Rainwater Harvesting and Its Impact on Farming Systems

J. S. Samra
Ministry of Agriculture and Cooperation, India

The 23rd International Grassland Congress (Sustainable use of Grassland Resources for Forage Production, Biodiversity and Environmental Protection) took place in New Delhi, India from November 20 through November 24, 2015.

Proceedings Editors: M. M. Roy, D. R. Malaviya, V. K. Yadav, Tejveer Singh, R. P. Sah, D. Vijay, and A. Radhakrishna

Published by Range Management Society of India

Rainwater harvesting and its impact on farming systems

J. S. Samra

ABSTRACT

Landless, small holders and other poors supplement their livelihood and adapt to climate change by grazing, stall feeding with crop residues and fodder cultivated under rainfed and irrigated conditions. Improving productivity by conserving rainfall, ground water recharging, harvesting and recycling of rainwater especially in degraded open access or shared land with community participation was quite successful over a wide range of precipitation and ecological situations. Various types of trenches, bunding, vegetative barriers, gully plugs, ponds, check dams, land slides and mine spoils stabilization etc. retained more soil moisture, seeds, vegetative propagules etc. *in situ* and prevented soil erosion. It regenerated and enhanced biomass production of grasses, other forages, crop residues and environmental externalities. It reduced socially undesirable seasonal migration of herders by 35-100%, number of goats, dependency on open or common access resources and increased bovine population, stall feeding and milk productivity. Limited irrigation with harvested and recharged rainwater led to farm diversification, more availability of crop residues and better income. Climate change has reduced number of rainy days, increased intensity and frequency of run off producing events and can be converted into still better opportunities of adaptation by rain water harvesting.

Keywords: Adaptation, Climate change, Common land, Diversification, Grazing land, Livelihood, Milk production, Poverty, Rainwater harvesting, Seasonal migration.

Introduction

Cultivation of irrigated fodders (like *berseem, lucrne, sorghum* etc.) is very much limited in India and livestocks are reared mostly on grazing, crop residues, hay and green tree fodder especially during droughts, severe winter and other scarcity periods/ seasons. Rainwater harvesting into tanks, ponds etc. especially in South India is an ancient practice mostly for raising irrigated food crops and their residues for grazing and stall feeding. In the process of economic evolution of land use due to demography, urbanization, and industrialization; marginal soils mostly under rainfed conditions were left out for pastures, silvi-pastures, grazing and other community services etc. mostly as open access natural resources. They are distributed in less than 750 mm rainfall area (30% of total geographical area of India), 750-1250 mm (42%) and more than 1250 mm (28%) and are generally degraded. Investments for improvement of their productivity were very meager due to 'tragedy of commons' as well as poverty of their users. They require very special policies, extension, interventions and structures for *in-situ* conservation of rainwater, storage in check dams, gully plugs etc. with active participation of communities, service providers and other stakeholders for faster and inclusive development of rural sector.

Overall agrarian economy of India is deprived and distressed. As per the latest socio-economic and caste census data of 2011 of India, about 73% of the total households are in the rural area, 51% of them work as manual casual labours and 30% are engaged in cultivation. The monthly income of the highest earning member is less than Rs.5000 (US$ 85) in 75% households and only 8.29% households

Fig. 1.

have over Rs.10,000 (US$ 170 per month @ 1$ = Rs.60) (Annon, 2015). Although 68% of rural dewelers own a mobile phone but overall development is lopsided. The deprived people are mostly landless, asset less, small and marginal farmers, 25% do not have access to dependable irrigation and possess limited assets of livestock. Rearing of animals is based predominantly on grazing in the open access grasslands, forests, fallow lands, crop residues and very limited cultivated fodders. In hills and mountains, semi-arid and arid ecologies droughts/floods resilient trees fill up green fodder gap during crucial dry and winter seasons. *In situ* conservation of rain water, runoff harvesting, ground water recharging for adaptation to climate change, resilience to vulnerability of agrarian distress is important for ensuring equitable prosperity with sustainable development. On an average India receives about 89 cm of annual rainfall, about 80% during monsoon season and is highly variable both spatially and temporally. Extreme events of droughts, unseasonal rains, high intensity storms etc. are increasing due to climate change and complicating management of rain water resources. India is gifted by nature with 4000 BCM of rain water per annum and hardly 30% of that is utilized and there are tremendous opportunities of its harvesting. A lot of situation specific traditional knowledge can also be integrated with latest technologies and community participation for minimizing conflicts in the rationalized sharing of especially open access common resources'. Soil and water conservation is expected to improve productivity of grasslands, enhance their biodiversity, provide drinking water for wild life, animals and harness realization of full potentials of livelihood and income generation of landless, small land holders, other disadvantaged individuals and communities.

Keeping in view the vast scope of improving sustainable management of natural resources of land, rainfall, grasslands, silvi-pasture, bushes, fodder trees, small ruminants, bovines and herders, published information has been compiled, collated and interpreted in the dynamic socio-economic context.

Results and discussions

Intensive multiple interactions among *in situ* rainwater conservation, runoff management and vegetative cover can be illustrated with classical pilots projects on long term basis on stabilization of highly disturbed topography of land slides and mine spoiled area in high rainfall mid Himalayas (Table 1 and 2). Drastic reduction in run off, sediments and debris flow, stream bed slopes, extended

Fig. 2.

Table 1. Effect of bio-engineering measures on vegetative cover and landslide stabilization after 30 years (Nalota Nala, Mussorie hills, Uttar Anchal, India, treated in 1964).

Description	Before treatment	After treatment
Runoff, mm	55	38
Dry weather flow, days	100	250
Sediment load, tones/ha/yr	320	5.5
Vegetation cover, percent	<5	>95
Nala bed slope (%)		
Lower reach	12	7
Middle reach	23	14
Upper	54	44
Toe cutting	Severe	Nil

Table 2. Impact of bio-engineering measure on vegetative cover and mine spoil stabilization at Sahastradhara, Doon valley hills, Uttaranchal, India.

Particulars	Before treatment (1983)	After treatment (1996)
Debris outflow, t/ha/yr	550	8
Monsoon runoff, %	57	37
Lean period flow, days	60	240
Vegetation cover, %	10	80

lean period flows due to spectacular improvement in vegetative cover or biomass is evident from these classical data sets.

Similarly a long term trial on sylvi-pasture potentials of a gravelly and bouldry land with high rainfall is also illustrated in table 3. On an average of 14 years data, differences in the biomass productivity of the two grasses and competition of different tree species were significant. Same was true for leaf fodder production from the trees (Table 4) indicating that systems are situation specific and adequate IT enabled extension is called upon for optimizing agro-ecological potentials.

Table 3. Production and effect of fodder tree species on fresh and dry weight (kg/ha) on intercropped grasses (Pooled over 14 years) in a gravelly land at Dehradun, India

Treatment	Average biomass weight (kg/)	
	Fresh	Dry
a) Tree species		
Albizia lebbek	6695	3592
Grewia optiva	6177	3461
Bauhania purpurea	7097	3878
Leucaena leucephala	6726	3655
CD (5%)	394	170
b) Grass species		
Chrysopogon fulvurs	5030	2687
Eulaliopsis binata	8317	4607
CD (5%)	252	166

Recently field trials on participatory soil and water conservation for enhancing productivity of forages and environmental externalities were carried out in marginalized ecology of high rainfall Western Himalayas by Dev *et al.*, (2014). A few high intensity storms (50-100 mm and more than 100 mm) mainly contributed to the harvestable runoff. Frequency and intensity of such storms is increasing due to climate change and provide better opportunities of rainwater harvesting.

Fig. 3.

Table 4. Production and effect of intercropped grasses on the fresh and dry weight (kg/ha) of forage leaves of different tree species (Pooled over 14 years) in bouldary lands (Dehradun Uttaranchal, India)

Treatment	Average biomass weight (kg/)	
	Fresh	Dry
Albizia lebbek	1004	364
Grewia optiva	575	262
Bauhania purpurea	933	362
Leucaena leucocephala	570	194
CD(5%)	188	75
Grass species		
Chrysopogan fulvus	946	371
Eulaliopsis binata	570	219
CD(5%)	62	25

As per average of three years over three sites rainwater runoff was reduced from 41.5% in control (no conservation measures) to 8.2% under the measures of trenching+ vegetative barrier, followed by trenching alone (11.6%) and vegetative barrier alone (29.8%) and conserved rain water led to significant improvement in the biomass productivity (Table 5). Trenches also retained soil and sediments eroded from their micro upper catchments and harnessed all related environmental externalities. The *in situ* conserved rain water, soil fertility, seeds, vegetative propagules etc. improved survival rate of trees and grasses and their bio-mass production significantly.

In high rainfall Southern India (Udhagamangalam) conversion of a natural grassland into eucalyptus (bluegum)

Table 5. Runoff (% of rainfall) from sylvi-pasture under different soil and rain water conservation measures in slopy lands of Himalayas, H.P. (average of three sites)

Treatment	2003	2004	2005	Mean
Trenching	9.1	14.3	11.3	11.6
Vegetative Barrier	29.8	32.4	27.3	29.8
Trenching + Veg. barrier	6.8	10.9	6.9	8.2
No conservation measure control	38.9	44.3	41.3	41.5
Rainfall(Av. of of 3 sites)	1219	155-	1067	1279

Table 6. Forages and fodder productivity improvement in watershed treated with rainwater and soil conservation measure in India

Watershed	State	Productivity (t/ha)		
		Pre-treatment	Post treatment	% increase
Sukhomajri	Haryana	2.47	5.05	104
Bunga	Haryana	0.20	3.20	1500
Bazar Gunyar	Haryana	0.10	0.50	400
Chhajawa	Rajasthan	0.10	5.42	4420
Navamota	Gujarat	1.00	2.00	100
Chhinatekur	A.P.	0.88	11.60	1218
G.R.Halli	Karnataka	1.50	8.19	446
Fakot	Uttarakhand	3.90	12.0	208
Average		1.27	5.95	372

Fig. 4.

plantation reduced water yield by 16% during 1st and 25.4% during second rotation. It decreased low flow by 2.0 times, peak flow by 3.75 times, grass productivity by 5.3 times and increased soil moisture losses (Sikka *et al.*, 1998). It again proves that there is a vast scope of manipulating the rainwater harvesting to realize the desired outcome of biomass production for maximizing livelihood for inclusive growth and development on sustainable basis.

Vegetatively planted grasses establish quickly provide a thick land cover, dissipate kinetic energy of rainfall, reduce soil erosion and recharge soil profile and ground water with moisture, enhance forage productivity and improve livelihood and resilience to weather abnormalities. Participatory management of watersheds for rain water harvesting across the country and its impact on forage productivity was reviewed by Arya *et al.*, (2011), Sharda and Arya (2009) and reported in table 6. Forage and fodder productivity improvement ranged from one to 12 folds with an average of 3.7 folds. Socially undesirable seasonal migration of cattle and male members of households reduced in the range of 35 to 100%, number of goats decreased and stall fed bovines increased. (Table 7). Contribution of seasonal migration to income reduced from 45% before the project period by 20 to 40% after watershed management measures. Limited irrigation improved cropping intensity, cropped area, production of crop residues, dependence on grasses decreased and grazing was regulated by the communities themselves.

A wide range of bio-physical interventions with the active participation of local communities were made during 1975 to 1986 for conserving rainfall, soil biodiversity, in arable and non-arable lands within a natural unit of a watershed at Fakot in mid-Himalayas (Samra, 1997). Diversification, overall integrated improvement in productivity of various economic activities, livestock rearing,

Fig. 5.

Table 7. Percent decline in cattle migrating households after rain water harvesting by watershed development projects in India

Village	% households migrating		
	Pre-project	Post project	Drop
Bunga, Haryana	79	20	59
Sambhalwa, Haryana	86	Nil	100
Sher Gujjaran, Haryana	81	46	35

Fig. 6.

Table 8. Impact of rain water harvesting and conservation of natural resources on farming system components (327 Ha, Fakote watershed in mid Himalyas, Uttaranchal)

Product	Pre-Project (1974-75) (Control)	Average of	
		During interven-tions (1975-86)	After with-drawal (1987-95) of service provider
Annual rearing method	**Heavy grazing**	**Partial grazing**	**Stall feeding**
Fodder dependency on forest (%)	60	46	18
Runoff (%)	42	18.3	13.7
Soil loss (t/ha/annum)	11	4.5	2.0
Food production (q)	882	4015	5843
Fruit production (q)	Neg.	62	1962
Milk production (000 lit.)	56.6	184.8	237.6
Floriculture income(000 Rs.)	Nil	Nil	120.0 (1994-95)
Cash crops income (000 Rs.)	6.5	24.8	202.5

forage and fodder management changed significantly (Table-8). Livelihood dependency on the open excess common forest resources decreased due to spectacular enhancement in the income from food, cash crops, aggregation for purchase of inputs and sale of outputs at competitive rates etc. Livestock rearing of heavy grazing changed to stall feeding due to more availability of crop residues, green fodder, grasses and community managed ban on grazing. Transformation process was not only sustainable but progressed further after active interventions were withdrawn by the service provider CSWCRTI from this pilot project. Almost similar achievements were also realized in another pilot project elsewhere in lower Himalayas (Kandi belt) at Sukhomajri Haryana (Table 9).

Apart from Hills and mountain, livestock sector, tree fodders, green grasses and crop residues are also very important in semi-arid regions like Rajasthan for generating income, employment, livelihood, drought resilience and adaptation to climate change. A 454 ha of pilot watershed was treated with 24.7 running km of graded bunds, 7 gully plugs, 29 check dams, 7 gabions, 8 loose boulder check dams and planting of grasses in wasteland and rainwater conservation structures etc. at Kota (Rajasthan). All these conservation measures reduced rainfall run off from an average of 24.7% to 7.7 % over three years (Table 10). It led to more *in situ* conservation of moisture and recharging of ground water (Prasad *et al.*, 1996). Annual fodder production due to planting of grasses in wasteland, high productivity of crops and more area under the cultivation of Sorghum and wheat increased by 63.5%. Soil and rainwater conservation measures enhanced overall livestock population by 102% of cows, 79% of buffaloes, 75% bullocks, 93% goats and milk production by 139% (Table 11).

Table 9. Salient achievements of rain water conservation in Sukhomajri watershed in foothills of Himalayas (Haryana)

Particulars	1975	1977	1981	1986	1988
Total food grain production (t/yr)	45.0	65.4	154.0	182.4	185.0
Total fodder from agriculture (t/yr)	73.1	104.6	246.4	292.0	317.0
Air dry grass productivity (t/ha)	0.10	0.50	1.84	2.05	2.5
No. of goats	246	144	36	10	6
No. of Buffaloes	79	129	148	291	313
Milk production (litres/day)	248	334	658	995	1200

In degraded hills of Southern Rajasthan (1055 mm rainfall), rain water harvesting by various types of trenches improved soil moisture content ranging from 14 to 24% and herbage production by 24 to 71% (Singh, 2012; Singh *et al.*, 2013).

As aridity increase contribution of livestocks, grass lands, sylvi-pasture, crop residues and cultivated fodders goes high and was about 40% in arid regions of Rajasthan, Gujarat etc. Rainwater conservation for fodder crops, sylvi-pastures and horti-pasture in Khadins (a local traditional system) dug out ponds, earthen bunds, trenching etc. in four clusters (three villages each) was carried out in Nagaur district of Rajasthan during 1010-14 by NRAA (Ramachandran, personal communication). Following salient outcomes were realized.

Fig. 7.

- 3705 ha of land was treated for conserving, harvesting and efficient utilization by community participation.
- 3000 cattle got access to safe drinking water.
- Green fodder crops were established on 300 ha
- 6112 tonnes of additional grasses/forages were produced
- Milk production increased @ two litres/ day/family
- There were several other social economic, environmental and alternative institutional benefits.

Table 10. Effect of rain water conservation measures on monsoon runoff from treated and untreated watersheds. (454 ha, Kota, Rajasthan)

Year	Runoff as % of rainfall — Untreated watershed Diara (16.9 ha)	Treated watershed Chhajawa (15.4 ha)	% reduction
1990	31.9	5.4	83
1991	20.0	10.1	50
1993	22.1	7.7	65
Average	24.7	7.7	69

Average annual rainfall 874 mm

Fig. 8.

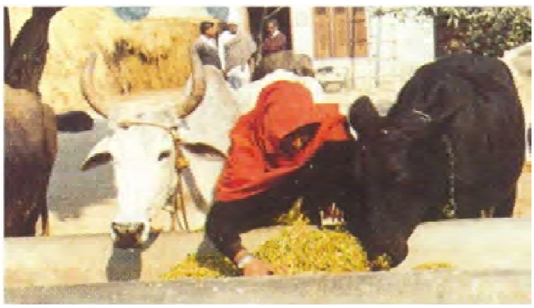
In another rainfall zone of central India five treatments of (i) contour staggered trenches (ii) Continuous contour trenches (iii) grass barriers on contours, (iv) deep basins and (v) control were experimented on horti-pasture (Amla and grasses) in the drought frequented Bundelkhand by Singh *et al.* (2014). Minimum run-off, highest soil moisture content and significantly higher growth of Amla was observed in staggered contour trenching as compared to control. Among the five treatments grass barriers conserved least moisture and also competed with Amla for the soil moisture utilization.

It is evident from the above few representative cases that a vast range of opportunities exist for rainwater harvesting and managing for harnessing most appropriate farming systems for better livelihood and environmental externalities on sustainable basis.

Rice straw being transported for storage to be used during scarcity period

A heap of silage for use during scarcity

Indigenous practices being followed by farmers to store forage



Mix feeding of green and dry fodder during scarcity

Fig. 9.

Table 11. Yearwise improvement in livestock population and milk production due to rain water conservation in Chhajawa (Rajasthan) watershed (454 ha)

Year	Livestock population				Milk production (kilo lit.)
	Cow	Buffalo	Bullock	Goat	
Pre-project					
1985-86	223	150	233	42	51.9
Post project					
1986-87	326	216	330	41	62.8
1987-88	346	198	270	64	87.1
1988-89	395	228	294	59	95.0
1989-90	413	230	377	72	109.2
1990-91	432	243	405	87	119.6
1991-92	440	249	408	85	121.0
1992-93	452	257	408	87	122.0
1993-94	449	261	398	83	123.4
1994-95	451	269	380	81	123.9
Average % increase	102	79	75	93	139

References

Annonymous. 2015. www. Secc.gov.in/welcome.

Arya, S.L., P. Panwar and R. P. Yadav. 2011. Role of Watershed Management in bridging demand supply gap of fodder for enhancing livelihood production in Shivalik, Haryana. *Agric. Economic Res. Rev.* 24: 225-233.

Dev I., S. Radotra, O. P. S. Khola, B. Misra, S., Sareen, J. P. Singh, A. K. Srivastava, B. Singh, S. K. Sharma, K. P. Chamoli, D. Kumar. 2014. Impact of participatory silvipastoral intervention and soil conservation measures for forage source enhancement in western Himalaya. *Indian J. Agric. Sci.* 84 (3):365-370.

Grewal, S. S., J. S. Samra, S. P. Mittal and Y. Agnihotri. 1995. Sukhomajri concept of integraed watershed management. Bull. No. T-26/C-5 Publ. CSWCRTI, Research Centre, Chandigarh 160019. Pp.157

Mittal, S. P., A. D. Sud, J. S. Samra, S. S. Grewal and G. Singh. 1991. Grasses for soil conservation in Shivalik hills. Published by CSWCRTI, Chandigarh 160019 India pp 1 to 52.

Prasad, S. N., R. Singh, C. Prakash, V. S. Katiyar, J. S. Samra and K. D. Singh. 1996. Watershed management of sustainable production in South-Eastern Rajasthan (Chhajawa Watershed) Pub. CSWCRTI, Kota, Rajasthan Bull. No.T-32/K-3 pp.51

Samra, J. S. 1997. Status of Research on watershed management Publ. CSWCRTI, Dehradun-248195 India pp.44

Sharda, V. N. and S. L. Arya. 2009. Community Management of CPRs in the agrarian economy.

Presented in 4th Word congress on conservation agriculture held during Feb., 4-7 by ICAR-NAAS at New Delhi.

Sikka A. K., J. S. Samra, V. N. Sharda, P. Samraj and V. Lakshman. 1998. Hydrological implications of converting natural grassland into bluegum plantations in Nilgiris. Publ. CSWCRTI, Udhagamanadalam 643004 (T.N.) India pp. 1-65.

Singh, G. 2011. Enhancing growth and biomass production of plantation and associated vegetation through rain water harvesting in degraded hills in Southern Rajasthan. *New Forest* 43: 349-364.

Singh, G., D. Mishra, K. Singh and R. Parmar. 2013. Effect of rainwater harvesting on plant growth, soil water dynamics and herbaceous biomass during rehabilitation of degraded hills in Rajasthan. *Forest Ecology and Management* 310: 612-622.

Singh, R, K. K.Garg, S. P. Wani, R. K. Tiwari and S. K. Dhyani 2014. Impact of Water Management interventions on hydrology and ecosystem services in Garhkund on Dabar Watershed of Bundelkhand region, Central India. *J. of Hydrology* 509: 132-149.

Vishwanathan M. K., J. S. Samra and A. R. Sharma. 1998. Biomass production of sylvipasture systems on gravelly lands of Doon valley (14 years of project pursuit) Publ. CSWCRTI, Dehradun-248195, India pp.126