water harvesting and supplemental irrigation to overcome dry spells during mid/ terminal droughts so as to stabilize the production.

Table 2. Effect of supplementary irrigation on the yield of rain-fed crops at different locations in India.

Location	Crop	Yield, t/ha		% increase with supplementary irrigation (Ratio of irrigated versus rain-fed yield)
		Without irrigation	With critical irrigation	
Ludhiana (4)*	Wheat	1.92	4.11	114.06 (2.14)
Rewa (4)	Wheat	0.57	1.88	229.82 (3.30)
Varanasi (2)	Barley	2.60	3.36	29.23 (1.29)
Bijapur (5)	Sorghum	1.65	2.36	43.03 (1.43)
Bellary (4)	Sorghum	0.43	1.37	218.60 (3.19)
Rewa (4)	Upland rice	1.62	2.78	71.60 (1.72)

Source: Reports of All India Coordinated Research Project on Dryland Agriculture, Hyderabad

Note: * Figures in parenthesis indicate average number of seasons

Supplemental Irrigation through Rainwater Harvesting

Supplemental irrigation is a key strategy, so far under utilized, to unlock rain-fed yield potentials. The objective of supplemental irrigation is not to provide stress-free conditions through the crop growth for maximum yields, but to provide just enough water to tide over moisture scarcity at critical growth stages to produce optimal yields per unit of water (Oweiss et al. 1999; Sharma and Smakhtin 2004). The existing evidence indicates that supplemental irrigation ranging from 50-200 mm/ season (50-200 m^3/ha) is sufficient to mediate yield-reducing dry spells in most years and rain-fed systems, and thereby stabilize and optimize yield levels. Agarwal (2000) suggested that India should not have to suffer from droughts, if local water balances were managed better. Collecting small amounts using limited macro-catchments water harvesting, local springs, shallow groundwater tables or most importantly conventional water harvesting during rainy season can achieve this. The assessment presented in this study presents the estimation of available (surplus) rainfall runoff during August (second fortnight)/ September that is required mainly to mitigate the terminal drought. The study identified the dominant rain-fed districts for different crops (contributing up to 85 % of total rain-fed production), made an assessment of the surplus/ runoff available for water harvesting and supplementary irrigation in the identified districts, estimated the regional water use efficiency and effect of supplemental irrigation on increasing production of different crops and, finally, a preliminary estimate of the economics of water harvesting for supplemental irrigation in rain-fed areas.

Identification of Dominant Rain-fed Districts

To make an improvement over the existing criterion of the ‘fixed’ or ‘variable’ percentage of the irrigated area in the district, all the districts in the descending order of area coverage (for a given crop) limited to a cumulative 85 % of total rain-fed area for each crop in the country, were identified and termed as 'dominant rain-fed districts' (for a given crop). The crops covered are sunflower, soybeans, rapeseed mustard, groundnut, castor, cotton, sorghum, pearl millet, maize, pigeon peas and rice (in kharif), and linseed and chickpeas (in rabi). Thus an area of 39 M ha was accounted under selected crops. This helped in the identification of the major region for a crop, in that although all the crops are grown in most of the districts, there are a few crops that have specific agro-climatic requirements. Details on dominant rain-fed districts for various crops are given in Table 3. Development activities related to a specific rain-fed crop should be taken up first in these identified districts and secure a major impact on productivity.

Table 3. Total and 'dominant districts' for the important rain-fed crops in India.

Crop	No. of districts in		
	Rain-fed states	AESR*3-13	Districts covering cumulative 85 % of rain-fed area (dominant districts)
Sunflower	224	179	11
Soybean	202	160	21
Rapeseed mustard	265	214	29
Groundnut	316	243	50
Castor	202	157	12
Cotton	296	237	30
Sorghum	346	261	71
Pearl millet	346	261	43
Maize	346	261	67
Pigeon pea	266	215	83
Chickpea	346	261	85

Source: Authors' estimates

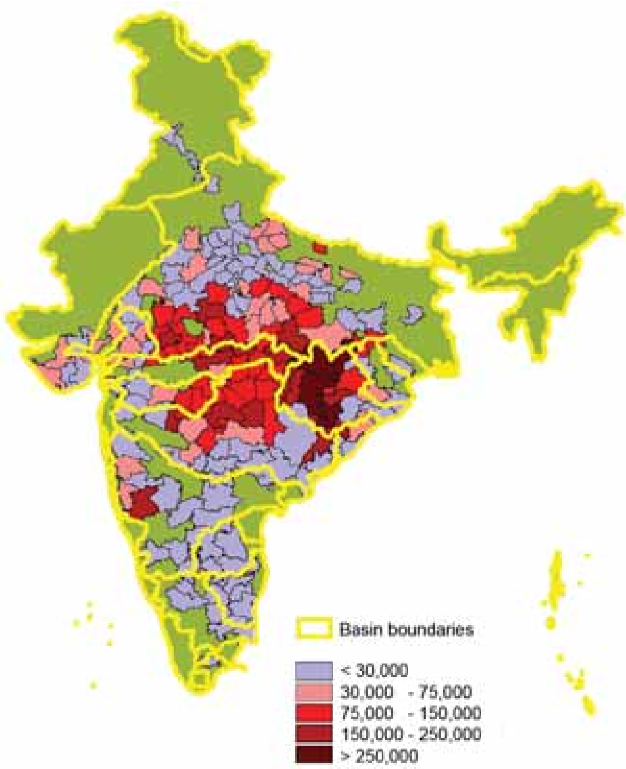
Notes: * Agro-Ecological Sub regions as defined by NBSSLUP, Nagpur

Assessment of Available Surplus/ Runoff for Water Harvesting and Supplemental Irrigation

Total rainfall in India is spread over few rainy days and fewer rain events (about 100 hours in the season) with high intensity, resulting in large surface runoff and erosion and temporary stagnation. In either of the cases this 'green water' is not available for plant growth, and has very low productivity. Local harvesting of a small part of this water and utilizing the same for supplementary/ protective irrigation to mitigate the impacts of devastating dry spells, offer a good opportunity for increasing productivity in the fragile rain-fed systems (Rockstrom et al. 2001; Sharma et al. 2005; Wani et al. 2003). For a national/ regional level planning on supplementary irrigation, one needs to make an assessment of the total and available surplus runoff, and the potential for its gainful utilization. In the present study, both crop season-wise and annual water balance analyses were done for each of the selected crops cultivated in the identified districts. Whereas, the annual water balance analysis assessed the surplus and/or deficit during the year to estimate the water availability and losses through evaporation; the seasonal crop water balance assessed changes in temporal availability of rainfall and plant water requirements. The water requirement satisfaction index was used for assessing the sufficiency of rainfall vis-à-vis the crop water requirements.

The total surplus from a district is obtained by multiplication of seasonal surplus with the rain-fed area under the given crop (Ferguson 1996). The total surplus available from a cropped region is obtained by adding the surplus from the individual dominant districts identified for each crop. An estimated amount of 11.5 M ha-m runoff is generated through 39 M ha of the prioritized rain-fed area. Out of the surplus of 11.5 M ha-m, 4.1 M ha-m is generated by about 6.5 M ha of rain-fed rice alone. Another 1.32 and 1.30 M ha-m of runoff is generated from soybeans (2.8 M ha) and chickpea (3.35 M ha), respectively. Total rain-fed coarse cereals (10.7 M ha) generate about 2.1M ha-m of runoff. Spatial distribution of runoff on agro ecological sub- region and river basin-wise is shown in Figure 2. Based on the experiences from watershed management research and large-scale development efforts, practical harvesting of runoff is possible only when the harvestable amount is larger than 50 mm or greater than 10 % of the seasonal rainfall (CRIDA 2001). Therefore, surplus runoff generating areas/ districts were identified after deleting the districts with seasonal surplus of less than or equal to 50 mm of surplus, and those districts generating runoff of less than 10 % of seasonal rainfall. Table 4 shows the summary of surplus and deficit for various crops after deletion of districts,

Figure 2. Spatial distribution of surplus runoff (ha-m) across dominant rain-fed districts and river basins of India.



Source: Authors' estimates

Table 4. Potentially harvestable surplus runoff available for supplemental irrigation under different rain-fed crops of India.

Crop group	Crop	Rain-fed crop area ('000 ha)	Surplus (ha-m)	Deficit (ha-m)
Cereals	Rice	6,329	4,121,851	0
Coarse cereals	Finger millet	303	153,852	0
	Maize	2,443	771,890	0
	Pearl millet	1,818	359,991	0
	Sorghum	2,938	771,660	0
Total (Coarse cereals)		7,502	2,057,393	0
Fiber	Cotton	3,177	757,575	8,848
Oilseeds	Castor	28	14,489	0
	Groundnut	1,663	342,673	1,646
	Linseed	590	306,360	0
	Sesame	1,052	416,638	0
	Soybeans	2,843	1,329,251	0
	Sunflower	98	11,811	0
Total (Oilseeds)		6,274	2,421,222	1,646
Pulses	Chickpea	3,006	1,304,682	9,166
	Green gram	458	80,135	0
	Pigeon pea	1,823	659,328	238
Total (Pulses)		5,287	2,044,145	9,404
Grand total		28,569	11,402,186	19,898

Source: Authors' estimates

which generate less than the utilizable amount of runoff. This constitutes about 10.5 M ha of rain-fed area, which generates seasonal runoff of less than 50 mm (10.25 M ha) or less than 10 % of the seasonal rainfall (0.25 M ha). Thus the total estimated runoff surplus for various rain-fed crops is about 11.4 M ha-m (114.02 billion cubic meters, BCM) from about 28.6 M ha that could be considered for water harvesting. Among individual crops, rain-fed rice contributes a higher surplus followed by soybeans. Deficit of rainfall for meeting crop water requirements is also visible for crops like groundnut, cotton, chickpeas and pigeon pea.

Based on this available surplus, the irrigable area was estimated for a single supplemental irrigation of 100 mm (including conveyance/ application and evaporation losses) at the reproductive stage of the crop both for normal and drought years. Runoff during drought years is assumed to be 50 % of runoff surplus during normal rainfall years (based on authors' estimates for selected districts and rain-fed crops). However, farmers tend to use the water more prudently during drought years and save larger cropped areas. The potential irrigable area through supplementary irrigation for both scenarios is given in Table 5. Out of 114 billion cubic meters water available as surplus, about 28 billion cubic meters (19.4 %) is needed for providing supplemental irrigation to irrigate an area of 25 million ha during the normal monsoon year, thus leaving about 86 M ha-m (80.6 %) to meet river/environmental flow and other requirements. During drought years also about 31 billion cubic meters of water is still available even after making provision for irrigating 20.6 million ha. Thus it can be seen that water harvesting and supplemental irrigation do not jeopardize the available flows in rivers even during drought years or cause significant downstream effects in the identified areas.

Table 5. Irrigable area ('000 ha) through supplemental irrigation (at 100 mm per irrigation) during normal and drought years under different rain-fed crops.

Crop group	Crop	Rain-fed crop area	Irrigable area during normal monsoon	Irrigable area during drought season
Cereals	Rice	6,329	6,329	6,215
	Finger millet	303	266	224
	Maize	2,443	2,251	1,684
	Pearl millet	1,818	1,370	837
Coarse cereals	Sorghum	2,938	2,628	1,856
Total (Coarse cereals)		7,502	6,515	4,601
Fiber	Cotton	3,177	2,656	1,725
	Castor	28	25	22
	Groundnut	1,663	1,096	710
	Sesame	1,052	919	741
	Soya beans	2,843	2,843	2,667
Oilseeds	Sunflower	98	59	30
Total (Oilseeds)		5,684	4,942	4,170
	Chickpea	3,006	2,925	2,560
Pulses	Pigeon pea	1,823	1,710	1,374
Total (Pulses)		4,829	4,635	3,934
Grand total		27,521	25,077	20,645

Source: Authors' estimates

Rainwater Use Efficiency and Production Potential of Rain-fed Crops

Water use efficiency under rain-fed agriculture is not a consistent value as evidenced in irrigated agriculture. In rain-fed areas, the water use efficiency (WUE) varies from district to district and from year to year based on the pattern of rainfall occurrence with drought years giving a higher value of water use efficiency. The present study aggregates water use efficiency at the district level for major rain-fed crops. Production projections were made for different crops in the respective rain-fed districts using the information on regional rainwater use efficiency, both for 'business as usual' scenario (only application of supplementary irrigation) and under ‘improved practices’ scenario (limited follow-up on recommended package of practices). Additional production (Table 6) was a product of irrigable area (Table 5), regional rainwater use efficiency and the amount of supplemental irrigation. The irrigable area through supplemental irrigation for different crops during the drought season varies between 50-98 % (98 % for rice crop to 50 % for sunflower growing districts) of the irrigable area during the normal (non-drought) season. Under improved management practices, an average of 50 % increase in total production cutting across drought and normal seasons is realizable with supplemental irrigation from a rain-fed area of 27.5 M ha. Production enhancement in the drought season in case of rice crop is high due to higher water application efficiency and also due to sufficient surplus of to bring almost the entire rice cultivated area under supplemental irrigation. This would also indicate that large tracts of rain-fed rice cultivated area are covered under high rainfall zones with sufficient surplus for rainwater harvesting. Significant production improvements can be realized in rice, sorghum, maize, cotton, sesame, soybeans and chickpeas. The success of the ‘Green Revolution’ in irrigated areas is one solid example built upon irrigation and improved technologies. Every one of the stakeholders from supplier to farmer to market responded with equal enthusiasm. A second ‘Green Revolution’ is not in the offing for long time for the reason that this needs to be staged on a water- scarcity/insufficiency zone.

Table 6. Yield increases with supplemental irrigation (SI) in normal and drought seasons (based on WUE of improved technologies).

Crop group	Crop	Rain-fed cropped area	Traditional production (‘000 tonnes) (‘000 ha)	Irrigable area (‘000 ha)		Additional production (‘000 tonnes)	
				Normal season	Drought season	Normal season	Drought season
Cereals	Rice	6,329	7,612	6,329	6,215	4,141	4,357
Coarse cereals	Finger millet	303	271	266	224	124	112
	Maize	2,443	2,996	2,251	1,684	1,744	1,408
	Pearl millet	1,818	1,902	1,370	837	836	555
	Sorghum	2,938	3,131	2,628	1,856	2,439	1,864
Total	(Coarse cereals)	7,502	8,300	6,515	4,601	5,143	3,939
Fiber	Cotton	3,177	430	2,656	1,725	294	206
Oilseeds	Castor	28	10	25	22	6	6
	Groundnut	1,663	1,182	1,096	710	284	203
	Sesame	1,052	365	919	741	202	176
	Soya beans	2,843	2,607	2,843	2,667	1,429	1,443
	Sunflower	98	49	59	30	12	7
Total	(Oilseeds)	5,684	4,213	4,942	4,170	1,933	1,835
Pulses	Chickpea	3,006	2,367	2,925	2,560	1,061	1,000
	Pigeon pea	1,823	1,350	1,710	1,374	282	245
Total	(Pulses)	4,829	3,717	4,635	3,934	1,343	1,245
Grand total		27,521	24,272	25,077	20,645	12,854	11,582

Economics of Water Harvesting and Supplemental Irrigation

Supplemental irrigation has substantive potential for increasing production from rain-fed crops across different districts, yet its adoption on a large scale shall depend upon its economic worthiness. Numerous such structures have been built under varying agro-climatic conditions under state sponsored programs, by nongovernmental organizations and with individual initiatives. The available literature has good evidence on the technical and financial viability of construction of such water harvesting structures for, improvement of water productivity and diversification of agriculture in rain-fed areas (Singh 1986; Oweiss 1997). The cost of provision of supplemental irrigation through construction of water harvesting structures varies a great deal between different states/ regions and locations, and within the same state (Samra 2007; personal communication; Table 7). Hence, a simple analysis based on the national average cost for rainwater harvesting structures (INR 18,500/ ha) was carried

Table 7. Cost of different water harvesting structures per hectare of the service area at different locations in India.

Location	Cost of water harvesting structures (2000 price level)		
	Minimum	Maximum	Average
Bagbahrar (Chhatisgarh)	4,100	29,200	11,000
Dindori (Madhya Pradesh)	6,800	25,000	18,000
Keonjhar(Orissa)	19,400	35,000	27,000
Darisai(Jharkhand)	8,300	27,800	18,000
National Average			18,500

Source:J.S. Samra, personal communication, presentation made to the Planning Commission

out for the provision of supplemental irrigation to the rain-fed crops. In the calculation of annualized cost, rate of interest as well as depreciation cost for the structures has been deducted. An assumption was made that rainwater harvested would be utilized for the existing crop only, and accordingly returns were considered for the existing crop only. However, in actual practice the farmer makes much better use of the created water resource by planting high-value crops and plantations and investments in livestock and aquaculture. The annualized cost for each crop and gross and net benefits with supplemental irrigation to each crop are shown under Table 8. It suggests that an estimated INR 50 billion annually is required to provide supplemental irrigation to around 28 M ha of rain-fed cultivated land, and half of that amount is required for rice and coarse cereals only. The data suggests that gross and net benefits are quite high for cotton, oilseeds, pulses and rice. However, the coarse cereal group, in general, and pearl millet, in particular, exhibit lower gross and net benefits even with SI and improved practices. This indicates the need for better varieties of these crops, which are more responsive to irrigation and nutrition.

Table 8. Crop-wise annualized cost and gross and net benefits (billion rupees) from supplementary irrigation with the harvested water.

Crop group	Crop	Rain-fed cropped area ('000 ha)	Annual cost	Gross benefit with SI and improved technologies	Net benefit with SI and improved technologies
Cereals	Rice	6,329	11.71	20.23	8.52
Coarse cereals	Finger millet	303	0.56	2.23	1.67
	Maize	2,443	4.52	7.05	2.53
	Pearl millet	1,818	3.36	1.88	-1.49
	Sorghum	2,938	5.44	6.38	0.95
Total (Coarse cereals)		7,502	13.88	17.54	3.66
Fiber	Cotton	3,177	5.88	14.15	8.27
Oilseeds	Castor	28	0.05	0.22	0.17
	Groundnut	1,663	3.08	8.86	5.79
	Sesame	1,052	1.95	6.82	4.87
	Soya beans	2,843	5.26	18.69	13.43
	Sunflower	98	0.18	0.36	0.18
Total (Oilseeds)		5,684	10.52	34.95	24.44
Pulses	Chickpea	3,006	5.56	49.05	43.49
	Pigeon pea	1,823	3.37	9.39	6.02
Total (Pulses)		4,829	8.93	58.44	49.51
Grand total		27,521	50.92	145.31	94.40

Conclusions

In spite of the rain-fed lands having the highest unexploited potential for growth**,** the risk of crop failures, low yields and the insecurity of livelihoods are high due to the random behavior of the rainfall. Rain-fed agriculture is mainly and negatively influenced by intermittent dry spells during the cropping season and, especially at critical growth stages coinciding with the terminal growth stage. District level analysis for different rain-fed crops in India showed that the difference in the district average yields for rain-fed crops among different rainfall zones was not very high, indicating that the total water availability may not be the major problem in different rainfall zones; and that for each crop there were few dominant districts, which contributed most to the total rain-fed crop production. A good strategy to realize the potential of rain-fed agriculture in India (and elsewhere) appears to be, to harvest a small part of available surplus runoff and reutilize it for supplemental irrigation at different critical crop growth stages. The study identified about 27.5 M ha of potential rain-fed area, which accounted for most of the rain-fed production and generated sufficient runoff (114 BCM) for harvesting and reutilization. It was possible to raise the rain-fed production by 50 % over this entire area through the application of a single supplementary irrigation (28 BCM) and some follow up on the improved practices. Extensive area coverage rather than intensive irrigation need to be followed in regions with higher than 750 mm/ annum rainfall, since there is a larger possibility of alleviating the in-season drought spells and ensuring a second crop with limited water application. This component may be made an integral component of the ongoing and new development schemes in the identified rural districts. The proposed strategy is environmentally benign, equitable**,** poverty-targeted and financially attractive to realize the untapped potential of rain-fed agriculture in India.

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