

Development of Dryland Agriculture on Watershed Basis in Hot Arid Tropics of India: A Case Study

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Abstract: A study on watershed management was initiated in 1986-87 at Jhanwar village (District, Jodhpur) and surveys were conducted to assess the problems, resources and potential of the area. The action plan was prepared and implemented. Farmers in the watershed area showed keen and sustained interest in adoption of improved dryland farming technologies, including sustainable land use systems. Productivity analysis of watershed area indicated considerable improvement in gross monetary returns under different cropping systems. Water harvesting, through creation of farm ponds and its recycling in agro-horticulture (*Ziziphus mauritiana*) system resulted in diversified production (fruit, fuel and fodder) and sustained 1.14 adult cattle unit $\text{ha}^{-1} \text{yr}^{-1}$. Development of pastures in community grazing lands increased forage production (2-3 t ha^{-1}) over traditional methods (0.3-0.4 t ha^{-1}). Adoption of various physical and biological land treatments in the eroded rocky catchment reduced the soil erosion and increased the ground water recharge. The program has resulted in an overall increase in the productivity by 25-30%. Although highly location specific, such a model has high replicability in large part of arid tropics in India and elsewhere.

Key words: Arid areas, watershed management, alternate land use systems.

Indian arid zone comprises about 12% of the country's total geographical area, spread over 0.32 million sq. km, covering the states of Rajasthan (61%), Gujarat (20%), Andhra Pradesh (7%), Punjab (5%), Haryana (4%), and Karnataka (3%). The region is characterized by low and erratic rainfall (100-400 mm year^{-1} , CV > 40%), high evapotranspiration (1860 mm year^{-1}), non-existence of well defined perennial river systems, scanty vegetation, etc. As such, the problems of this hot arid tropical tract are multifarious and complex. The increasing population pressure of both human and animal vis-a-vis modernization has further constrained this fragile ecosystem leading

to acute scarcity of food and fodder resources. Hence, to restore ecological balance and sustained productivity, development of watershed is imperative for sustainable production (Daulay *et al.*, 1990; Bhati and Daulay, 1992). This paper presents a case study of integrated development of dryland agriculture on watershed basis in hot arid tropical region.

Material and Methods

The Jhanwar watershed development project in Jodhpur district (Rajasthan) was launched in 1986-87 as a part of national program. The watershed extend from

72°50'00"E to 72°54'47"E longitudes and from 20°11'36"N to 20°16'33"N latitudes and is about 25 km S-W of Jodhpur city. The total area of the watershed is about 4600 ha covering five villages namely Bujawar (38%), Jhanwar (35%), Chokha (21%), Rohila Kalan (4.8%) and Doli (1.2%). About 38% of the watershed area is rocky, 15% is fallow, and the remaining 47% is under cultivation during *kharif* season. Only 37 ha area is under irrigation. In the first phase (1987-92), a part of watershed, comprising 1200 ha area prone to soil and water erosion hazards, was selected for effective execution of development plan on priority basis.

The upper reaches of this area were mainly rocky with almost negligible vegetative cover. The slope of hilly terrain varied from 15 to 25%. These geomorphological formations have resulted in very high run-off resulting in the formation of three big *nallahas*, depleting the resource base at down fields by way of washing away seeds, fertilizers and other soil nutrients. Several drains have been induced which damage the crops. Thus, uncontrolled run-off, both from *nallahas* and drains, has resulted in sheet and gully erosion.

The quantum, distribution and frequency of the rainfall is very erratic in the watershed area. The average annual rainfall is 360 mm, of which, 90% occurs during monsoon season with 9 to 11 rainy days in a year. Soils in the watershed area are mainly sandy with low fertility. There was no dependable water source, i.e., canal, well, reservoir, etc., in the watershed area. These have resulted in low production of crops (100 to 300 kg ha⁻¹) and pasture grasses (0.5-1.0

t ha⁻¹). Socio-economically, the farmers of the watershed area have a poor economic base. The average land holding is 3.5 ha and it has to support, on an average 29.8, members in a family with 8 to 10 livestock heads. About 65% of the total area taken in first phase was put under cultivation during *kharif* season. Pearl millet is the major crop of the area followed by mung bean. Table 1 presents the details of land use pattern of the watershed area.

Various kinds of surveys, viz., hydrological, bench-mark, land capability, etc., were conducted to assess the problems and potentials for integrated development of the area on watershed basis. The plan focused mainly on three broad aspects.

Water retention bunds around the margin of tablelands to arrest the sheet flow, guided bunds for contour cultivation, dry stone check-dams and brush-wood check-dam at suitable locations in gullies to dissipate energy of discharge and stone masonry structures (anicuts) on three main *nallahas* have been adopted. For effective implementation of the programme on soil and water erosion control, the area was protected from the biotic interference through loose stone wall and ditch-cum-mound fencing.

To enhance the productivity of farm lands, various agronomical techniques like improved varieties, primary and secondary tillage operations, seed rate, fertilizer use, integrated pest management, *in-situ* and interplot water harvesting and recycling systems were adopted. To stabilize production, various alternate land use systems, i.e., agro-horti, agri-pasture, farm forestry, etc., were also the mandate of the action plan.

Table 1. Details of land use pattern in Jhanwar model watershed area (Phase I)

Land use units	Area (ha)	Percentage of total area
Stony, dunny gullied waste land	70.00	5.42
Permanent pasture and community grazing land	143.92	11.15
Settlement	46.24	3.58
Tanks and <i>nallahas</i>	29.14	2.25
Roads and cart track	41.61	3.22
Current fallow	122.13	9.46
2-year current fallow	12.94	1.00
Permanent fallow	4.22	0.32
Total cropped area	841.84	65.22
Double cropped area	21.32	1.65
Net area sown	820.52*	63.59
Total area	1290.72	100.00

* Out of a total net sown area (820.52 ha), pearl millet (490.40 ha), pearl millet + moth bean (76.99 ha), mung bean (153.38 ha), moth bean (36.00 ha) and clusterbean (46.00 ha) occupied the major area.

To motivate the farmers for their active participation in the developmental work and creating awareness about program, various training programs, demonstrations, farmer's fair and field days were organized. In fact, the active participation of the beneficiaries was strived from the beginning of the development plan for maintenance of the assets created during the execution. A summary of various activities planned and executed in the watershed area are presented in Table 2.

Results and Discussion

On-farm impact

Farmers in the watershed area showed keen interest in the adoption of improved crop varieties and their management. Due to program implementation, 90% of the farmers started using seeds of improved varieties of dryland crops. In all, 6500 kg seeds of improved crop varieties, 300 kg

seeds of improved tree strains, along with 6000 tree seedlings of various tree species, i.e., *Prosopis cineraria*, *Acacia senegal*, *Ziziphus rotundifolia*, etc., were planted under agro-forestry system and 6000 plants of *Ziziphus mauritiana* were planted for agro-horticulture development in the watershed. With the adoption of improved dryland technologies, i.e., improved seeds and management practices, productivity increased by more than double over traditional practices (Table 3).

The gross monetary returns in operational research fields have been very high, i.e., intercropping of mung bean (Rs. 2,612 ha⁻¹) and moth bean (Rs. 2,175 ha⁻¹) with pearl millet (2:2), pearl millet (Rs. 1,597 ha⁻¹), mung bean (Rs. 2,066 ha⁻¹) and moth bean (Rs. 2,037 ha⁻¹), as compared to the average gross monetary returns with traditional practices (Rs. 840 ha⁻¹). Further, the run-off potential at various farm sites could be better utilized by efficient water

Table 2. Progress of Jhanwar model watershed project area (1987-92)

Technology	Total target (ha)	Physical achievements upto 1992 (ha)	Expenditure (Rs. in lakh)
Farm forestry	550	185	0.420
Reclamation of gullied land	200	120	1.504
Pasture development	150	120	4.040
Improved dryland crop	25	7	0.010
Masonry dams	3	3	1.298
Stone check dams	100	135	0.158
Brush wood check dams	80	70	0.114
Stabilizing <i>nallaha</i> bank	1000*	6000*	0.394
Farm pond	12	10	2.559
Animal health cover	-	-	0.171
Agro-horti	60	29	1.570
Solar energy	-	42**	0.152
Subsidy	-	-	0.868
Others	-	-	0.270
Total			13.528

* Metre, ** Solar cooker.

harvesting (i.e., creation of farm ponds) and recycling (i.e., establishment of ber orchard). Thus, the farmers could, not only obtain the diversified food and fodder production to support 1.14 ACU ha⁻¹ year⁻¹, but could also get employment round the year. This was possible because of the creation of reliable water sources.

Development of community grazing land

About 60 ha of community grazing land was developed as an ideal pasture through reseeded of *Cenchrus ciliaris*. Before initiation of the project work, the forage production was negligible (0.30-0.40 t ha⁻¹), but with the adoption of improved pasture establishment and management techniques, productivity of these lands increased substantially (2 to 3 t ha⁻¹). The pasture could sustain 1.09 ACU ha⁻¹ year⁻¹. For better establishment, grasses were protected from

grazing, in the first two years, by making ditch-cum-mound fencing around the periphery. Live fencing having three rows of *A. tortilis* were also planted in staggered fashion in trenches. An innovative approach, involving farming community through *gram panchayat* namely, "cut and carry system" was also adopted. In this system the farmers themselves protected the pasture from illicit grazing through mutual cooperation. The system, besides protection and better establishment of both tree and grass, generated extra revenue of Rs. 1500 to 2000 ha⁻¹ year⁻¹ through collection of grass seed, which is in heavy demand and is sold at the rate of Rs. 50-75 per kg.

Development of catchment area

Adoption of various engineering and biological treatments in 70 ha of gullied/degraded area lying underneath the rocky

Table 3. Productivity improvement in dryland crops in Jhanwar model watershed project area (1987-92)

Crop	Average productivity (upto 1987) (q/ha/year)	1988		1990		1992	
		Local variety+ management	Improved variety+ management	Local variety+ management	Improved variety+ management	Local variety+ management	Improved variety+ management
Pearl millet	3.00	1.82	4.00	2.82	6.00	3.72	6.50
Moth bean (sole)	0.44	1.25	3.10	1.32	2.64	1.65	3.82
Mung bean (sole)	1.00	1.20	2.57	1.82	4.25	1.50	2.38
Clusterbean (sole)	0.40	1.20	2.45	1.68	3.32	1.94	4.25
Mixed (pearl millet + moth bean + sesame)	1.80	-	-	-	-	-	-

catchment ridges of the watershed substantially increased the vegetation (Table 4). Amongst the tree species, the highest increase in plant density was observed in *Commiphora wightii* (813.3%) followed by *Acacia jacquemontii* (650%) and *Prosopis cineraria* (622.2%). These tree species are of high economic, medicinal and social value in the arid environment. Further, the

constructed structures resulted in stabilization of loose pediments with silt deposition of 27.3, 87.7 and 126.0 tons in masonry dam numbers 1, 2 and 3 having catchment area of 8.8, 9.2 and 12.0 ha, respectively (Fig. 1).

In general, a rising trend was observed in the ground water table in the watershed

Table 4. Plant population in the eroded area (30 ha) during the project period

Plant species	Masonry dam-1 (8.8 ha)		Masonry dam-2 (9.2 ha)		Masonry dam-3 (12.0 ha)		Total (30 ha)		Per cent increase
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	
Natural vegetation									
<i>Capparis decidua</i>	32	104	28	115	43	96	103	315	205.8
<i>Maytenus emarginata</i>	18	137	9	38	14	46	41	221	439.0
<i>Acacia jacquemontii</i>	1	50	1	4	8	22	10	76	650.0
<i>Prosopis cineraria</i>	5	38	1	2	3	25	9	65	622.2
<i>Commiphora wightii</i>	6	79	1	20	8	38	15	137	813.3
<i>Lycium barbarum</i>	22	102	6	36	8	55	36	193	436.1
<i>Grewia tenax</i>	2	9	1	3	5	11	8	23	187.5
Planted species									
<i>Acacia tortilis</i>	23	605	27	63	21	343	71	1011	1323.9
<i>Prosopis juliflora</i>	10	40	6	29	3	19	19	88	363.1
<i>Acacia senegal</i>	2	51	2	13	3	82	7	146	1985.7
<i>Ziziphus nummularia</i>	18	176	8	115	18	137	44	428	872.8

Initial and final plant population were recorded in 1987 and 1994, respectively.

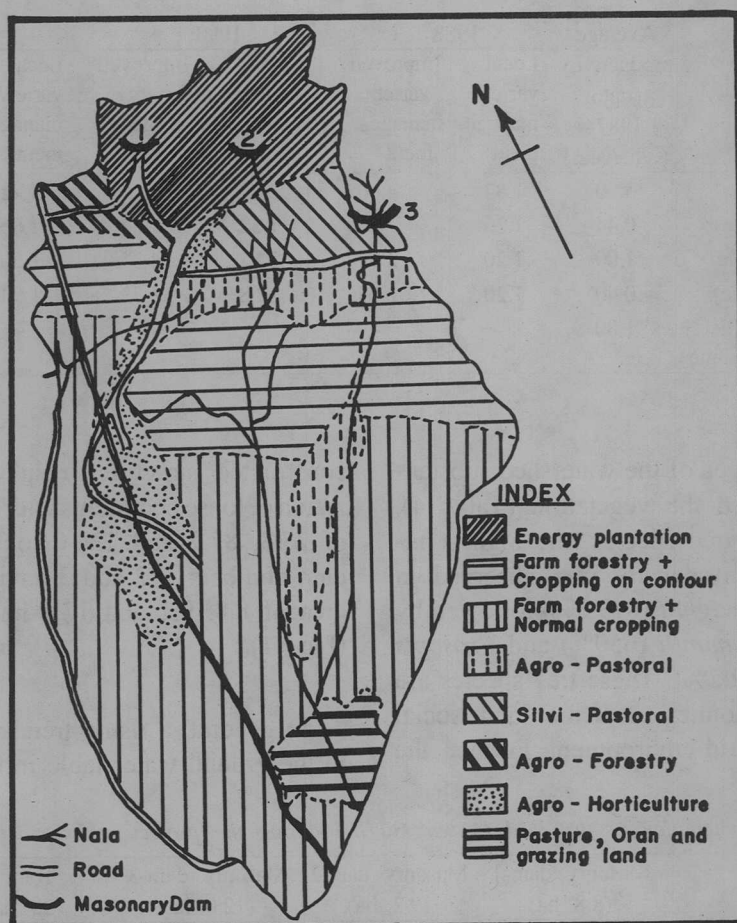


Fig. 1. Details of farming systems planned for the Jhanwar watershed.

area. A well located near the catchment area recorded a 3.75 m rise in water table over project period.

Conclusions

The paper presents a case study of integrated agriculture development plan on watershed basis in the area representing 300-400 mm annual rainfall with sandy

undulating topography. The development plan included various softwares and hardwares as per the need of the particular site in the area. The program has resulted in overall increase in productivity by 25-30%. Although highly location specific, such a model has high replicability in large part of hot arid tropics of India and elsewhere.

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