SOIL CONSERVATION SOCIETY OF INDIA

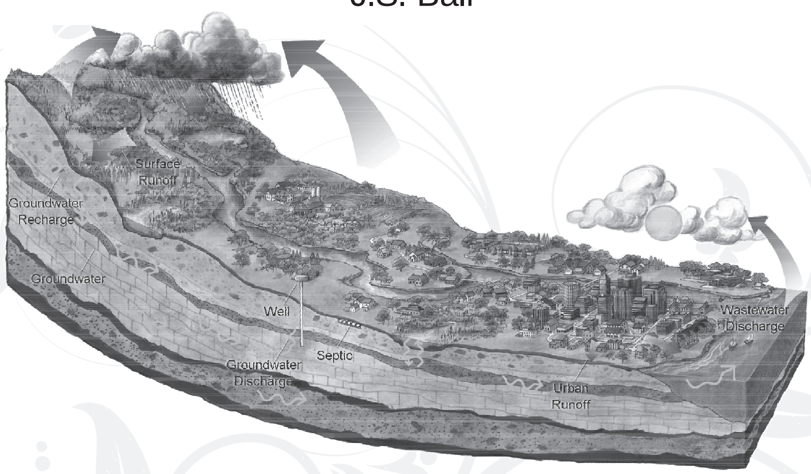
Journal of SOIL AND WATER CONSERVATION

Volume 11 No. 4 ISSN 0022–457X October-December 2012

Contents

Pledge

J.S. Bali



I pledge to conserve Soil,

that sustains me.

I pledge to conserve Water,

that is vital for life.

I care for Plants and Animals and the Wildlife,

which sustain me.

I pledge to work for adaptation to,

and mitigation of Global Warming.

I pledge to remain devoted,

to the management of all Natural Resources,

With harmony between Ecology and Economics.

Journal of Soil and Water Conservation **11**(4): 277-280, October-December 2012
ISSN: 022-457X

Management of excess runoff and soil loss under different cropping systems in rainfed foothill region of North-west India

K.R. SHARMA[1] and SANJAY ARORA[2]

Received: 27 April 2012; Accepted: 1 October 2012

ABSTRACT

A field experiment was conducted during *kharif* season on nearly 2 % sloping lands in *kandi* (drought prone) region of Jammu with the objective to evaluate different intercropping in maize (*Zea mays*) with cowpea (*Vigna unguiculata*) and mash (*Vigna mungo*) and their sole stands. Intercropping of mash and cowpea with maize gave higher maize-equivalent yields (43.32 and 42.43 q ha^{-1}, respectively) than sole maize (42.05 q ha^{-1}). Mash and cowpea in sole stands had less runoff and soil loss than their intercrop with maize. The runoff and soil loss was minimum under maize intercropped with mash which accounted to be 10.6 per cent of rainfall and 2.77 Mg ha^{-1}, respectively. Highest runoff and soil loss was observed in cultivated fallow followed by maize as sole crop.

Key words: erosion, runoff, soil loss, maize, legumes

INTRODUCTION

Soil erosion by water is a serious hazard in foothill region of Shivaliks in North-west Himalayas, a narrow belt of 10-25 km width, having an area of about 9 % of geographical area of Jammu & Kashmir. The area represents Shivalik deposits, indicating that it is alluvial detritus derived from sub-aerial wastes of mountains swept down by rivers and streams. It has a sub-humid climate with an annual rainfall of 800-1250 mm of which 80% is received during monsoon season.

The seriousness of the problems can be imagined from the fact that in highly denuded Shivaliks, 4-6 cm topsoil layer often disappears during a single monsoon. Due to great variation in steepness of this slope ranging from slightly gentle (1 to 2%) to steep slope (>10%) in *kandi* (drought prone) belt of Jammu, erosion is the major problem of soil husbandry. Soil erosion is creating great damage in this region of Jammu. Even in lands with a slope of 2 to 3 per cent in clay loam soil, there is loss of 106.5 t ha^{-1} $year^{-1}$. In all districts of Jammu region, the damage to soil because of water erosion is considerable, especially in the tracts lying under outer or Shivalik Himalayas, most of which occurs during south-west monsoon season (Hadda et al., 2006). The soils of the *kandi* region of Jammu are found to be highly erodible because of their coarser texture, low in organic matter and water holding capacity (Arora, 2006; Gupta et al., 2010).

The soil erosion has converted most of the fertile soils of the region into barren, fallow and degraded lands. About 32 per cent of the total geographical area of Jammu and Kashmir is found to be highly degraded. Soil erosion creates a vast quantity of debris which in turn, is accumulated at the base of the rivers and streams, and shrink their basins, as a result of which a slight rainfall causes flash floods. In fact, soil erosion is at once cause and effect of the depletion of the forests (Gupta and Arora, 2010). The most damage of all is the way the erosion of top soil and vanishing the vegetation, reduces the amount of water which would otherwise percolate into the soil and later on charge vital ground water acquires

[1]Professor, Division of Soil Science and Agricultural Chemistry, Sher-e-Kashmir University of Agricultural Sciences and Technology, Faculty of Agriculture, Chatha - 180009, Jammu (J&K), India
[2]Present address: CSSRI, RRS, Bharuch (Gujarat)

(Kukal et al., 1993). It is estimated that soil loss is about 3.6 to 10 t ha^{-1} through erosion during maize crops. None of the farmer in the area is having knowledge and interest regarding rainwater management for ground water recharge and during our survey no water harvesting structures or ponds were located in the villages surveyed. Although one or two existed in poor shaped developed a decade back. Lack of technical knowledge and poor economic status are the major constraints identified for conservation and management of water and soil in the area (Arora and Bhatt, 2006).

Maize is the principal *kharif* season crop of the Western Himalayan region of India and is mainly sown with the onset of monsoon (Khola et al., 1999). Canopy cover is the first line of defense against water erosion with direct reduction in splash effect, reduced soil sealing and more soil infiltrability. Legumes are considered to be the best soil conservators (Tejwani and Mathur, 1972) and legumes as intercrops impart sustainability in the system (Sharma and Chaubey, 1991). However, no information is available presently on the extent of contribution in canopy cover and yield by various *kharif* pulses to maize in intercropping in comparison to sole crops in this region. Therefore, the present study was undertaken to evaluate the protection and production worth of two *kharif* legumes *viz*. cowpea and mash with and without maize.

MATERIALS AND METHODS

The field experiment was conducted in Jammu at a latitude of 30° 39' N and longitude of 74° 53' E and at an elevation of 332 m above mean sea level representing the *kandi* belt of Jammu plain areas and part of Kathua and Udhampur districts of Jammu province. The objective of the experiment was to evaluate different crops and combination of legume crops with maize on soil loss and runoff with the treatments comprising of T_1 = Sole maize, T_2 = Sole mash, T_3 = Sole cowpea, T_4 = Maize+ mash, T_5 = Maize + cowpea and T_6 = cultivated fallow. The treatments were replicated thrice in randomized block design.

The total recorded rainfall during the *kharif* season was 642 mm considering only those rainstorms which produced >10 mm of rainfall in single rainstorm. The annual rainfall received was 966 mm, of which 862.5 mm during *kharif* (June-September) and remaining only 61.3 mm during rabi (October-April). The monthly average rainfall received during monsoon period is presented in Fig. 1. The soils of the experimental site are medium to coarse in texture with low to medium in moisture retention capacity. The characteristics of the soil of the experimental site are presented in Table 1.

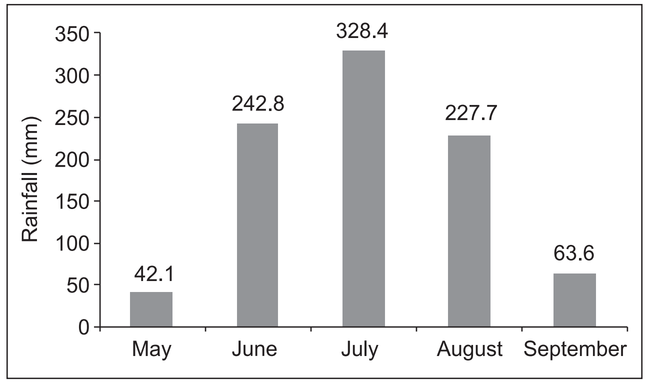


Fig. 1. Average rainfall during monsoon period

Since the economical crop produce under various treatments were different, maize equivalent yields were calculated on the basis of prevailing market rates of respective economical products of different crops in Jammu. The data were statistically analysed as per the procedures outlined by Cochran and Cox (1957).

Table 1. Characteristics of the soil of the experimental site

Soil characteristics	Values
pH (1:2.5)	7.2
EC (dS m^{-1})	0.32
Organic carbon (%)	0.35
Available N (kg/ha)	168
Available P (kg/ha)	11.4
Available K (kg/ha)	128
Sand (%)	65.4
Clay (%)	18.5
Textural class	Sandy loam
Bulk density (Mg m^{-3})	1.48
Water retention at 1/3 bar (%)	13.0
Water retention at 15 bar (%)	4.0

RESULTS AND DISCUSSION

Crop yields

There was certain increase in mean maize equivalent yields of intercropping systems than their respective sole stands of intercrops (Table 1). It was found to be 3 and 0.8 % higher under maize+mash and maize+cowpea intercrops over the sole maize (Table 2).

Higher maize-equivalent yields under intercropping than sole cropping of maize and / or legumes were also reported by Sharma et al. (1998) and Khola et al. (1999). These were attributed to better utilization and complementary nutrient use (Willey, 1979). Intercropping of legumes reduced the grain yield of maize which indicated the interspecific competition or allelopathic effects of legumes on maize was more than intraspecific competition or autotoxic effect of maize on maize that was in order cowpea> mash. The higher grain yield under maize + mash may be attributed to minimum adverse effects of growing mash in maize.

Maize also had adverse effects on grain yields of legumes in intercropping which was 52.3 per cent in maize+mash and 58.6 per cent in Maize + cowpea. Thus reduction in the grain yields of legumes due to maize was nearly same with mash and cowpea which revealed that interspecific competition in intercropping was more than intraspecific competition in different legumes.

Soil moisture storage

Periodic soil moisture storage was recorded in the standing crops and it was observed that in-situ gravimetric soil moisture was highest under maize+mash (14.64 %) at 60 days after sowing (DAS) (Table 2). This may be due to reduced runoff and more canopy cover preventing losses of moisture from the soil.

Table 2. Effect of intercropping on grain yield and maize equivalent yield.

Treatments	Yield ($q\ ha^{-1}$) Maize	Yield ($q\ ha^{-1}$) Intercrop legume	Maize equivalent Yield ($q\ ha^{-1}$)	Soil moisture storage at 60 DAS (cm / 60cm)
Maize sole	42.05	-	42.05	8.45
Mash sole	-	6.17	19.75	10.40
Cowpea sole	-	8.26	26.43	11.35
Maize+ mash	32.98	3.23	43.32	14.64
Maize +cowpea	26.94	4.84	42.43	12.22
Cultivated fallow	-	-	-	7.30
CD (5%)	-	-	2.35	-

DAS: days after sowing

Runoff and soil loss

It was observed that highest runoff (nearly 45 per cent of rainfall) was obtained in cultivated fallow as compared to sole maize (36.5%) or cowpea or mash in combination with maize (Table 3). Sole cowpea and sole mash produced comparatively low runoff resulting lower soil loss as compared to sole maize. However, combination with maize or maize alone was inferior in reducing runoff.

Table 3. Effect of intercropping on soil loss and runoff

Treatments	Runoff (% of rainfall)	Soil loss (Mg ha-1)
Maize sole	36.5	7.45
Mash sole	24.8	5.82
Cowpea sole	18.7	4.63
Maize+ mash	10.6	2.77
Maize + cowpea	14.2	3.34
Cultivated fallow	45.2	8.67

Monetary returns

Further, cowpea gave the highest monetary returns in terms of crop produce and maize-mash intercropping recorded the highest land equivalent ratio (LER) as compared to other intercropping or sole crop (Table 4). Maximum gross returns to the tune of Rs. 21658 ha^{-1} was observed under maize+mash which was nearly 3 per cent higher over the sole maize.

Table 4. Effect of intercropping on monetary return and biological feasibility

Treatments	Gross monetary returns (Rs ha^{-1})	Land equivalent ratio (LER)
Maize sole	21025	1.00
Mash sole	9872	1.00
Cowpea sole	13216	1.00
Maize+ mash	21658	1.32
Maize + cowpea	21214	1.22
Cultivated fallow	-	-
CD (5%)	2132	NS

Biological feasibility

Effect of crop species combinations on LER were statistically non-significant. Amongst intercrops, highest LER was observed under maize + mash, while minimum LER was found under maize + cowpea. Although maize + mash produced maximum LER, it could not give maximum gross return that is simply because LER does not take into account the relative monetary value of products (Willey, 1979) and also LER is independent of yield levels (Chetty and Rao, 1979).

Biological sustainability of intercropping over sole cropping of maize and legumes were indicated by higher LER values (1.22 to 1.32) under different crop species combinations (Table 4).

CONCLUSION

The study showed that intercropping of maize with legumes will be beneficial not only in terms of yields and monetary returns but also conserving the soil and in-situ moisture for the succeeding crops in the *kandi* (foothill) region. Also, keeping in view the atmospheric nitrogen fixing ability of legumes, the soil fertility can also be enhanced due to intercrops as compared to sole maize.

REFERENCES

Arora, Sanjay 2006 Preliminary assessment of soil and water conservation status in drought prone foothill region of north-west India. *Journal of World Association of Soil Water Conservation* J1-5: 55-63.

Arora, Sanjay and Bhatt, R. 2006 Effect of in-situ soil moisture conservation practices on soil moisture storage and yield of maize (*Zea mays* L.) in a rainfed foothill region of North-west India. *Tropical Agriculture* 82(3): 37-42.

Arora, Sanjay and Hadda, M. S. 2003 Soil moisture conservation and nutrient management practices in maize-wheat cropping system in rainfed North-western tract of India. *Indian Journal of Dryland Agricultural Research and Development* Vol 18 (1) : 70-74.

Arora, Sanjay, Sharma V., Kohli A. and Jalali V.K. 2006. Soil and water conservation for sustainable crop production in *Kandi* region of Jammu. *Journal of Soil and Water Conservation* 5(2) : 77-82.

Chetty, C.K.R. and Rao, U.M.B. 1979. Experimental designs for intercropping systems and analysis of data. In: Proceedings of International Intercropping Workshop, ICRISAT, Hyderabad, January 10-13, pp. 277-281.

Cochran W.G., Cox, G.M. 1957. Experimental design, 2nd ed. John Willey and Sons Inc., New York.

Dhruvanarayana, V.V. and Ram Babu 1983. Estimation of soil erosion in India. *J. Irri. Drain. Engg.* 109 : 419-434.

Gupta, R.D., Arora, Sanjay, Gupta, G.D. and Sumberia, N.M. (2010) Soil physical variability in relation to soil erodibility under different land uses in foothills of Siwaliks in N-W India. *Tropical Ecology* 51(II): 183-198.

Gupta, R.D. and Arora, Sanjay 2010. Watershed management and Eco-restoration of degraded lands in Northwest Himalayas. *Journal of the Soil and Water Conservation* 9(4) 249-253.

Hadda, M.S., Arora, Sanjay and Vashistha, M. 2006). Resource management for soil and water conservation in relation to crop productivity. *Journal of Soil and Water Conservation, India.* 5(4): 1-8.

Khola, O.P.S., Dube, R.K. and Sharma, N.K. 1999. Conservation and production ability of maize (*Zea mays*) – legume intercropping systems under varying dates of sowing. *Indian J. Agron.* 44(1) : 40-46.

Kukal, S. S., Khera, K. L. and Hadda, M. S. 1993. Soil erosion management on arable lands of submontane Punjab, India: a review. *Arid Soil Research and Rehabilitation*. 7(4): 369-375.

Sharma, R.S. and Chaubey, S.D. 1991. Effect of maize-legume intercropping systems on nitrogen economy and nutrient status of soil. *Indian J. Agron.* 26 : 60-63.

Sharma, V.M., Chakor, I.S. and Manchanda, A.K. 1998. Effect of maize (*Zea mays*)- based legume intercropping on growth and yield attributes of succeeding wheat (*Triticum aestivum*) and economics. *Indian J. Agron.* 33(2) : 231-236.

Tejwani, K.G. and Mathur, H.N. 1972. Role of grasses and legumes in soil conservation. *Soil Cons. Digest* 1: 21-29.

Willey, R.W. 1979. Intercropping its importance and research needs. Part I. Competition and yield advantage. *Field Crops Abs.* 32(1) : 1-10.

Journal of Soil and Water Conservation **11**(4): 281-286, October-December 2012
ISSN: 022-457X

Declining land quality: A challenge to agriculture growth

ARUN CHATURVEDI[1], NITIN PATIL[2], T.N. HAJARE[3], S.N. GOSWAMI[4] and R.S. GAWANDE[5]

Received: 29 April 2012; Accepted: 18 September 2012

ABSTRACT

The country is destined to combat with increasing agricultural productivity with its finite land resources. Net area sown per person has decreased from 0.329 ha in 1950-51 to 0.12 ha in 2007-08 showing a decline of 62 per cent during the span of 57 years. Similarly, gross cropped area per person also declined from 0.365 ha in 1950-51 to 0.17 ha in 2007-08 indicating a decrease of 52 per cent. The problem is compounded by the fact that sizeable land is not in a healthy state. Land degradation is the major cause of concern because despite differences about aerial extent, different reports are unanimous that large chunk of the land is being lost due to degradation. It is well understood that the health status of natural resources determines the productive capacity of soils and land. The severity of the problem due to land degradation in the country can be gauged from the fact that in different States, the economic losses account for 10 to 27 per cent of the total value productivity, the average being 12 percent for the country. This has implications for the sustainability of agriculture and food security of the nation.The present study examines the current scenario, especially land degradation, and discusses policy imperatives to protect precious land resources. Macro level and micro level implications are discussed. The suggestions include legislation to protect soils, no subsidy on electricity / groundwater pumping, discouraging free supply of irrigation water etc. There is an urgent necessity to formulate a national policy for compilation, coordination and sharing of information in respect of soil, land use and degraded lands.

Key words: soil health, land quality, agricultural productivity, land degradation

INTRODUCTION

It is estimated that 44 per cent of India's total land area is affected by land degradation, which has severe implications for livelihood and food security (MOEF 2009). Land, labour and capital are the three important resources which constitute the factors of agricultural production. In India, land gets least recognition due to a general perception that there is no dearth of land and its availability in large quantity has given complacency to the society. For most people in urban areas, land is an anchorage space which can be manipulated. It has become fashionable to talk about an anthropocentric approach for development. The question is, can there be human development in a country like India without a proper utilization of its land resources? Land being a finite natural national resource, its efficient use and management is vital for economic growth and development of the country.

The total geographical area of India being 328.73 million hectare (m ha), 306.06 m ha comprises the reporting area and 264.5 m ha only is under use for agriculture, forestry, pasture and other biomass production systems. Since 1970-71, the net area sown has remained around 140 m. ha (Ministry of Agriculture and Cooperation 2007-08). India supports approximately 16% of the world's human population and 20% of the world's livestock population on merely 2.5% of the world's geographical area. The demands on the finite land resources are increasing exponentially due to the growing population at the rate of 1.3 per cent. India's population is projected to reach 1.5 billion by about 2035 A.D. This population growth is making the man to land ratio more unfavorable. The per capita net sown area has been declining from 0.33 ha (1951-52)

[1-5] Division of Land Use Planning, National Bureau of Soil Survey & Land Use Planning, 633, Amravati Road, Nagpur – 440010
e-mail arunchat55@gmail.com

to 0.12 ha (by 2010 A.D.). The food production no doubt increased from 52 m tones (in 1950's) to 235 m tones (The Hindu April 24, 2011) but this has been largely as a result of expansion in cultivated area, irrigated area and use of high inputs. The significant growth of agriculture has been at a cost of decline in soil quality and risk of soil degradation. According to a study (Challa *et al*, 2007), about 57 per cent of soils are under different kinds and degrees of degradation and these are getting further deteriorated with risk of jeopardizing our food security systems. On the top of it, many more issues concerning environment, sustainability, carrying capacity of our land resources including increased demand of land and water for non- agricultural uses etc. are gaining importance. These adversely affect soil health and, in turn, human health.

The steady growth of human as well as livestock population, the widespread incidence of poverty, and the current phase of economic and trade liberalization are exerting heavy pressures on India's limited land resources for competing uses in forestry, agriculture, pastures, human settlements and industries. These multifunctional uses of land demands a more focused attention to develop agricultural / non agricultural uses for sustaining the increasing population (http: / / envfor.nic.in / soer / 2001 / ind_land.pdf).

Any agrarian economy is highly natural resource dependent. The status of natural resources determines the productive capacity of soils and land. Similarly, its degradation is also closely related to poverty for the people who are dependent on land. Studies on the socio-economic scenario of eroded / degraded lands of Chhindwara District M.P. have concluded that Soil and Land Degradation and Poverty have a direct relationship. The Severe and Very Severe Eroded lands of the district were mostly inhabited by tribal population, had less literate population, had fewer amenities and infrastructure facilities in comparison with the better lands (Chaturvedi, 1988). FAO studies have also concluded that soil erosion and other degradation lead to nutrient depletion reducing the soil fertility and thus reducing the agricultural production leading to poverty.

Land degradation: The Indian scenario

Land degradation is a ubiquitous and is also a natural phenomenon due to the basic nature of soil and land formation and the various bio-physical properties inherent in the soils. The degradation is, however, assuming serious proportions due to the increasing human interference. Problems are aggravating further with more and more new lands being brought under canal irrigation without proper education of the farmers in using irrigation water and managing the existing lands judiciously. The widespread land degradation resulting in reduced productivity is the most serious threat to our efforts to achieve sustainability goals. Land degradation is a serious threat to social, economic and political stability, particularly in developing country like India.

The major factors causing land degradation are: unsuitable agriculture practices, unsuitable water management, land use changes- conversion of prime forest land to agriculture uses, diversion of agriculture lands, pastures and grazing lands to other uses, uncontrolled and illegal logging / felling in forests, industrial and mining activities and discharge of effluents / pollutants and increased livestock pressure. Impact of land degradation is the loss of productivity and bio-diversity as it adversely affects the crop lands subjected to soil erosion and there is a rapid decline in the production.

In India, the estimates on land degradation / wastelands given by different agencies are highly variable (Table 1), which may largely be due to differing definitions of degraded lands and / or differentiating criteria used. Then there are different approaches in evaluating the soils and land degradation, the natural processes and the human dimension and also the question of scale of mapping. In such a scenario the estimation of degraded /

Table 1. Estimates of degraded / waste lands of India by different agencies

S. No.	Agencies / Organisation	Area (m ha)
1.	National Commission on Agriculture, Govt. of India (1976)	175.0
2.	Soil and Water Conservation Division, Ministry of Agriculture, Govt. of India	173.6
3.	Society for Promotion of Wastelands development (1984)	93.7
4.	National Bureau of Soil Survey and Land Use Planning (1994) (Being Revised)	187.7
5.	Department of Land Resources (2000)	63.8
6.	Department of Agriculture & Cooperation (1994)	107.4
7.	National Wasteland Development board, MoEF, (1985).	123.0

wastelands in India has varied from 63.8 m. ha. to as much as 187.7 m ha. (nearly 57 per cent of TGA).

Irrespective of the disagreement on precise aerial extent, there is no doubt that the soils are stressed and the decline in their productivity must be arrested. In addition to the extent of the soil/land degradation in India, the issue of its utilization is equally important. Chaturvedi and Thayalan (2003) have reported that in the North Deccan Plateau region of Madhya Pradesh, cultivation is taking place even in the very severely eroded lands. These are small farmers (mostly tribal) who cultivate coarse grains like *kutki* (little millet, *Panicum sumatrense*) for survival. These fragile lands are thus being further degraded in the absence of any conservation measures and low technology.

Vasisht *et al* (2003) have translated the physical extent of land degradation due to various causal factors into economic terms to gauge the severity of the problem. Presenting a methodology for assessing the economic losses on account of land degradation, they have applied the model to the Indian case to estimate the losses due to land degradation in economic terms. According to them, the total economic losses in the country are estimated at nearly Rs. 285.51 billion**.** The severity of the problem due to land degradation in the country can be gauged from the fact that in different States, the economic losses account for 10 to 27 per cent of the total value productivity, the average being 12 percent for the country. This has implications for the sustainability of agriculture and food security of the nation.

An analysis of the extent of land degradation in the major states of the country reveals that the extent of degradation (Table 2) is the highest in the State of Madhya Pradesh (26.2 m ha) and the minimum in Punjab (0.9 m ha). In terms of the proportion of degraded land to total geographical area of the State, the highest proportion of degraded land is in Kerala (67 per cent), followed by Madhya Pradesh (59 per cent) while the minimum is in Jammu and Kashmir (10 per cent). The other States in which the problem of land degradation is severe are Andhra Pradesh (57 per cent), Himachal Pradesh (54 per cent), Gujarat (53 per cent), and Uttar Pradesh (52 per cent). Among the 17 States for which the data were available, with the exception of Jammu and Kashmir (10 per cent) and Punjab (18 per cent), 15 States had over one-third of area degraded due to one or more of the causal factors. These data highlight the severity of the problem of land degradation in the country.

Table 2. Extent of land degradation in major states of India

States	Degraded land area (000' ha)	Degraded land as % of total geographical area
Andhra Pradesh	15662	57
Assam	2807	36
Bihar 6291	36	
Gujarat	10336	53
Himachal Pradesh	3008	54
Haryana	1384	31
Jammu & Kashmir	2225	10
Karnataka	7681	40
Kerala	2608	67
Maharashtra	13328	43
Madhya Pradesh	26209	59
Orissa	6121	39
Rajasthan	13586	40
Tamil Nadu	5273	41
Uttar Pradesh	15253	52
West Bengal	2752	31
Punjab	896	18
All India	187700	57

Source: NBSS & LUP (ICAR), Nagpur, 2000

Policy initiatives to combat land degradation

The Government has initiated many programmes to combat the menace of soil and land degradation. These are Integrated Wasteland Development Project (IWDP), Desert Development Programme (DDP). Drought Prone Areas Programme (DPAP), Reclamation of Alkali Soil (RAS), Watershed Development Project in Shifting Cultivation Areas (WDPSCA), National Watershed Development Project In Rainfed Areas (NWDPRA), River Valley Project & Flood Prone Rivers (RVP & FPR) of the Government between 1999-2002, the maximum being in Rajasthan and Gujarat. The irony is that in the same period, the net sown area decreased and area under non-agriculture uses increased. Uttar Pradesh had an area of 715000 ha under these programmes but in the same period a large amount of good agriculture land was deprived of its biological productivity through conversion to non-agriculture uses, some being irreversible in nature. A very important issue in appreciating the relevance of land degradation and its impact on Indian agriculture is the ownership of these lands. Most of the degraded lands in the country are not under private ownership and are owned either by the Government or under local authorities.

Net area sown per person decreased from 0.329 ha in 1950-51 to 0.12 ha in 2007-08 showing a decline

Classification	1950-51	1960-61	1970-71	1980-81	1990-91	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08 *(P)*
Geographical Area	328.73	328.73	328.73	328.73	328.73	328.73	328.73	328.73	328.73	328.73	328.73	328.73	328.73
Reporting area	284.32	298.46	303.75	304.16	304.86	305.18	305.12	305.34	305.56	305.58	305.43	305.64	305.67
1. Forest	40.48	54.05	63.83	67.46	67.81	69.53	69.41	69.57	69.65	69.65	69.67	69.71	69.63
2. Not Available for Cultivation (A+B)	47.52	50.75	44.61	39.55	40.48	41.48	41.57	42.07	42.23	42.47	42.57	42.96	43.22
(A) Area Under Non-agricultural Uses	9.36	14.84	16.48	19.60	21.09	23.89	24.05	24.26	24.65	24.89	25.10	25.54	25.92
(B) Barren & Un-culturable Land	38.16	35.91	28.13	19.96	19.39	17.59	17.52	17.80	17.58	17.58	17.46	17.42	17.29
Other uncultivable land excluding fallow (A+B+C)	49.45	37.64	35.13	32.31	30.22	27.74	27.5	27.5	27.11	27.13	27.06	27.05	26.82
(A) Permanent Pasture & other Grazing Land	6.68	13.97	13.26	11.99	11.40	10.67	10.53	10.54	10.49	10.46	10.45	10.43	10.39
under Miscellaneous Tree Crops & Groves not included in Net Area Sown	19.83	4.46	4.37	3.58	3.82	3.44	3.45	3.36	3.38	3.4	3.39	3.37	3.31
(C) Culturable Waste Land	22.94	19.21	17.50	16.74	15.00	13.63	13.52	13.61	13.24	13.27	13.22	13.26	13.12
4. Fallow Lands (A+B)	28.12	22.82	19.33	24.55	23.37	25.07	25.90	33.74	25.81	25.17	24.64	25.97	25.15
(A) Fallow Lands other than Current Fallows	17.45	11.18	8.73	9.72	9.66	10.29	10.56	11.88	11.34	10.69	10.60	10.50	10.34
(B) Current Fallows	10.68	11.64	10.60	14.83	13.70	14.78	15.35	21.86	14.47	14.48	14.04	15.47	14.81
5. Net Area Sown (6-7)	118.75	133.20	140.86	140.29	143.00	141.36	140.73	132.47	140.76	141.17	141.49	139.95	140.86
6. Total Cropped Area (Gross Cropped Area)	131.89	152.77	165.79	172.63	185.74	185.34	188.29	175.58	190.08	191.55	193.05	193.23	195.83
7. Area Sown more than once	13.15	19.57	24.93	34.63	42.74	43.98	47.55	43.11	49.32	50.38	51.56	53.28	54.97
8. Cropping Intensity*	111.1	114.7	117.7	123.1	129.9	131.1	133.8	132.5	135.0	135.7	136.4	138.1	139.0

Cropping Intensity is percentage of the gross cropped area to the net area sown.

Note: 1. Figures in parenthesis indicate percentage to the Reported Area.
2. The decline in net area sown in 2002-03 reflects the impact of the severe drought of 2002-03 on agriculture operations.

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation.

of 62 per cent during the span of 57 years (Table 3). Similarly gross cropped area per person also declined from 0.365 ha in 1950-51 to 0.17 ha in 2007-08 indicating a decrease of 52 per cent. Grazing area per animal showed a gradual declining trend from 0.047 ha in 1960-61 to 0.021ha in 2007-08 indicating a decline of around 50 per cent. This has shown a gloomy scenario to animal rearing population about the future scarcity in grazing land for increasing animal population.

Policy imperatives for land use planning

In order to prevent land resources from further degradation and to ensure appropriate land use for production of food, fuel, and fodder on sustainable basis, it should address the following issues:

- Deciding the most appropriate land use based on the resource potential and empowering the State land use Board to implement it.
- Discourage irrational use of irrigation water. Supply of subsidized or free electricity for pumping groundwater, subsidized irrigation water supply need to be dispensed with to slow down accelerated land degradation in irrigation commands.
- Policy initiatives to encourage adoption of soil conservation practice with each farmer as a unit, a tough measure to implement because conservation practices require community approach for protecting a contiguous belt of land. Innovations like mandatory compensation to be paid by upstream farmer (not adopting measures) to the downstream farmer every annum till the belt is developed need to be considered.
- Like forest resources, legislation to protect soil / land resources need to be pursued.
- Creating awareness amongst the farmers and land users for implementation of recommended land uses.
- Synergy between the departments and agencies working for land use and its implementation.
- Scientific generation of database for various land resources and land uses, for various category of users, national and regional planners, district and watershed level implementers through resource surveys and classification.
- A national policy for compilation, coordination and sharing of information in respect of soil, land use and degraded lands need to be developed and adopted by all for availability of real time data for planning, development and monitoring of the programmes. Measures to conserve soil moisture in fallow lands so that these lands under current fallow (left uncultivated during seasons of erratic rainfall) can be effectively utilized.
- Development / Reclamation of degraded lands in planned and phased manner to bring into additional cultivable areas to meet the demands of food for teeming population.
- Involvement of people for sustainable use of soil and water, need to be taken up at Panchayat levels involving Panchayati Raj Institutions.

Future scenario

The minimum amount of arable land required to sustainably support one person is 0.07 of a hectare. This assumes a largely vegetarian diet, no farmland degradation or water shortages, virtually no post-harvest waste, and farmers who know precisely when and how to plant, fertilize, irrigate, etc. (Norman Myers, 1998). According to the population projections of Planning Commission, we shall need to feed an extra 300 million people by 2021 and 600 million by 2061 (Srinivasan and Shastri, 2002). This would mean that almost 2.1 m. ha of additional land would be required in another 12 years, land with no farmland degradation or water shortages, high quality management practices by highly efficient and learned farmers.

The Planning Commission has projected that the net area sown or arable land of the country will remain constant at 142 million hectares. Annual growth in net area sown was at around 1% in the early period of planning which fell to around 0.6% and then to 0.3% in subsequent decades and is now not growing at all. It is reasonable to assume that the geographical area of the country or the extensive land frontier for exploitation has reached its limit. This is an important issue, the implications of which are not being realized with the urgency they deserve. The availability of land is expected to emerge as a major constraint on agricultural growth. Due to increasing demand of land for housing, rising level of urbanization and industrialization, increasingly larger quantity of agricultural land is being shifted to non-agricultural uses. In the past such loss of agricultural land was being compensated by converting forest land into agricultural land. However, there is no scope for further conversion of the forest land. As per 2007-08 land use statistics, the total area under forestry was 69.63million hectares which constituted 22 per cent of total reported area. The Planning Commission has set a target of bringing one-third of the geographical area (109.56 million hectares) under forest cover by the end of the next decade. This will require an additional area of 40.73 million ha to be brought under forestation. Apart from that, because of increasing housing demand, urbanization and industrialization, the area under non-agricultural uses is likely to increase. In 2007-08, 25.92 million hectares were under non-agricultural uses. Between 2001-02 and 2007-08, the area under non-agricultural uses increased at the annual rate of 0.85 per cent. Assuming the same trend to continue, the area under non-agricultural use is likely to be 28.12 million hectares by the end of 2021-22. Thus, forestry and non-agricultural use would require additional 42.93 million hectares over the perspective period till 2021-22. At present, nearly 77.89 million hectares of land are lying uncultivated or fallow, of which 13.79 million hectares are under pasture and tree crops. Thus nearly 64.19 million hectares of land are available, sufficient to meet the additional requirement of area for forestry and non-agricultural use at the macro level provided forestry and non-agricultural use are undertaken on such land. However, at the micro level, non-agricultural use is spreading into the uncultivated land area. This is likely to reduce the cultivated area, or spreading cultivation into marginal, fallow and other less suitable lands with serious economic and environmental consequences.

REFERENCES

Challa O., S.N. Goswami and M.V. Venugoplan 2007. Emerging Land Use related issues and policy imperatives to resolve land use conflicts. Paper presented at India-IIASA Joint Workshop on "Economic Societal and Environmental Benefits provided by Indian forests held at India International Centre Annexe, New Delhi-110012 during 25th - 27th April, 2007.

Chaturvedi Arun 1988. Socio Economic Constraints in Optimisation of Land Use in Chhindwara District, M.P. Ph.D. Thesis (unpublished), Nagpur University, Nagpur.

Chaturvedi Arun and S. Thayalan 2003. Eroded/ Degraded Lands of North Deccan Plateau and their Utilisation. ANNALS of National Association of Geographers', India.(NAGI). Vol. XXIII, No. 1.

Norman Myers 1998. The next green revolution: Its environmental underpinnings. Presented at the Interdisciplinary Dialogue on Malthus and Mendel: Population, Science and Sustainable Security, held at M. S. Swaminathan Research Foundation, Chennai, 28 January 1998.

Srinivasan K. and V.D. Shastri 2002. A Set of Population Projections of India and the Larger States based on 2001 Census Results. Background Paper, Planning Commision. New Delhi.

MOEF 2009. State of Environment Report India. Ministry of Environment and Forests, New Delhi. URL: http://www.hindu.com/2011/04/24/stories/2011042456831300.htm

Vasisht, A. K., Singh, R. P., Mathur, V. C. 2003. Economic implications of land degradation on sustainability and food security in India. Agropedology (No. 2) 19-27.

Journal of Soil and Water Conservation **11**(4): 287-295, October-December 2012
ISSN: 022-457X

Micro irrigation for efficient water management

NEELAM PATEL[1] and T.B.S. RAJPUT[2]

Received: 18 July 2012; Accepted: 14 November 2012

ABSTRACT

India shares 16% of the global population with only 2.4% of land and 4% of water resources. India has one of the largest irrigation networks in the world but more than half of the cultivated area in the country still remains without irrigation facility. Water use efficiency in irrigated areas particularly under canal irrigated areas is very poor. Increasing food grain requirements for burgeoning population in the country puts increasing pressure on land and water resources. Micro irrigation system result into higher water use efficiency and water productivity and thus offer a viable option for meeting the increased demand of food grains, fruits and vegetables and other high value crops. However, these systems are expensive to install and require the farmer to be trained in optimally using these systems. Government of India had initiated a Centrally Sponsored Scheme on Micro irrigation. Viewing micro irrigation technology as an integral part of comprehensive water management strategy with the focus on enhancing water productive efficiency (more revenue per drop of water) Ministry of Agriculture has now launched National Mission on Micro Irrigation for the promotion of micro irrigation on a sustainable basis. Out of a potential of 27 Mha area projected to be brought under drip irrigation in he country, by the end of 2011 an estimated 2.52 Mha has already been brought under drip irrigation in the country.

Key words: micro irrigation, water management

INTRODUCTION

Indian agriculture, accounting for 25% of the nation's Gross Domestic Product (GDP), 15% of exports and 60% of the employment continues to be the mainstay of economy. Having achieved laudable success in agricultural production in the last 50 years (50 Million ton to 230 Million ton) India has transformed herself from a food deficit country to a food surplus country. Still there are many challenges, which Indian agriculture is facing, in a fast changing technical and socio-economic scenario. Relating to the natural resources and production base, water has emerged as the most crucial factor for sustaining the agricultural sector. India accounts for 16 percent of the world's human population and nearly 30% of the cattle with only 2.4% of the land and 4% of the water resources. Even if the full irrigation potential is exploited, about 50% of the country's cultivated area will still remain unirrigated, particularly with the current level of irrigation efficiency. The share of water for agriculture would reduce further with increasing demand from other sectors. But the water demand for agricultural purposes is estimated to increase in order to produce more cereals, horticultural produce and raw material for a fast expanding food industry. Efficient management of water is, therefore, key to future growth of Indian agriculture. The requirement of water by all sectors in 2025 is estimated to be 105 M ha m (Water Resources Development in India, 2010). Share of water for agriculture is expected to get reduced from the present level of 85 % to 69 % by 2025. On the other hand, the actual agricultural water demand is estimated to increase from 470 Billion Cubic Meters (BCM) in 1985 to 740 BCM in 2025. During the same period, the demand for non-agricultural use of water will multiply four fold from 70 BCM to 280 BCM.

Misplaced and inappropriate policies leading to indiscriminate use of water, lack of appropriate technologies, poor technology transfer mechanisms and inadequate and defective institutional support systems have led to serious agro-ecological and

[1]Senior Scientist and [2]Principal Scientist, Water Technology Centre, Indian Agricultural Research Institute, New Delhi-110012, Email: neelam@iari.res.in

sustainability problems in irrigated areas. Water table rise and water logging covering an area of 8.5 M ha are major problems in canal command areas. Secondary salinization, receding water table at a rate of, as high as one meter annually along with under ground water pollution in many states are the daunting problems in tube well irrigated areas. The water use efficiency (WUE) in Indian agriculture, at about 30-40%, is one of the lowest in the world, against 55% in China.

The vulnerability of Indian agriculture is bound to be severe if the present trend of water use and management efficiency is not changed. The International Water Management Institute forecasts that by 2025, 33% of India's population will live under absolute water scarcity condition. Rainfed lands are not only low in productivity and sustainability, but also more prone to risks, as compared to irrigated areas. Rainfed areas are also the location where, proportionately a greater concentration of poor and hungry persons lives. This can be obviated to some extent by expanding irrigated areas through improving water management and water use patterns. Presently, the problem facing the country is not the development of water resources but the management of the developed water resources in a sustainable manner. By adopting efficient water management practices, the bulk of India's agricultural lands could be brought under irrigation. Micro irrigation is one such practice.

DEVELOPMENT OF MICRO IRRIGATION IN INDIA

Micro irrigation (drip irrigation, trickle irrigation) is based on the fundamental concepts of irrigating only the root zone of the crop rather than the entire land surface and maintaining the water content of the root zone at near optimum levels. It is one of the latest methods of irrigation, which is becoming increasingly popular in areas with water scarcity and salt problems. Economic considerations usually limit the use of drip irrigation system to orchards and vegetables in water scarcity areas. The concept of drip irrigation goes back at least to the ancient Egyptians who placed porous pots in the soil and filled them with water. Use of subsurface clay pipes for irrigation in Germany led to doubling of crop yields in 1860 and perhaps that was the beginning of the concept of applying irrigation water directly to the root zone. Nehemiah Clark, in 1873, obtained the first known US patent for a water-emitting device as a dripper (a simple hole).

Almost at the same time experiments of irrigating with porous pipes began. Drip irrigation in principle evolved from subsurface irrigation when in 1920, the drainage tubes (with open joints) of subsurface irrigation were replaced experimentally by porous pipes for the purpose of irrigation. Another version of porous pipe was the perforated pipe, which allowed the exit of water through holes or slits in its wall and the flow caused by the pressure inside the pipes. The perforated pipe was used in Germany, which made the concept feasible, and various experiments were then centered on the development of drip system using perforated pipe made of various materials. During early 1940, Symcha Blass, an Israeli engineer observed that a large tree near a leaking faucet exhibited a more vigorous growth than the other tree in the area, which were not reached by the water from the faucet. This example of leaking faucet led him to the concept of an irrigation system that would apply water in small amounts.

In several parts of India, it is an age old practice of system similar to drip was used for irrigating 'tulsi' plant. An earthen pitcher used to be hanged above the plant with the help of ropes. The pitcher used to have a small hole at the bottom with wick of straw through which water used to discharge in drops over the plant. In India, micro irrigation was originally practiced through some indigenous methods like, micro irrigation using bamboo pipes in Meghalaya, perforated clay pipes and pitchers in Maharashtra and Rajasthan. In Meghalaya an ingenious system of tapping of stream and spring water by using bamboo pipes to irrigate plantations is widely prevalent. The tribal farmers of Khasi and Jaintia hills use this 200-year-old system to irrigate the betel leaf or black pepper crops planted in mixed orchards. Bamboo pipes are used to divert perennial springs on the hilltops to the lower reaches by gravity. The channel sections, made of bamboo, divert and convey water to the plot site where it is distributed without leakage into branches, again made and laid out with different forms of bamboo pipes.

During the initial phase of drip irrigation, viz., during 1971, the area under drip irrigation totaled 56,000 hectares worldwide. In 1998, the area under micro irrigation was around 2.8 million ha. In India, the area under drip irrigation had grown from a negligible level in 1975 to around 25.23 lakhs ha in 2011-12 (NCPAH, 2012). In India, Maharashtra, Tamil Nadu and Karnataka are some of the states which have taken a lion's share in drip irrigated area constituting 39.7 per cent, 28 per cent and 24.3 per cent respectively of total area under micro irrigation.

In India, though the research work on drip irrigation had started at Water Technology Centre, Indian Agricultural Research Institute, New Delhi and Tamil Nadu Agricultural University almost simultaneously in 1970 but it took a couple of years before the farmers initiated to adopt (Michael, 1978, Sivanappan et. al., 1987). However, micro irrigation systems were initially not popular due to poor quality of components and lack of services from the manufacturers / traders. It took more than ten years before Indian business started showing interest in the systems, after getting convinced that the system has potential in the country. By the time researches in different ICAR Institutions and Agricultural Universities had provided adequate data to prove that the systems not only save water but also help in improving crop yields and the quality of the produce. The positive results of the experimentations by the grape growing farmers in Maharashtra proved the much needed catalyst in increasing the popularity of the micro irrigation system by assuring the farming community of its benefits including its cost effectiveness.

GOVERNMENT OF INDIA INITIATIVES

Recognizing the urgent need for increasing Water Use Efficiency (WUE), Government of India had constituted a National Task Force on Micro Irrigation under the Chairmanship of the then Chief Minister of Andhra Pradesh, Shri N. Chandrababu Naidu. The Task Force made the following recommendations.

1. Micro irrigation is to be promoted in a holistic manner involving appropriate cultivars, agronomic practices and post harvest handling, processing and marketing.
2. Fifty per cent (50%) financial assistance should be provided to farmers for adoption of micro / sprinkler irrigation.
3. Micro irrigation should be made compulsory in command areas of new irrigation projects. There is a need to introduce a policy of "no lift without drip" to ensure benefits to large number of farmers with the same amount of water.
4. High taxes such as sales tax, trade tax, purchase tax and local taxes like octroi, entry tax, etc. ranging from 4 to 10 percent are waived.
5. An apex body in the form of National Council on Precision Farming be established and vested with the responsibility of providing technical guidance, channelizing resources, monitoring and electronic database management, establishing linkage with market chain besides overseeing the overall development of micro irrigation in the country.
6. Adequate post-installation maintenance and extension services need be provided to the farmers.
7. The network of 22 Precision Farming Development Centers (PFDCs) to be strengthened and converted into centers of excellence. These should be equipped to function as quality testing centers for micro irrigation.
8. The Task Force estimated potential for Drip irrigation of 27 Mha and for Sprinkler irrigation as 42.5 Mha as given in Table 1.

Table 1. Theoretical potential of micro irrigation in India

Crop	Area (Million Ha)		
	Drip	Sprinkler	Total
Cereals	-	27.6	27.6
Pulses	-	7.6	7.6
Oil seeds	3.8	1.1	4.9
Cotton	7.0	1.8	8.8
Vegetables	3.6	2.4	6.0
Spices and condiments	1.4	1.0	2.4
Flowers, Medicinal, aromatic plants	-	1.0	1.0
Sugarcane	4.3	-	4.3
Fruits	3.9	-	3.9
Coconut & Plantation crops, Oil palm	3.0	-	3.0
Total	27.0	42.5	69.5

Based on the recommendations of the Task Force, Government of India had initiated a Centrally sponsored micro irrigation scheme in the country with 50% financial support to farmers from Central as well as State Government budgets in the ratio of 4:1. National Committee on Plasticulture Applications in Horticulture was made its coordinating agency. The results of the efforts of the scheme may be seen in Table 2.

Table 2. The state-wise total area under Drip/ Sprinkler Irrigation (ha) till 31.03.2010

State	Drip	Sprinkler	Total
Andhra Pradesh	655767	320881	976648
Arunachal Pradesh	613	0	613
Assam	116	129	245
Bihar	578	33201	33780
Chattisgarh	8798	133961	142759
Goa	849	1544	1544
Gujarat	299279	246852	546131
Haryana	17400	541910	559309
Himachal Pradesh	116	581	697
Jharkhand	1273	8842	10115
Karnataka	293593	385675	679268
Kerala	16593	4004	20597
Madhaya Pradesh	101288	171437	272726
Maharashtra	779295	346600	1125895
Manipur	30	0	30
Mizoram	72	106	178
Nagaland	0	3962	3962
Orissa	12109	43958	56067
Others	15000	30000	45000
Punjab	26758	11533	38291
Rajasthan	53934	1090033	1143967
Sikkim	23460	11339	34799
Tamil Nadu	201396	28196	22592
UP	13963	16832	30794
Uttaranchal	38	6	44
West Bengal	538	150576	151114
Grand Total	2522854	3581309	6104163

Source: NCPAH, Ministry of Agriculture, GoI, 2012

Drip irrigation can be used for most crops, such as:

Orchard crops : Grapes, Banana, Pomegranate, Orange, Citrus, Tamarind, Mango, Fig, Lemon, Custard Apple, Sapota, Guava, Pineapple, Coconut, Cashew nut, Papaya, Aonla, Litchi, Watermelon, Muskmelon etc.

Vegetables : Tomato, Chilly, Capsicum, Cabbage, Cauliflower, Onion, Okra, Brinjal, Bitter gourd, Bottle gourd, Ridge gourd, Cucumber, Peas, Spinach, Pumpkin etc.

Cash Crops : Sugarcane, Cotton. Arecanut, Strawberry etc..

Flowers : Rose, Carnation, Gerbera, Anthurium, Orchids, Jasmine, Lily, Mogra, Tulip, Dahilia, Marigold etc.

Plantation : Tea, Rubber, Coffee, Coconut etc.

Spices : Turmeric, Cloves, Mint etc.

Oil seed : Sunflower, Oil palm, Groundnut etc

Forest crops : Teakwood, Bamboo etc.

The Government of India (GOI) plans to cover 17 Mha under drip and sprinkler systems by the end of XI plan. The Micro Irrigation Scheme has been launched by the GOI with this objective. Micro irrigation system was found to result in 30 to 70 % water savings in various orchard crops and vegetables from along with 10 to 60 % increases in yield as compared to conventional methods of irrigation. Mulching with drip further enhanced the crop yield to the tune of 10-20 % and controlled weeds up to 30-90%.

Table 3. Area Covered under Drip/Sprinkler irrigation under CSS on Micro Irrigation

Financial Year	Drip Irrigation(ha)	Sprinkler Irrigation(ha)	Total (ha)
2006-07	155000	144000	299000
2007-08	209000	241000	450000
2008-09	250000	324000	574000
2009-10	1897280	3044940	4942220
Total	2511280	3753940	6265220

Source: Progress reports from state governments

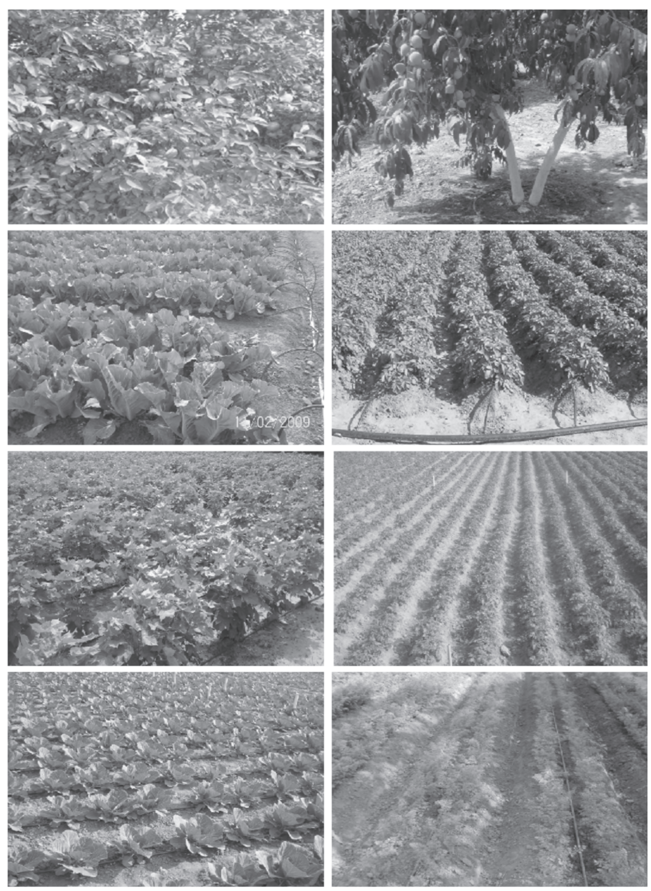


Fig. 1 Micro irrigation in different crops

IMPACT OF MICRO IRRIGATION

A review of selected literature on micro irrigation technology is strongly suggestive of economic viability of this technology for many crops of India. What is no less striking is that this economic viability exists even without taking into account the Government subsidy available on micro irrigation under various development programs. The cost for installing the system works out Rs. 15,000 – Rs. 25,000/ ha for widely spaced crops like coconut, mango etc to Rs. 60,000 – 90,000/ ha for closely spaced crops like cotton, sugarcane, vegetables etc. The cost depends upon the crop, spacing, water requirements, source of water supply etc. The economics of micro irrigation has been calculated and payback period was worked after interviewing more than 50 farmers for different crops (Table 4). It is observed that the payback period is about one to 2 years for most of the crops and the benefit cost ratio varies from 2 to 5 (Sivanappan, 2009).

The impact in introducing the micro irrigation system is grouped under.

1. Benefit to the Nation
2. Benefit to the farmers

(a) Benefit to the Nation

(i) Saving in infrastructural cost on irrigation projects:

With the adoption of micro irrigation, there would be saving of irrigation water required (40-70%) for the crops. Under the principle of "water saving is water created" there would be benefit to the nation in the form of saving in cost or creating irrigation infrastructure for increasing the irrigated area. In place where there is no water for extending irrigation facility, the same can be done by converting from surface irrigation to drip irrigation. The Task Force on micro irrigation has worked out, for a coverage of additional area of 17 M ha under irrigation by the end of IX plan, the saving of water will be about 5.9 M ha m. Based on the saving in irrigation water and the total value of the savings which otherwise will have incurred for creating equal amount of irrigation potential, works out to be about Rs. 45,000 crores.

(ii) Saving in subsidized electricity supplied to agriculture sector due to reduction in electricity consumption with micro irrigation. It is estimated about Rs. 3767 crores.

(ii) Saving in subsidized electricity supplied to agriculture sector due to reduction in electricity consumption with micro irrigation. It is estimated about Rs. 3767 crores.

(iii) Saving in subsidy for the fertilizer due to saving in fertilizer by adopting drip / fertigation. Micro irrigation saves about 30-40% of the fertilizer used i.e., about Rs.5500 crores / annum.

(iv) Employment generation:

1. Due to micro irrigation industry
2. Semi skilled persons required for installation & maintenance
3. Direct employment in agriculture since more area is brought under irrigation
4. Indirect employment – post harvest, transportation, marketing etc.

(b) Benefits to farmers due to increased yield and good quality of produce

Micro irrigation led agriculture should be viewed as one of the eco-technological approaches to attain sustained and enhanced agriculture production and productivity. Through micro irrigation, the green revolution could be transformed into an evergreen revolution to ensure the sustainability, profitability and equity. Since micro irrigation greatly enhances water, fertilizer and energy use efficiency and promotes precision agriculture, the green revolution could be achieved without the burden of environmental degradation.

5. Micro irrigation research in India

Different Institutes of Indian Council of Agricultural Research, State Agricultural Universities and other Water Management Research Institutes investigated different aspects primarily on crop, water, and fertilizers etc. related management technologies. which are summarized in brief in the following paragraphs.

i) Studies on water saving and yield enhancement

Many studies across the country compared different micro irrigation methods with conventional methods of irrigation like border, check basin, furrow or surge irrigation and established beyond doubt the superiority of micro irrigation methods in different aspects of water management (Table 4) (Annonymous, 2001).

Table 4. Increase in yield and water savings in micro irrigation as compared to surface irrigation

Crop	Increase in yields, %	Water saving, %
Tomato	25-50	40-60
Chilli	10-40	60-70
Sugarcane	50-60	30-50
Bottle Gourd	20-40	40-50
Okra	25-40	20-30
Cauliflower	60-80	30-40
Potato	20-30	40-50
Pomegranate	20-40	50-60
Cabbage	30-40	50-60
Cabbage	50-60	50-60
Brinjal	20-30	40-60
French Bean	55-65	30-40

ii) Crop Geometry

Micro irrigation methods encourage researchers to investigate different planting arrangements for maximizing crop yields. Also the cost of the micro irrigation system depends on the crop geometry. Some of the significant findings of the research efforts in terms of optimal plant to plant and row to row spacing of different crops for getting the maximum yields and least cost of the system are presented in Table 5 (Anonymous, 2001).

iii) Fertigation Studies

The introduction fertigation opened up new possibilities for controlling water and nutrient supplies to crops and maintaining the desired concentration and distribution of ions and water in the soil. Most research is focused on comparing the conventional fertilization method with fertigation, especially the NPK use efficiency and their impact on the quantity and quality of produce. Adoption of fertigation by farmers in several crops registered significant fertilizer savings (20 to 60%) in different crops (Table 6). New fertilizers for fertigation include slow and controlled release fertilizers which ensure continuous plant nutrition over months besides matching nutrient release rate with plant needs, labour saving and reduced leaching.

Table 6. Effect of fertigation on yield of different crops

Crop	% Saving in fertilizer	% Increase in yield
Tomato	40	18
Castor	60	32
Okra	40	18
Cotton	-	20
Onion	40	16
Potato	40	-
Broccoli	40	10
Tomato	50	28
Banana	20	11
Tomato	40	33
Bangalore blue grapes	20	-
Sugarcane	50	-
Sapota	40	-
Gerbera	-	37
Banana	40	-
Tomato	20	25

6. Advances in Micro Irrigation

Initially, micro irrigation was used primarily for high-value crops such as fruits, vegetables, nuts, and sugarcane. As system reliability and longevity improved, its application was extended to lower-valued agronomic crops (viz., cotton, tobacco, peanuts, corn, castor, chickpea, soybean, sunflower etc.) and spices & condiments (ginger, turmeric, cardamom etc), primarily because the system could

Table 5. Effect of crop geometry on the yield and water saving under micro irrigation

Crop	Location	Recommended Row to Row and Plant to Plant Spacing, cm x cm	Increase in Yield, %	Water Saving, %
Okra	Delhi	30 x 15	66	71
Tomato	Delhi	40 x 40	81	54
Banana	Coimbatore	200 x 400	70	-
Okra	Coimbatore	30 x 40	30	-
Banana	Kharagpur	200 x 400	50	50
Pea	Solan	20 x 11.50	80	-
Tomato	Solan	20 x 42.1	42	-
Cabbage	Hyderabad	20 x 72	50	50
Banana	Navsari	120 x 200	28	40
Chilli	Coimbatore	20 x 72	50	50
Sugarcane	Navsari	60 x 120	17	46

be used for multiple crops & years owing to varied planting patterns (mainly paired row pattern), reducing the annual system cost with enhanced rate of return on investment.

i) Emitter types and design

In many countries still the dominant emitter type used by the farmers in several field & horticultural crops is either point source (individual button drippers) or line-source (integral drip lines and drip tapes). In the USA, Israel, Australia, Spain, South Africa, India, Mexico, China, France, Germany, Thailand, Philippines, Malaysia etc there is an increasing tendency to use line-source emitters primarily for sugarcane, corn, tobacco, mulberry, vegetables, flowers etc. Subsurface drip with pressure compensating dripper and flap outlet is gaining momentum in several crops viz., turf grass, cotton, sugarcane, corn, potatoes, vegetables, grapevines etc in the USA, South Africa, Israel, Australia, Turkey, Argentina, France etc.

ii) Low-flow irrigation

Soil water potential and water content in the vicinity of active roots generally controls the rate of water and nutrient uptake by plants. In drip irrigation, frequency and emitter discharge determine the variation in soil water potential, and consequently, root distribution and plant water uptake patterns. Drip irrigation systems generally consist of emitters that have discharge rates varying from 2 to 8 Lph. In semiarid summer climates crop water use is generally 6 to 8 mm / day, and water is supplied two or three times a week. Therefore the duration of water application is much shorter than the time over which plants take up water. Even if the water is supplied on a daily basis, a water application rate of 2 Lph delivers the consumptive needs of plants in a small fraction of the time over which plants photosynthesize and transpire. This means that even for water applications exactly equal to plant water needs, part of the water may not be used by the plant and would most likely drain below the root zone. Lowering emitter discharge rates to as close as possible to plant water uptake rates may reduce these percolation losses. Recently, low pressure drip systems have been developed that provide emitter discharge rates lower than 1.0 Lph (Battalwar, 2009)..

The low pressure drip irrigation system (LPS) is a systematic development of low cost drip system which performs as drip except that the water is applied on the soil surface or below the soil surface through discrete emitters with low discharge rates (0.6 – 1.0 LPH) and narrow spacings. The low pressure capability of LPS (0.3 – 0.5 bars) provides an effective low energy and economical upgrade for flood / furrow irrigation. LPS is specifically designed to enable growers to use existing infrastructure like leveled fields, water sources and pumps, minimize front end investment, provide fast return on investment, reduce energy cost on pumping and pressurizing, move and reuse equipment easily, provide low system maintenance and management.

iii) Automation

There is an increasing trend to shift from manual to automatic operations. Irrigation can be almost totally automated by using micro irrigation systems. This requires linking the irrigation water lines to a remote control mechanism that uses small computers. Israel first introduced these computerized controls into its farm management systems in the early 1970s. In either small or large micro irrigation systems and greenhouses, the computer can control water flow, detect leaks, shut off faulty lines, adjust water application for wind speed, air temperature, and soil moisture content; filter backwash; apply fertilizer on schedule; monitor plant growth & water relations. An added advantage of the computerized systems is their ability to locate malfunctions and alert the operators to make necessary repairs before the faulty element causes too much damage or water loss. Accurate and precise application rates, increased yields (2 – 10%) savings in water & energy (10 – 30%), reduced labour cost, minimized return flow, aquifer & stream pollution; improved pest and disease control are among the major advantages that are offered by adopting automation techniques in micro irrigation.

iv) Use of waste water through micro irrigation

Use of wastewater for irrigation of industrial crops, fruits, managed landscapes, golf & race courses has been actively practiced in other countries for many years, especially in Israel & USA. However, wastewaters often contain microbial and chemical contaminants that may affect public health and environmental integrity. Wastewater pre-treatment strategies and advanced irrigation systems may limit contaminant exposure to crops and humans. Subsurface drip irrigation (SDI) shows promise for safely delivering reclaimed wastewater. The closed system of SDI subsurface pipes and emitters minimizes the exposure of soil surfaces, above ground plant parts, and groundwater to reclaimed wastewater. Experiments in several countries revealed that subsurface drip irrigation prevented the virus movement onto crop leaf surfaces. However, beneficial and safe use of reclaimed wastewater for subsurface drip irrigation will depend on management strategies that focus on irrigation pre-treatment, virus monitoring & inactivation strategies, field and crop selection, appropriate drip design & component (emitter type & discharge rate; filter type) selection, assessment of water quality, monitoring and periodic leaching of salts.

v) Linking of major and medium irrigation projects with micro irrigation

Though in some foreign countries like Australia etc. this type of micro irrigation linkage with surface irrigation is reported yet in India it is only practiced in few states (though the scope and needs are very high). But, some attempts were made in Punjab to store canal water in pond and then its application through drip, Haryana to link it with sprinkler irrigation system. Recently the Government of AP has initiated a move linking a major irrigation project in the district of Nalgonda with sprinkler irrigation.

In Gujarat the government is giving a very serious thought of bringing the whole Sardar Sarovar (Narmada Project) project of 18 lakhs hectares under drip and sprinkler. The water availability, soil irrigabilty and the proposed cropping pattern go very much in favour of this. A techno economic feasibility study on pilot scale has been initiated in this regard in the state. It has been given to understand that the Government of TamilNadu is also contemplating of introduction of MIS in surface irrigated systems.

Though the linking of major, medium and minor irrigation projects with MIS is technically feasible and profitable, yet, modalities for the sharing of the cost involved for the additional storage structures, pumping and networking have to be worked out. Further crop / cropping pattern selection and diversification will be the major factors in deciding its economic viability. Presently water is applied once in every 7 to 15 days in surface / gravity irrigation depending on the soil and crop. Hence, moisture / water stress will be noticed just before irrigation and the growth of the crop is affected. Furthermore, it is difficult to constantly give the required quantity of water to the root zone using surface irrigation so yields are often less than optimum. Water productivity can be maximized by sifting from surface irrigation to drip irrigation (Table 7) (Sivanappan, 2009).

Table 7. Water productivity gains in percentage from shifting to drip irrigation from surface irrigation in India

Crop	Change in yield	Change in water use	Change in water productivity
Banana	+52	-45	+173
Cabbage	+2	-60	+150
Cotton	+27	-53	+169
Cotton	+25	-60	+255
Grapes	+23	-48	+134
Potato	+46	-0	+46
Sugar cane	+6	-60	+163
Sugar cane	+20	-30	+70
Sugar cane	+29	-47	+91
Sugar cane	+33	-65	+205
Sweet Potato	+39	-60	+243
Tomato	+5	-27	+49
Tomato	+50	-39	+14

Source: Adapted from data in Indian National Committee on Irrigation and Drainage, Drip Irrigation in India, Compiled by R.K.Sivanappan (New Delhi 1994)

7. Success stories of under Centrally Sponsored scheme on Micro irrigation

Kinnow (Mr. Raghubir Singh, Village: Dataranwali, District : Ferozpur, Punjab)

- More than 26.7 t/ha yield
- Gross Income increased from Rs. 62,500/- to Rs. 175,000/- per ha

Potato (Mr. Sukhdev Singh, Village: Bhai Roopa, District : Bathinda, Punjab)

- Diversification from cotton and wheat
- Crop saved from fog
- More than 30% increase in yield
- More than 50 t/ ha yield
- Gross Income increased from Rs. 75,000/- to Rs. 120,000/- per ha

Cotton (Mr. Gurdas Singh, Village Lehra Mohabbat, District Bathinda, Punjab)

- Sand dunes converted to cotton fields
- Less attack of Mealy Bug
- More than 20% increase in yield compared to traditional irrigation
- More than 3.75 t/ha yield.
- Gross Income increased from Rs. 75,000/- to Rs. 1,12,500/- per ha.

8. Forward Path for Promotion of Micro Irrigation in the Country

Viewing micro irrigation technology as an integral part of comprehensive water management strategy with the focus on enhancing water productive efficiency (more revenue per drop of water) and equity & equality must be the guiding principle promotion of micro irrigation on a sustainable basis. This requires a include holistic approach including capacity building & training of stakeholders, institutional support, standardization & quality control, credit support from international financial institutions like World Bank, ADB, JBIC etc, tax & fiscal incentives, strengthening of R & D for improved technological support, improving the availability of water soluble fertilizers at affordable prices etc.

Steps can be taken immediately for the promotion of micro irrigation system-

- Water to be treated as a national resource
- Integration of Macro & Micro Irrigation technologies
- Expenditure for laying Micro Irrigation Systems should be treated as an investment rather than an expense.
- Adequate Policy measures for financial assistance as well as availability of funds at soft interest rates.
- Reduction of system cost through cost economical designs
- Development of Package of Practices for various crops in different agro-climatic zones.
- To create technology awareness among various stake holders through audio, video aids & media.

REFERENCES

Anonymous 2001. Annual progress report, National Committee on Plasticulture Applications in Horticulture, Department of Ag. and Co-operation, Min. of Ag., GOI, New Delhi, p. 98.

Anonymous. 2012. National Committee on Plasticulture Applications in Horticulture 2012, Ministry of Agriculture, GoI.

Michael, A.M. 1978. Irriation- Theory and Practice, Vikas Publishing House, New Delhi, 801 Pages.

Sivanappan, R.K., Padmakumari, O. and Kumar, V. 1987. Drip irrigation. Keerti Publishing House (P) Ltd., 278-281.

Sivannapan, R.K. 2009. Development of micro irrigation technology in India. Micro irrigation, ISBN 978-81-88708-48-2, pp 1-7. Proceedings of winter school on Micro irrigation sponsored by ICAR.

Water Resources Development in India 2010. Edited by C.D. Thatte, A.C. Gupta, M.L. Baweja, Central Water Commission. Ministry of Water Resources, GoI, p 173.

Journal of Soil and Water Conservation **11**(4): 296-300, October-December 2012
ISSN: 022-457X

Water saving technique for intercropping in Castor (*Ricinus communis L.*)

AJIT SINGH[1], VIJAYA RANI[2] AND N.K. BANSAL[3]

Received: 28 May 2012; Accepted: 16 October 2012

ABSTRACT

Castor (*Ricinus communis L.*) is most important oilseed crop of India due to the fact that its oil has diversified uses and has great value in foreign trade. Water use, yield and economics in relation to intercropping of pulses in castor on raised bed (both castor and pulses was sown by inclined cell plate bed planter in single operation) were studied during 2010-11 in Haryana state, India. The results were compared with conventional method of seeding technique, wherein the pulses are sown by seed drill and castor is drilled manually in field. There was a saving of 28.33% in irrigation water in raised bed than flat bed method of intercropping. The increase in yield of castor when intercropped with green gram, moth bean and cluster bean on raised bed was 31.33%, 29.77% and 30.43% compared to intercropping of castor with green gram, moth bean and cluster bean on flat bed. The increase in yield of green gram, moth bean and cluster bean was 4.51%, 5.2% and 6.27% on raised bed. The cost saving of intercropping of pulse in castor on raised bed was Rs.1698.53 as compared to conventional method. The per cent increase in income of castor + green gram, castor + moth bean and castor + cluster bean on raised bed intercropping was 14.93 %, 9.02 % and 18.25 % over flat bed intercropping. The benefit cost ratio for raised bed intercropping was 3.25, 2.76, and 2.89 with the three pulse crops, respectively.

Key words: castor, intercropping, pulses, raised bed, irrigation

INTRODUCTION

Agriculture constitutes the largest sector of our economy. Majority of our population, directly or indirectly, depends on this sector. It contributes about a quarter of our Gross Domestic Product (GDP) and accounts for about half of employed labour force and is the largest source of foreign exchange earnings. Currently agriculture

in India is facing a severe threat of shortage of irrigation water because of traditional methods of cultivation, less trend towards agricultural mechanization and lack of farmers' awareness in advance methods of farming. Castor

(*Ricinus communis L.*) is one of the ancient and important non-edible oilseed crop grown during the monsoon season mainly for its seeds, from which 40-50% oil is extracted. It does well both under dryland or rainfed farming and limited irrigation due to deep root-system. Its cultivation is becoming popular in north –western part of the country owing to its better performance under stress conditions and higher export potential that has great industrial and medicinal value. India is the leader in global castor production and dominates in international castor oil trade, Anonymous (2008). Total area and production of castor crop in India for the year 2010-11 was 0.859 million hectares and 1.19 million tonnes, respectively **(**CCS of India 2010-11). Being a long-duration, widely-spaced crop with comparatively thin plant population in comparison with other field crops, it offers a great scope for using its inter-space by growing short-duration crop and thereby helps to harvest the potential productivity, Patel *et al*. (2007). Inter-cropping of short-duration crop like green-gram (*Phaseolus radiates L.*), black gram (*P. mungo L.*) and cluster bean (*Cyamopsis tetragonoloba (L.) Taubert*)

[1] Senior Research Fellow, Deptt. of Dryland Agriculture, er.ajitsangwan@gmail.com
[2]Assistant Professor, [3]Head & Senior Research Engineer, Deptt. of Farm Machinery & Power Engineering, CCS Haryana Agricultural University, Hisar-125004, Haryana (India).

with castor is remunerative for dry land conditions, Singh and Singh (1988).

Presently, the intercropping in castor is carried out on flat fields. Firstly, the pulse crops of short duration are inter-sowed by seed drill and then castor is drilled manually. The process of drilling castor which is done manually or by animal drawn plough is very tedious and time consuming. Moreover, heavy as well as low rainfall can harm the intercropping in castor with pulse crops on flat field. This may be overcome by using raised bed seeding technique wherein if rainfall is low, moisture can be saved and in case of heavy rainfall, water can be drained out through the furrows and the seed sown may have favourable condition to germinate and thus production may be increased. Moreover, the raised bed system helps in minimising losses of water (15-40%) during application and distribution in field, Dhindwal *et al*. (2006). The other advantages of raised bed system, as envisaged by Hobbs (2002) are the maximum harvesting and utilization under low rainfall, avoidance of temperature flooding, improved drainage under high intensity rainfall, higher N- use efficiency and less lodging. Thus, there was a need to evaluate the feasibility of raised bed system for intercropping of pulses in castor.

METHODS AND MATERIALS

The field experiments for the performance evaluation of the tractor drawn bed planter were conducted at CCSHAU Hisar. The test field was divided into 21 plots of size 16 m × 5.5 m. Each treatment was replicated thrice. Following treatments were used for the study. T_1 - castor + green gram (raised bed), T_2 - castor + moth bean (raised bed), T_3 - castor + cluster bean (raised bed), T_4 - castor + green gram (flat bed), T_5 - castor + moth bean (flat bed), T_6 --- castor + cluster bean (flat bed), T_7 -- castor (sole on flat bed). T_1, T_2 and T_3 were sown by bed planter where in both castor and the pulse crop were sown in one operation. In treatment T_4, T_5 and T_6, the pulse crop was first sown by seed drill and castor was drilled manually in the field. In T_7 treatment sole castor was drilled manually.

The experiment was laid out in randomized block design with three replications. The castor hybrid DCH -177 was sown with a seed rate of 5 kg/ha adopting a spacing of 60 cm × 110 cm on 15th July, 2010. The three intercrops viz., green gram (variety, Asha), moth bean (variety, RMO-40) and cluster bean (variety, HG-563) were intercropped in castor. Fertiliser application was done only for the castor crop (Diammonium phosphate), while intercrops were not fertilised separately. First Irrigation was applied 45 days after sowing and subsequently two more irrigation were applied as per recommendations of package and practice of castor and pulse crop. The Water used, yield and economics were studied for the different treatments.

Measurement of irrigation water

Irrigation to the experimental plots was applied through a lined open channel provided in the field. Float method (Michael, 1978) was used to measure the velocity of flow in the open channel. The discharge was estimated as The volume of water applied in each plots was measured by float method and expressed as under:

$$Q = A \times V \times 1000$$

Where

Q = Discharge through channel (liters sec^{-1})

A = Cross-sectional area of flow (m^2)

V = Average velocity of water flowing through channel (m sec^{-1})

The time of irrigation was decided by the pre decided depth (10 cm) of water ponding at the surface. Irrigation stream was turned off as soon as the depth of water ponding reached the desired level at the end of plot/furrow.

Economics

The cost of operation of machine in different treatments included the fixed cost and variable cost. Fixed cost includes such items such as depreciation, interest, insurances taxes and housing. Variable cost includes fuel, lubricates, operator's wages and repair and maintenance cost. Cost of operation was compared with conventional practice.

Income was calculated on the basis of support price of different crops as announced by government of India. Gross return (Rs ha^{-1}) was worked out by subtracting the total cost of cultivation of treatments from the gross income of respective treatments. Benefit cost ratio (B: C) was calculated to ascertain income variability of the treatment using following formula:

$$\text{B: C ratio} = \frac{\text{Gross return (Rs ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs ha}^{-1}\text{)}}$$

RESULTS AND DISCUSSION

The results for yield presented in Table1, indicate that there was significant variation in treatments for sowing methods & intercropping. The yield was higher in case of raised bed intercropping for both castor and pulse crop than flat bed intercropping as indicated by the mean values in the Table1. Dhindwal *et al.* (2006) also reported a higher yield in pigeon pea, cluster bean and green gram in raised bed as compared with flat bed. The improvement in above yield attributes could be possible due to better moisture conservation under bed system and lesser weed infestation. The yield of castor is also higher when intercropped with pulses in comparison to sole castor on flat bed, as indicated in Table1.

It is imperative to grow crop using less water without any adverse effect on crop productivity. The data on comparative time to irrigate one hectare and saving of irrigation water in bed system is reported in Table 2. There were saving of the order of 28.33 per cent in the irrigation water in raised bed than flat bed method of intercropping. Kumar *et al.* (2002) reported the performance evaluation of two row tractor drawn bed planter in comparison with flat bed. There was 45 per cent saving in irrigation water. Dhindwal *et al.* (2006), Jena (2009), Sharma *et al.* (2001) reported saving of 25 per cent, 39.62 per cent to 45 per cent, 30 per cent to 40 per cent in irrigation water in raised bed over flat bed, respectively.

The economics of raised bed and flat bed method for intercropping of pulse in castor were calculated on the basis of actual use, field test data and cost of cultivation data are reported in Table 3 & Table 4. It is evident from Table 3 that saving in cost of sowing with bed planter was Rs 1698.53 per hectare. Kumar *et al.* (2002) reported 25.41 per cent reduction in cost of operation by bed planter.

The per cent increase in income of raised bed intercropping was 14.93 per cent, 9.02 per cent, 18.25 per cent over flat bed intercropping of green gram, moth bean and cluster bean Table 4. Kamboj *et al.* (2008) reported that net returns obtained from sugarcane + wheat crop intercropping on raised bed were Rs.19,723 ha^{-1} higher compared to the sole crop of sugarcane on flat bed . Idnani and Gautam (2008) reported that green gram in raised bed system recorded the highest net return of Rs 10177 per hectare. Dhindwal *et al.* (2006) reported raised bed planted pigeon pea, cluster bean and green gram gave additional net benefit of Rs 2820 ha^{-1}, 830 ha^{-1} and 1465 ha^{-1}, respectively compared with flat sown crops.

The per cent increase in income for cluster on flat bed intercropping was 35.54 per cent, 20.07 per cent, 24.18 per cent with green gram, moth bean and cluster bean over sole crop of castor on flat bed Table 4. Gupta and Rathore (1993) showed increase in income by intercropping of moong bean with castor

Table 1. Mean values of yield (q ha^{-1}) for castor and pulses on raised bed and flat bed

Intercropped crop	Raised bed	Castor equivalent yield Raised bed	Flat bed
Castor + green gram	32.33 + 5.51	42.24	28.43 + 4.56
Castor + moth bean	30.77 + 6.20	36.36	28.43 + 5.37
Castor + cluster bean	31.43 + 7.27	38.17	26.63 + 6.07
Sole castor	-		27.89
Critical difference at 5%	Sowing methods	Intercropping	Sowing methods × Intercropping
for yield values of castor	0.792	0.970	NS

Table 2. Quantity of Irrigation water applied in different treatments for raised bed and flat bed method of sowing (area 88 m^2)

Treatments	Discharge rate	Raised bed		Flat bed		Saving in
	(lit.sec^{-1})*	Time (Min)	Quantity of water (lit)	Time (Min)	Quantity of water (lit)	irrigation water (%)
Castor + green gram	16.1	9.49	152.78	13.56	218.31	30
Castor + cluster bean	16.1	9.76	157.13	13.56	218.31	28
Castor + moth bean	16.1	9.89	159.22	13.56	218.31	27
Mean	16.1	9.71	156.37	13.56	218.31	28.33

*Source of water –Tube well

Table 3. Comparative cost of sowing for raised bed and flat bed

Parameters		Raised bed	Flat bed
Cost of operation of machine,	Rs/ha (Rs/h)	Bed planter - 1397.20 530.94	Seed drill - 595.73 357.44
Cost of sowing,	Rs/ha	1397.20*	3095.73**
Saving in raised bed over flat bed,	Rs/ha	1698.53	-

*All sowing operation was done with bed planter for both castor and pulse crop
**All the intercrops were sown by seed drill and castor was drilled manually

Table 4. Comparative income for raised bed and flat bed intercropping

Intercropped crop	Raisedbed, Rs ha^{-1}	Flat bed, Rs ha^{-1}	Per cent increase in raised bed over flat bed	Per cent increase in raised bed over sole castor	Benefit cost ratio	
					Raised bed	Flat bed
Castor + green gram	153650	133690	14.93	35.54	3.25	2.53
Castor + moth bean	136110	124852	9.02	20.07	2.76	2.30
Castor + cluster bean	140765	119045	18.25	24.18	2.89	2.14
Sole castor	-	113360	-	-	-	-

(Rs 12995 per hectare) over castor alone (Rs 7588 per hectare) on flat bed. Prasad and Verma (1986) also reported increase in income of intercropping of moong bean with castor (Rs 5044 per hectare) over castor alone (Rs 3098 per hectare) on flat bed.

The benefit cost ratio was found to be higher for raised bed intercropping than flat bed intercropping. The values are 3.25, 2.76 and 2.89 as shown in Table 4 when intercropping was done with green gram, moth bean and cluster bean. Same trend was observed by Porwal *et al*. (2006). Idnani and Gautam (2008) reported that green gram in raised bed system gave benefit cost ratio 1.03.

CONCLUSION

The raised bed system of planting proved a resource-conservation technology. Intercropping of pulses in castor on raised bed increased the crop yield, saved irrigation water over flat bed. Based on cost of sowing and income of raised bed over the flat bed, the raised bed system is a highly remunerative for castor intercropping and it may be used by the farmer.

REFERENCES

Anonymous. 2008. Castor seed seasonal report, www.karvycomtrade.com/.../karvysSpecialReports_ 20080424_ 02.pd..

Castor Crop Survey. 2010-11. The Solvent Extractors' Association of India.

Dhindwal, A S, Hooda, I S, Malik, R K and Kumar, S. 2006. Water productivity of furrow irrigated rainy season pulses planted on raised beds. *Indian J. of Agron*. **51** (1):49-53.

Gupta, I N and Rathore, S S. 1993. Intercropping in castor (*Ricinus communis L.*) under dryland condition in Rajasthan. *Indian J. of Agron*. **38** (2):182-186.

Hobbs, P R. 2002. Resource conservation technologies. A second revolution on South Asia. (In). Proceeding of International workshop on Herbicide resistance management and zero tillage in rice wheat cropping system, held during 4-6 March at CCS HAU, Hisar. PP. 67-76.

Idnani, L K and Gautam, H K. 2008. Water economization in summer green gram (*Vigna radiata var radiata*) as influenced by irrigation regimes and land configurations. *Indian J.of Agric. Sci.* **78** (3):214-219.

Jena, S. (2009). Optimization of ridge and furrow dimensions for development of tractor drawn multicrop ridger seeder. unpublish COAE&T M. Tech. thesis, CCS HAU, Hisar.

Kamboj, B R, Malik, R K, Garg, R, Yadav, A, Singh, S, Goyal, N K, Lathwal, O P, Malik, Y P, and Mehla O P. 2008. Bed planting-A Novel Technique to Encourage Multiple Land Use. Technical Bulletin (29). Directorate of Extension Education, CCS Haryana Agricultural University, Hisar, India. Pp.24

Kumar, V, Sharma, DN and Sardana, PK. 2002. Techno-economic evaluation of bed seeding technique in wheat crop. *J. of Agri. Engg*. **39**: 32-43.

Parsad, S N and Verma, B 1986. Effect of intercropping castor with green gram, black gram, sesame and sorghum on yield and net return. *Indian J. of Agron*. **31** (1): 21-25.

Patel, K S, Patel, M K, Patel, G N and Pathak, H C 2007. Intercropping in castor under irrigated condition. J. Oilseeds Res. **24** (1): 121-123.

Porwal, M K, Agarwal, S K and Khokar, A K. 2006. Effect of planting methods and intercrops on productivity and economics of castor –based intercropping systems. *Indian J. of Agron*. **51** (4):274-277.

Michael, A M. 1978. Irrigation, theory and practice (First edition). Vikas publishing house pvt. Ltd. 576, Masjid Road, Jangpura, New Delhi- 110 014.

Sharma, D N, Kataria, D P and Bahl, V P. 2001. On-farm field trials of tractor drawn multicrop ridge-furrow and flat bed seeding machine for rainfed and irrigated conditions. *J. of Agri. Engg.* **38** (1):24-33.

Singh, J P and Singh, B P. 1988. Intercropping of mung bean and guar in castor under dryland condition. *Indian J. of Agron*. **33** (2): 177-180.

Journal of Soil and Water Conservation **11**(4): 301-306, October-December 2012
ISSN: 022-457X

Adequacy and equity of rotational distribution of irrigation water of gravity flow Ranbir Canal system of Jammu province–A case study

A.K. RAINA[1], VIJAY BHARTI[2], PARSHOTAM KUMAR SHARMA[3] and A. SAMANTA[4]

Received: 1 March 2012; Accepted: 27 September 2012

ABSTRACT

Water distribution systems often have multi-objectives such as on the basis of location criteria affect on adequacy, equity etc. The canal systems distributing the water through net work of majors and minors have different design capacities, command areas and lengths requiring different duration of operation. Irrigation scheduling under these conditions especially for rotational water distribution becomes a complex process. Hence, in this research study is conducted in relation to location criteria regarding, the adequacy and equity criteria of canal net work of study area emerging from Ratian head works as per state irrigation department nomenclature as D-10 and D- 10A of gravity flow Ranbir Canal system of Jammu. The canal net work receive irrigation water from head works on 14 days rotation basis with 7 days turn for D-10 and D- 10A. The canal network of the study area further, has 13 branches having designed command area of 13375 ha of farmers land within famous Basmati bowl of Jammu province. Based on the present study the adequacy weights range between 0.74 to 1.19 and equity weights are less than 1.0 in each of canal within network. This establishes a fact that there is in- adequate and unequal rotational distribution of irrigation water being presently supplied by state irrigation department. This may be one of the causes for stagnant productivity levels of 20 qtls/ha of Paddy (Basmati) within the study area despite application of better quality seed, fertilizer dose and up to the mark farm power energy level.

Key words: rotational water distribution, Ranbir Canal, irrigation

INTRODUCTION

The Ranbir Canal falling within Jammu district is a gravity flow canal system, with Chenab River as its water resource. The diversion of the gravity system starts at Akhnoor village having designed discharge of 28.3 m^3/sec. It has a designed command area of 38,623 ha which falls under the command of 17 numbers of distributary canals named by state irrigation department as D1 to D17.

As per preliminary bench mark survey, it is observed that the Ranbir canal system has deficit irrigation availability in relation to different crop stages during Kharif season. This may be considered as one of the reasons for stagnant productivity levels of rice-wheat rotation, despite application of better level of inputs and package of practices, farm power technology in vogue and fertilizer application adopted by farmers of the famous Basmati belt of Jammu called R.S. Pura. A number of models have been developed for irrigation scheduling with optimization and simulation techniques. Rajput et.al (1989) developed a procedure for operation of canals using water balance equation for the estimation of daily soil moisture status taking a hypothetical case of four branch canal system. This model can be applied to real field situations only if the number of branch canals in the network is in multiples of four. Vedula et al. (1993) have developed an irrigation scheduling model for optimal allocation of water during different periods of the season for a single

[1] Chief Scientist
[2] Jr. Scientist/ Asstt. Professor, WMRC, SKUAST-J
[3] Agronomist, Division of Agricultural Engineering, SKUAST-J
[4] Sr. Scientist/ Assoc. Professor, WMRC, SKUAST-J

crop using dynamic programming. The model takes into account the soil moisture contribution for estimating the irrigation requirement. Yuanhua and Hongyuan (1994) have developed a model for canal scheduling with rotational water distribution by computing the initial soil moisture daily through water balance equation and forecasting the weather data and subsequently the irrigation date and depth. Most of these models have difficulties in field applications for the following reasons:

(a) The assumptions made and or the pre-defined mathematical structure involved in developing the optimization problem does not match with the real conditions of the field.

(b) The field measurement data required for these models such as the soil moisture status or plant stress are generally not collected and used in most of the irrigation systems in many countries. Zhi et al. (1995) have proposed a 0±1 linear programming model for outlet scheduling. However, application of this model is limited to irrigation systems where the distribution outlets along the canal (be it main, lateral, tertiary) have the same discharge capacity and such systems are hypothetical. In this study based on the concept of Molden and Gates (1990) and Santhi et.al (1999), individual weights like adequacy and equity weights will be estimated for 13 numbers of distributary canals emerging from Ratian Head works. The canal network supply irrigation to the designed command area of 13,375 ha. The data base generated will amply clear the scenario regarding efficacy of present rotational distribution of irrigation water being followed within these command areas by the state irrigation department.

MATERIAL & METHODS

Study area

Detailed study is undertaken within the study area. It is established that scheduling of rotational irrigation within the area is on rotation of 14 day basis each rotation has number of days equal to 7. Accordingly, the groupings in relation to location criteria $W1_{kt}$ are considered in the study. The full supply levels (FSL) have been monitored and cross checked with the official records of the concerned departments. Overall cropping pattern in the area such as rice-wheat rotation and number villages and designed command area within canal network of the study area has been surveyed and data base generated for the study. Identification of canal network with command area, cropping pattern and designed duty of water is presented in table.1. On the basis of 33 year's monthly normal rainfall of the study area, the effective rainfall for each month is calculated as per SCS method. This effective rainfall on monthly basis is considered to calculate net water requirement for different crop growth stages of Basmati rice (Kharif) as presented in Fig.1. The study area is akin to total command area of the irrigation system and is taken as representative area for

Table1. Identification of canal network with designed command area, predominant cropping pattern and duty of water

S. No.	Identification of canal network	Designed command area (ha)	Name of Village with predominant cropping pattern	Designed Discharge (Cumecs)	Duty (ha/ cumec)
1.	*MI_1 (D-10)	60	Kotlishah Dowla, Tanda Minor (Rice-Wheat)	0.04	1500.0
2.	**MA_2 (D-10)	3760	Ratian head to Kapoor pur (Rice-Wheat)	2.46	1528.5
3.	MI_3 (D-10)	240	Musachak minor (Rice-Wheat)	0.17	1411.7
4.	MA_4 (D-10)	2530.8	Main Tanda minor (Rice-Wheat)	2.69	940.5
5.	MI_5 (D-10)	924.8	Chakroi minor (Rice-Wheat)	0.65	1422.7
6.	MA_6 (D-10A)	1000	Katyal minor (Rice-Wheat)	0.70	1428.5
7.	MI_7 (D-10A)	40	Badyal-A (Rice-Wheat)	0.02	2000.0
8.	MI_8 (D-10A)	34	Badyal-B (Rice-Wheat)	0.02	1700.0
9.	MA_9 (D-10A)	2896	Ratian head to Koratana (Rice-Wheat)	2.83	1023.3
10.	MI_{10} (D-10A)	100	SKUAST Channel (Rice-Wheat)	0.07	1428.5
11.	MI_{11} (D-10A)	600	Khanna chak minor (Rice-Wheat)	0.42	1428.5
12.	MI_{12} (D-10A)	270	Samka minor (Rice-Wheat)	0.25	1080.0
13	MI_{13} (D-10A)	920	Chandu chak minor (Rice-Wheat)	0.65	1415.3
	Total Area	13375.6			

*MI minor and
**MA major

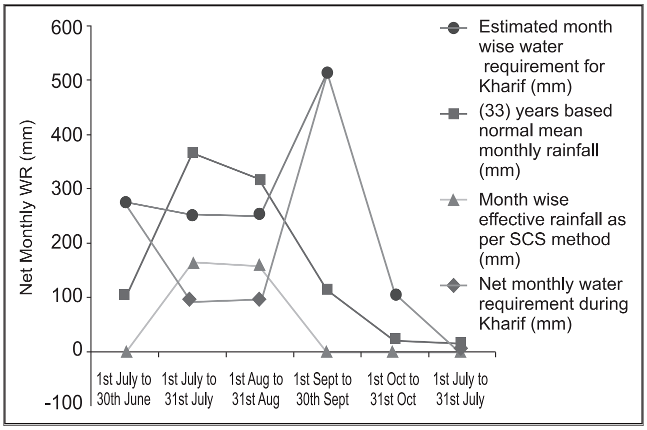


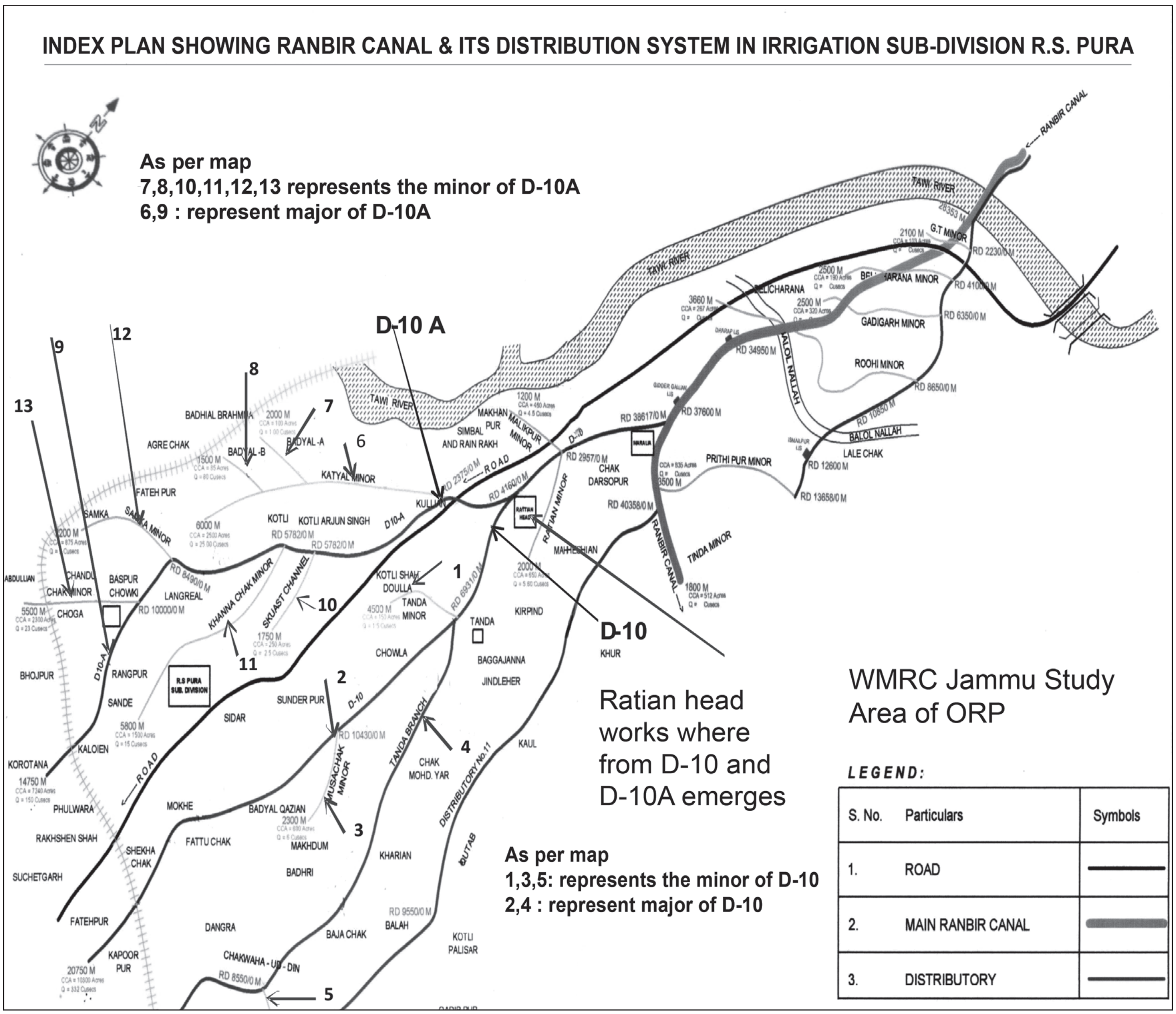
Fig. 1 Net monthly water requirement within study areas during Kharif season

research findings regarding adequacy and equity criteria of the system under rotational distribution of water followed by state irrigation department of Jammu presented in photoslide.1.

RESULTS AND DISCUSSION

For practical application, location criteria of canal network as per ground reality are one of the most important criteria to be considered while scheduling the canals. In the present research as per equation.1, two groupings of location criteria are considered in relation to rotational water supplies.

$$g \approx \frac{\sum_{k=1}^{n} \text{Distributaory capacity } k}{\text{main canal capacity}} \quad \text{.......... Equation 1}$$



Two groupings (1 & 2)
W1kt = 0.9 for k õ Group g of dist. canals,
t = g, 2g, 3g, . . . , m
W1kt = 0.1 for k " Group g of dist: canals,
t = g, 2g, 3g, . . . , m

Where, $W1_{kt}$ is the weight for the canal 'k' of the canal system for the turn 't', and 'n' the number of turns within two canals emerging from head works, 'g' the number of groupings of canals for turns in a rotation and 'm' the number of turns in a crop season. In the present study the design capacity of main canal which feeds Ratian head works is 9.4 m^3/sec which further, is distributed on rotational basis to canal network of study area through D-10 and D-10A with 14 days rotation on 7 days turn basis. The design capacity of D-10 and D-10A is 9.4 m^3/sec and 4.3 m^3/sec. Therefore, in reference to equation 1, the two groupings are calculated i.e. 9.4+4.3 = 13.7 / 9.4= 1.45, in relation to this two groupings of location criteria for the study area considered as indicated above. These groupings help in devising combined effect of individual weights on the irrigation planning of the system.

Adequacy criteria $W2_K$ relates to the desire to deliver targeted amounts of water needed for crop irrigation to delivery points in the system as per (Molden and Gates, 1990). In the present model based on the concept of (Santhi *et.al* 1999) the weights are assigned to each canal in proportion to its required duration of operation over the crop duration. The canal losses for different reaches are assumed to be constant during the season. However, the antecedent moisture remains fairly constant when water flows in the canals during the irrigation season. Hence, the seasonal variation is not considered in computing the canal losses. Number of days of operation of canal network is computed dividing the demand by its discharge capacity. This weight takes care of the adequacy satisfying the crop demand. Thus, this weight for each of the distributary canal remains constant throughout the crop season.

$$W2_k = \frac{d_k}{D} \text{ for K= 1,2,3 ...., n} \qquad \text{Equation 2}$$

Where $W2_k$ stands for the weight of the canal k, d_k for the duration of operation required (in days) to meet the demand of the canal k at full supply discharge and D for the crop duration in days. On this concept adequacy weight criteria and duty of canal network of study area is calculated as presented in tables 2 & 3 and figs.2 & 3. The fig.2 clearly indicates that the canal network of the study area can complete irrigation supply either running for more number of days or less number of days in relation to cropping period. Therefore, during crop period targeted amounts of water needed for crop irrigation to delivery points is presently inadequate and is in the range of 0.74 to 1.29 presented in column 7 of table.2.

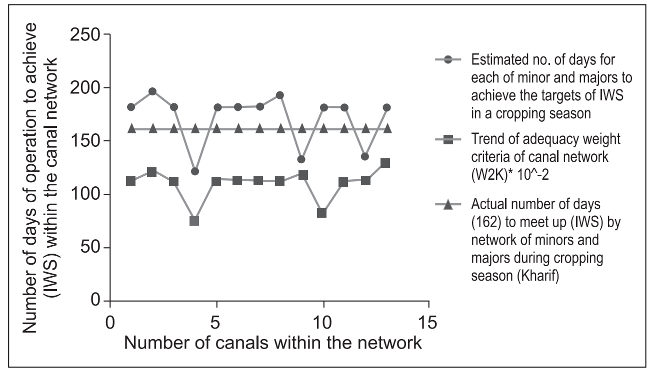


Fig. 2. Adequacy and estimated number of days required during Kharif season within canal network to achieve irrigation water supply (IWS)

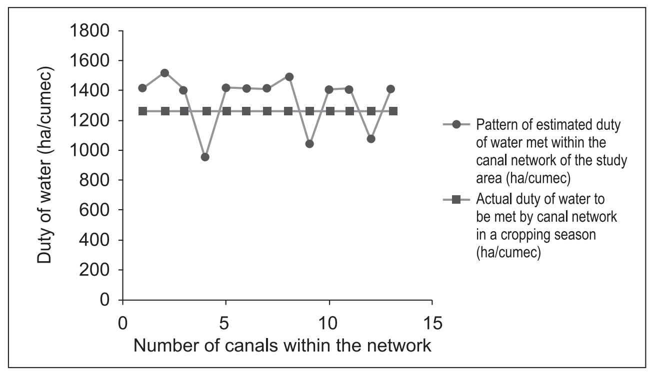


Fig. 3. Variation in meeting duty of water in the study area (ha-m)

Equity criteria $W3_K$ are one of the main objectives of the rotational water distribution. It can be defined as the spatial uniformity of the ratio of the delivered amounts of water to the targeted amounts is determined as per (Molden and Gates, 1990). Further, as per (Santhi *et.al* 1999) present model used in the study is a planning model, gives the fairest way to achieve equity with a view to allocate the water in proportion to the irrigable area under the canals with proper accounting of conveyance losses. Conveyance loss, being an important factor of equity, has to be incorporated in the equity calculations.

Table 2. Adequacy weight criteria $W2_K$ and estimated number of days required to meet up requisite irrigation water requirement within canal network

Designed command area (ha)	Water requirement for rice crop during Kharif (mm)	Irrigation water requirement (IWR) (m^3)	Designed discharge of each canal within the network (m^3/sec)	Discharge of canal network per day (m^3 / day)	Estimated number of days required within canal network to meet up (IWR)	Adequacy Weight criteria $W2_K$*10^-2	Identification of canal network
1	2	3= (1*2)	4	5	6= (3/5)	7= (6/162)	8
60.0	1111	666600	0.04	3672.6	181	112.0	*MI_1 (D-10)
3760.0	1111	41773600	2.46	213015.6	196	121.0	**MA_2 (D-10)
240.0	1111	2666400	0.17	14690.7	181	112.0	MI_3 (D-10)
2530.8	1111	28117188	2.69	232603.2	120	74.6	MA_4 (D-10)
924.8	1111	10274528	0.65	56314.4	182	112.0	MI_5 (D-10)
1000.0	1111	11110000	0.70	61211.3	181	112.0	MA_6 (D-10A)
40.0	1111	444400	0.02	2448.4	181	112.0	MI_7 (D-10A)
34.0	1111	377740	0.02	1958.7	192	112.0	MI_8 (D-10A)
2896.0	1111	32174560	2.83	244845.5	131	119.0	MA_9 (D-10A)
100.0	1111	1111000	0.07	6121.1	181	81.1	MI_{10} (D-10A)
600.0	1111	6666000	0.42	36726.8	181	112.0	MI_{11} (D-10A)
270.0	1111	2999700	0.25	22036.0	136	112.0	MI_{12} (D-10A)
920.0	1111	10221200	0.65	56314.4	181	129.0	MI_{13} (D-10A)
13375.6							

In column (7) no. of days in a cropping season are = 162., **MI minor and ***MA major*

$W3_k$ is the weight representing the equity criteria indirectly, A^*_k the virtual area of the distributary canal k, A_k is the designed command area of the canal k, $loss_k$ is the percentage of loss per kilometer (expressed as a fraction) of the canal k and length (k)stands for the length of the canal k. It assumes that the loss increases with the length of the canals (Hiemcke, 2000). In the present study the conveyance loss in each of the canal is taken as 1% per kilometer.

Accordingly, the equity criteria is estimated for the canal network of the study area and presented in table 3 and fig. 4. The data and figures clearly indicate that equity criteria for all the distributaries are far less than 1.0 as given in table 3 and equity trend follows disproportionately with the respective designed command areas of canal network of the study as presented in fig.4. This proves that spatial uniformity ratio of delivered and targeted amount of water in each canal is not maintained under present scheme of rotational distribution of water followed by the concerned departments.

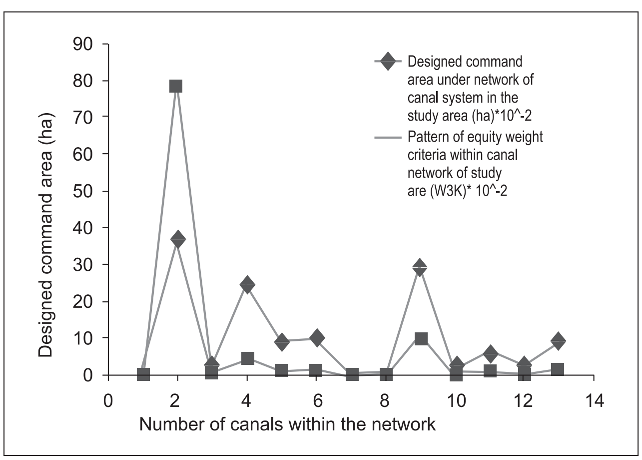


Fig. 4. Pattern of equity trends within canal network

Table 3. Estimated and normal duty of water met by canal network

Identification of canal network	Estimated duty of water met by canal network (ha / cumec)	Normal duty of water to be met during the cropping period (ha / cumec)
MI_1 (D-10)	1500.0	1260.9
MA_2 (D-10)	1528.5	1260.9
MI_3 (D-10)	1411.7	1260.9
MA_4 (D-10)	940.5	1260.9
MI_5 (D-10)	1422.7	1260.9
MA_6 (D-10A)	1428.5	1260.9
MI_7 (D-10A)	2000.0	1260.9
MI_8 (D-10A)	1700.0	1260.9
MA_9 (D-10A)	1023.3	1260.9
MI_{10} (D-10A)	1428.5	1260.9
MI_{11} (D-10A)	1428.5	1260.9
MI_{12} (D-10A)	1080.0	1260.9
MI_{13} (D-10A)	1415.3	1260.9

Table 4. Equity Criteria $W3_K$ of canal network of gravity flow Ranbir Canal command areas of Jammu

Identification of canal network	Designed command area within canal network (ha)	Length of each minor/ major (Kms)	Water conveyance loss of each dist. (1-loss_k)	5= (4^3)	Virtual command area under each canal Ak* (ha)	Equity weight of each canal (AK*/Sum Ak*) (W3K*10^-2)
1	2	3	4	5	6= 2/5	7= 6/"AK*
*MI_1 (D-10)	60	4.5	0.95	0.81	73.8	0.07
**MA_2 (D-10)	3760	16.5	0.83	0.04	76239.3	79.61
MI_3 (D-10)	240	2.3	0.97	0.94	253.1	0.26
MA_4 (D-10)	2530.8	7.5	0.92	0.55	4541.4	4.74
MI_5 (D-10)	924.8	4.5	0.95	0.81	1137.7	1.18
MA_6 (D-10A)	1000	6	0.94	0.68	1449.5	1.51
MI_7 (D-10A)	40	2	0.98	0.96	41.6	0.04
MI_8 (D-10A)	34	1.5	0.98	0.97	34.7	0.03
MA_9 (D-10A)	2896	10.6	0.89	0.30	9497.7	9.90
MI_{10} (D-10A)	100	1.7	0.98	0.96	103.1	0.10
MI_{11} (D-10A)	600	5.8	0.94	0.70	848.5	0.88
MI_{12} (D-10A)	270	2.2	0.97	0.95	283.5	0.29
MI_{13} (D-10A)	920	5.5	0.94	0.73	1255.7	1.30
	Total Command Area: 13375.6				Total virtual command area: "AK* 95760.2	

CONCLUSION

1. The location criteria $W1_{kt}$ of the canal network of study area are practically grouped in relation to ground reality that 5 numbers of canals fall under D-10 and 8 numbers of canals fall under D-10A having rotational irrigation water supply (IWS) of 14 days basis with 7 days of water supply per rotation during cropping period of 162 days during kharif season.
2. The adequacy criteria $W2_k$ of canal network of study area are varying in relation to cropping period and $W2_k$ weights are in the range of 0.74 to 1.29, which, indicates canal network can achieve irrigation water demand (IWD) of the respective command areas either early or after the cropping period, therefore does not possess adequacy. As far as duty of water is concerned instead of 1260 ha / cumec for the cropping period it is in the range of 940 to 1500 ha / cumec as presented in fig. 3. Its percentage variation ranges between -25 to + 21 in relation to normal duty of water, therefore, it is erratic.
3. Equity criteria $W3_k$ spatial uniformity of the ratio of the delivered amounts of water to the targeted amounts. The equity weights $W3_k$ within the canal network of the study area indicate variance as none of the value of these weights is close to 1 as presented in table 3 and fig. 4.
4. This proves a fact that present rotational water distribution criteria followed by state irrigation department is inadequate and unequal commensurate with design command area.
5. There is urgent need to revisit the randomly selected 14 days rotational water distribution with 7 days turn for canal network of the study area by state irrigation department for Ranbir canal system of Jammu.

ACKNOWLEDGEMENT

AICRP on Water Management, Jammu Centre, SKUAST- Jammu.

REFERENCES

Rajput, T.B.S., Michael, A.M., 1989. Scheduling of canal deliveries. I. Development of an integrated canal scheduling model. Irrigation and Power 46(2), 23±39.

Molden, D.J., Gates, T.K., 1990. Performance measures for evaluation of irrigation water delivery systems. J. Irrigation Drainage Eng. ASCE 116(6), 804±823.

Yuanhua, Hongyuan, 1994. Real-time Operation Scheduling of Canal System with Rotational Irrigation. International Conference on Irrigation Management Transfer, Wuhan, China, September 1994.

Vedula, S., Ramesh, T.S.V. Mujumdar, P.P., 1993. Real-time irrigation scheduling. In: International Conference on Environmentally Sound Water Resources Utilisation, Bangkok, Thailand, November 1993, pp. III-25±III-31.

Zhi, W., Mohan Reddy, J., Feyen, J., 1995. Improved 0±1 programming model for optimal ¯ow scheduling in irrigation canals. Irrigation Drainage Systems 9, 105±116.

Santhi, C. Pundarikanthan, N.V, 1999 A new planning model for canal scheduling of rotational irrigation. International journal of Agricultural Water Management 43 (2000) 327-343.

Journal of Soil and Water Conservation **11**(4): 307-310, October-December 2012
ISSN: 022-457X

Assessment of underground water quality in Mundlana Block of Sonipat district in Haryana

RAMESH SHARMA[1], PARDEEP[2], S.K. SHARMA[3], SANJAY KUMAR[4] and B.S. NEGI[5]

Received: 23 February 2012; Accepted: 13 September 2012

ABSTRACT

The present study is based on 221 water samples collected from 26 villages of Mundlana block of Sonipat district. Based on electrical conductivity (EC), sodium adsorption ration (SAR) and residual sodium carbonate (RSC) of waters, 24.4, 25.3, 8.1, 24.1 and 18.1 per cent water samples were found good, marginally saline, saline, high SAR-saline and highly alkali categories, respectively. EC, RSC and SAR ranged from 0.34 to 22.32 dS/m, nil to 9.10 me/L and 0.24 to 28.18 (m mol/L)$^{1/2}$, respectively. Among cations, sodium was dominant ion which ranged from 0.37 to 155.43 me/L followed by magnesium (0.25 to 44.75 me/L) and calcium (0.50 to 23.50 me/L), whereas, among anions, $C1^-$ was dominant ion (1.20 to 133.60 me/L) followed by SO_4^{-2} (0.67 to 86.76 me/L), HCO_3^- (0.40 to 13.00 me/L) and CO_3^{-2} (0.20 to 6.00 me/L). During last three decades, significant groundwater quality degradation has been observed and good quality water percentage is deteriorated by 28.2 per cent approximately.

Key words: EC, groundwater, RSC, SAR, salinity, sodicity

INTRODUCTION

Quality of water is assuming great importance with the increasing demand in industries, agriculture and rise in standard of living. Agriculture is the major user (89 per cent) of the India's water resources but the estimates show that the growing demands from municipalities, industry and energy generation will claim about 22 per cent (24.3 m ha-m/year) of the total water resources (105 m ha-m/year) by the year 2025 AD, thereby, further reduce the good quality water supply for irrigation (Minhas and Tyagi 1998). The adequate amount of water is very essential for proper growth of plants but the quality of water used for irrigation purpose should also be well within the permissible limit, otherwise, it could adversely affect the plant growth. Supplementary irrigation with tubewell is important in India where one – third of the land surface falls under arid and semi-arid climate and the rainfall is seasonal and erratic. About 75-80 per cent of human requirements for water are fulfilled by groundwater. Unlike surface waters, underground waters are not always suitable for irrigation, their salt content and composition depends upon the location and geo-climatic factors. The water quality in watershed is directly affected by vegetative cover, agricultural practices and other land management techniques (Bhattaria *et al.* 2008).

In the Haryana state, on an average 37 per cent of the ground water is of good quality, 8 per cent marginal and 55 per cent are of poor quality. Amongst poor quality water, 11 per cent saline, 18 per cent sodic and 26 per cent saline-sodic in nature (Manchanda 1976). The farmer use poor quality ground water due to limited availability of canals as well as good quality groundwater for crop production. Continuous use of poor quality water without drainage and soil management may adversely affect the soil health and agricultural production. Attempts also have been made in the past to establish water quality zones of Haryana state (Manchanda 1976), but a major change in water quality has occurred over the years due over exploitation and a shift in the cropping pattern (Phogat *et al*. 2008). Pressures on groundwater resources in semi-arid regions due to irrigation can be released through the judicious use of this scarce

[1-5] Deptt. of Agricultural & Cooperation, Ministry of Agriculture, Govt. of India, Krishi Bhawan, New Delhi-110001
[2-4] Department of Soil Science, CCSHAU, Hisar, Haryana, 125004

resource by knowing the groundwater quality of that area. Therefore, it is necessary to continuously monitor the quality of underground water for assessing the possible adverse effect on soil health. Keeping in view these facts, quality appraisal of underground water in Mundlana block of Sonipat district was done for sound irrigation planning of the area.

METHODS AND MATERIALS

Survey and characterization of underground irrigation waters of Mundlana block of Sonipat district, Haryana was undertaken during 2006-07. The district Sonipat comprises of seven blocks namely Sonipat, Kharkhoda, Ganaur, Rai, Gohana, Kathura besides Mundlana. Mundlana block lies between 29º07'25'' to 29º17'25'' N latitude and 76º33'30'' to 76º52'05'' E longitude (Fig.1). Area of Mundlana block is 305.7 sq.km., comprising 13.5 per cent of the total district area. Geologically, Sonipat district is a part of the Indo-Gangatic plain of Peluvial age which has been laid down by tributaries of the Indus river system and other nonexistent rivers. Water table is shallow in areas having canal system and water quality is poor in these areas. The problem of water logging and salinisation exist there. However, in Yamuna belt the water table is deep because of over exploitation of underground water. Two hundred and twenty one water samples were collected from Mundlana block through random sampling of the running tubewells of the block from all sides of each village. The samples were analyzed

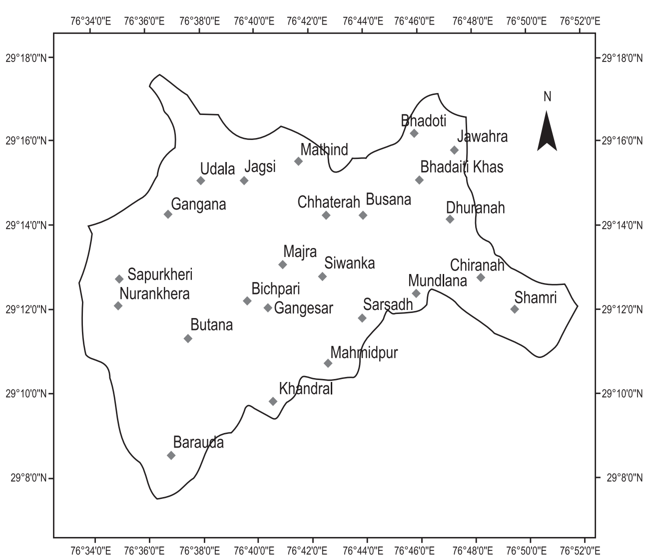


Fig.1. Location map of Mundlana block of Sonipat district

for pH, electrical conductivity (EC), CO_3^{-2}, HCO_3^-, Cl^-, Ca^{+2}, Mg^{+2} and Na^+ by following the procedures outlined in USDA Handbook No. 60 (Richards 1954). Water samples were categorized on the basis of criteria (Table 1) adopted by All India Coordinated Research Project on Management of Salt Affected Soil

Table 1. Criteria for water quality classification (Anonymous, 1989)

Quality	EC (dS/m)	SAR (m mol/L)½	RSC (me/L)
Good	<2	<10	<2.5
Marginally saline	2-4	<10	<2.5
Saline	>4	<10	<2.5
High SAR - saline	>4	>10	<2.5
Marginally alkali	<2	<10	2.5-4.0
Alkali	<2	<10	>4.0
Highly alkali	Variable	>10	>4.0

and Use of Saline Water through the values of EC, residual sodium carbonate (RSC) and sodium adsorption ratio (SAR) of the samples (Gupta *et al.* 1994). SAR and RSC were calculated as described by the following equations.

$$RSC\ (me/L) = (CO_3 + HCO_3) - (Ca + Mg) \quad \text{... (i)}$$

$$SAR\ (m\,mol/L)^{1/2} = \frac{\text{Na}}{\left\{\frac{Ca+Mg}{2}\right\}^{1/2}} \quad \text{... (ii)}$$

RESULTS AND DISCUSSION

In Mundlana block, electrical conductivity (EC) ranged from 0.34 to 22.32 dS/m with a mean of 3.39 dS/m (Table 2). The lowest EC of 0.34 dS/m in water samples was observed in village Jawara and its

Table 2. Range of different water quality parameters in Mundlana block of Sonipat district

Quality parameter	Range	Mean
pH	7.40-11.50	8.05
EC (dS/m)	0.34-22.32	3.39
RSC (me/L)	nil -9.10	3.81
SAR (m mol/L)½	0.24-28.18	9.18
Ca^{+2} (me/L)	0.50-23.50	3.44
Mg^{+2} (me/L)	0.25-44.75	8.62
Na^+ (me/L)	0.37-155.43	21.03
K^+ (me/L)	0.07-1.69	0.43
$C1^-$ (me/L)	1.20-133.60	14.11
SO_4^{-2} (me/L)	0.67-86.76	13.96
HCO_3^- (me/L)	0.40-13.00	4.07
CO_3^{-2} (me/L)	0.20-6.00	1.51

highest value (22.32 dS/m) was recorded in village Shamari (Fig.1). The pH ranged from 7.40 to 11.50 with an average of 8.05 and the lowest pH of 7.40 in water samples was observed in village Chirana. The SAR ranged from 0.24 to 28.18 (m mol/L)$^{1/2}$ with a mean value of 9.18 (m mol/L)$^{1/2}$. The lowest SAR value was observed in village Gangana and its highest value was recorded in village Bichhpuri. The RSC varied from nil to 9.10 me/L with an average value of 3.81 me/L. Maximum value of the RSC (9.10 me/L) was found in the village Ahmedpur Majra. In case of cations, sodium was dominant ion which ranged from 0.37 to 155.43 me/L followed by magnesium (0.25 to 44.75 me/L), calcium (0.50 to 23.50 me/L) and potassium (0.07 to 1.69 me/L). Mean value for Na^+, Mg^{+2}, Ca^{+2} and K^{+2} were 21.03, 8.62, 3.44 and 0.43 me/L, respectively.

In case of anions, chloride was the dominant ion with maximum value of 133.60 me/L observed in village Shamari and minimum value of 1.20 me/L recorded in village Mundlana. Highest value of sulphate (86.76 me/L) was recorded in village Barauda. Bicarbonate content ranged between 0.40 to 13.00 me/L and its minimum value found in Butana village. The carbonates varied from 0.20 to 6.00 me/L with maximum value (6.00 me/L) found in the water samples of village Bichhpuri. Mean value for CO_3^{-2}, HCO_3^-, Cl^- and SO_4^{-2} were found to be 1.51, 4.07, 14.11 and 13.96, respectively. Shahid *et al.* (2008) also reported the similar results in Julana block of Jind district. It was further observed that cations and anions in groundwater followed the order $Na^+ > Mg^{2+} > Ca^{2+} > K^+$ and $Cl^- > SO_4^{-2} > HCO_3^-$, respectively. In arid and semi-arid regions, various workers have reported the dominance of sodium and chloride ions in irrigation waters (Paliwal and Yadav 1976; Sharma 1998; Shahid *et al.* 2008).

The mean chemical composition and related quality parameters in different EC ranges for Mundlana block are given in table 3. Maximum numbers of samples (61) were in the EC range of 1-2 dS/m. The study revealed that 68.3 per cent of the samples showed EC less than 4 dS/m, 30.4 per cent had EC 4 to 10 dS/m and only 1.3 per cent samples were above 10 dS/m. Number of samples upto EC of 2 dS/m was increased, with further increase in EC, the number of samples deceased and its number was reduced significantly after an EC of 5 dS/m. Only three samples were recorded with EC greater than 10 dS/m. Concentration of Na^+, Mg^{2+}, Ca^{2+} and K^+ increased with increase in the EC of the water samples and the magnitude of increase in sodium and magnesium concentration was much higher than the other two. Concentration of chloride and sulphate anions increased with the increase in the EC of the water samples. However, the sulphate content remained higher than the chloride in waters having EC upto 5.0 dS/m, whereas, waters having EC greater than 5.0 dS/m had more average chloride content than sulphate. Bicarbonates were also found to be in appreciable quantities, whereas, carbonates were in low quantities, but the concentration of these two anions did not show any relation with EC of irrigation water.

According to AICRP classification, the maximum samples were found in marginally saline (25.3 per cent) category followed by good quality (24.4 per cent) (Fig.2). The per cent samples in high SAR saline, high alkali and saline were 24.0, 18.1 and 8.1, respectively. No sample was found in marginally alkali and alkali categories. Minhas *et al.* (1998) also reported that 32.84% of running wells in India were rated to be of poor quality. Earlier studies conducted by Manchanda (1976) indicated that in Mundlana block, 34, 11, 11, 11 and 33 per cent of groundwater

Table 3. Average chemical composition of tubewell water samples of Mundlana block in different EC classes

EC class (dS/m)	No. of water samples	Na^+	Ca^{+2}	Mg^{+2}	K^+	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}
						me/L			
0-1	10	2.05	1.48	3.03	0.26	0.46	2.22	2.28	2.41
1-2	61	9.19	1.50	3.29	0.34	1.46	4.11	4.15	4.88
2-3	44	15.75	2.10	6.07	0.46	1.58	4.64	7.65	10.77
3-4	36	21.73	3.92	8.80	0.42	1.82	4.19	12.49	16.66
4-5	30	29.28	3.00	9.68	0.50	1.80	4.11	17.01	19.33
5-6	15	30.70	7.08	14.82	0.44	1.71	3.71	23.37	14.18
6-7	9	37.67	5.53	18.06	0.43	0.91	3.16	36.44	20.94
7-8	6	44.00	7.13	22.50	0.50	1.17	4.98	45.07	22.65
>8	10	64.80	13.28	28.00	0.76	0.90	3.41	59.96	42.30

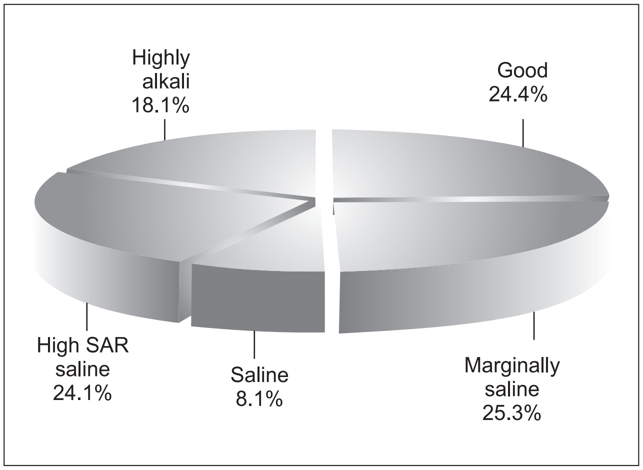


Fig. 2. Quality of groundwater (per cent) in Mundlana block of Sonipat district

was under good, normal, marginally saline, sodic and saline-sodic categories, respectively. During last three decades, significant groundwater quality degradation has been observed. Good quality water percentage changed from 34 to 24.4 indicates that the quality of groundwater is deteriorated by 28.2 per cent.

CONCLUSIONS

The ground waters of Mundlana block are Na-Mg-Ca type dominated by chloride and the brackish waters are generally saline and alkali in nature. Good quality and marginally saline waters can be successfully used for crop production without any hazardous effect on soil and plant. The presence of sulphate, being important plant nutrient, is beneficial for crop production. The sulphate content of these waters in addition to supplying the sulphur nutrient to plant is beneficial in reducing the sodium hazard of waters having higher sodium content. Groundwater having EC more than 4 dS/m require special management practices depending upon the soil type, crop grown and climatic factors. Alkali water can be used successfully by using gypsum as an amendment tool (Anonymous, 2010). The waters rated as saline and high SAR saline is unfit for irrigation. Their indiscriminate use may cause secondary salinization and sodification of soil resulting in adverse effect on crop growth. But in emergency these waters can be used with special management practices depending upon the rainfall, crop to be grown and soil type.

REFERENCES

Anonymous. 1989. AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture, Progress report, CSSRI, Karnal.

Anonymous. 2010. AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture, Annual report, CCSHAU, Hisar.

Bhattaria, G. R., Srivastva, P., Margen, L., Hite, D. and Hatch, U. 2008. Assessment of economic and water quality impacts of land use change using a simple bio-economic model. Environmental management, 42, 122–130.

Gupta, R. K., Singh, N. T. and Sethi, M. 1994. Water quality for irrigation in India. Tech. Bull. 19, CSSRI, Karnal , India.

Manchanda, H. R. 1976. Quality of underground water of Haryana. Haryana Agricultural University, Hisar.

Minhs, P. S., Sharma, O. P. and Patil, S. G. 1998. Twenty five years of research on management of salt affected soils and use of saline water in agriculture. CSSRI Karnal India

Minhas, P. S. and Tyagi, N. K. 1998. Guidelines for irrigation with saline and alkali waters. Technical Bulletin no. 1/98, CSSRI, Karnal. pp.1.

Paliwal, K. V. and Yadav, B. R. 1976. Irrigation water quality and crop management in the union territory of Delhi. Research Bulletin 9 IARI, New Delhi. pp. 166.

Phogat, V., Sharma, S. K., Satyavan and Kumar, S. 2008. Assessment of groundwater quality for irrigation of Jind district for irrigation. Proceedings of 16th Nat. Symp.on Environ. (NSE-16), 16-18 Jul., 2008, Guru Jambheshwar Univ. Sci. and Tech., Hisar, India..

Richards, L. A. 1954. Diagnosis and improvement of saline and alkali soils. U.S.D.A. Hand Book No. 60 . Oxford & IBH Publishing Co., New Delhi.

Shahid, M., Singh, A. P., Bhandari, D. K. and Ahmad, I. 2008. Groundwater quality appraisal and categorization in Julana block of Jind district, Haryana. J. Indian Society of Soil Science. 56(1) 123-125.

Sharma, D. R. 1998. Assessment of the nature and extent of poor quality of underground water resources. National Seminar on Strategies for the Management of Poor Quality Water in Agriculture, held at CSSRI, Karnal. pp 4-5.

Journal of Soil and Water Conservation **11**(4): 311-315, October-December 2012
ISSN: 022-457X

Assessment of irrigation water quality of cold arid Ladakh region

SOMEN ACHARYA[1], A K KATIYAR[2], V K BHARTI[3], GURU CHARAN[4],
B. PRAKASH[5] and R. B. SRIVASTAVA[6]

Received: 7 May 2012; Accepted: 12 September 2012

ABSTRACT

Present study was undertaken to determine irrigation water quality of cold arid Ladakh region. In Ladakh region, nearly all irrigation water is driven from snow melting water. Most of the irrigation is done by canal systems. Skillfully constructed water channels carrying water from its source to the cultivated fields are the backbone of agriculture in Ladakh. Irrigation water quality was determined on the basis of pH, EC, TDS, SAR, RSC, SSP, salt index values. Mean pH of irrigation water of Indus and Nubra valley was recorded 7.93 and 7.90 respectively. Using EC and SAR values, irrigation water of Indus valley falls in C2S1 class and Nubra valley in C1S1 class which is considered to be good for irrigation purposes with no salinity hazard. Average RSC value of Indus and Nubra valley was found 0.25 and 0.35 mel^{-1} respectively which is within the safe limit. From the overall results it can be concluded that there is no hazard in irrigation water of Ladakh region in terms of salinity, sodium or bicarbonate hazard and can be used safely for growing crops.

Key words: irrigation water, Ladakh, cold arid desert

INTRODUCTION

Water is the most important factor required for plant growth in agriculture production. Bulk weight of all living organisms consists of 80 to 90 % water. Water need for plant growth is met with soil water storage in plant root zone. Under rainfed conditions, soil water storage is continuously replenished with natural rainfall; however, irrigation is essential in arid and semi-arid climate to maintain soil water storage at an optimum level to get higher yield.

Irrigation can be defined as the replenishment of soil water storage in plant root zone through methods other than natural precipitation (Kirda, 1997). Characteristics of irrigation water quality vary with the source of water. All water sources used in irrigation contain impurities and dissolved salts irrespective of whether they are surface or underground water. There are regional differences in water quality, based mainly on geology and climate. There may also be great differences in the quality of water available on a local level depending on whether the source is surface water (rivers, ponds and springs) or from groundwater aquifers with varying geology (Will and Faust, 2002).

In agriculture, irrigation water quality is related to its effects on soils, crops and management practices necessary to overcome problems linked with water quality. Chemical constituents of irrigation water can affect plant growth directly through toxicity or deficiency, or indirectly by altering plant availability of nutrients. To evaluate quality of irrigation water, it is necessary to identify the parameters that are important for plant growth. Therefore, appropriate tests should be conducted prior to apply irrigation water in the field for better growth and yield of the crops.

Ladakh is the northern most part of India situated at an altitude of 8,500 to 15,000 ft above MSL. The topography is rugged with rocky terrains. Valleys are sandy, open, long broad with some water bodies.

[1] Scientist, [2] SRF, [3] STA, [4] Director, Defence Institute of High Altitude Research, DRDO, C/o 56 APO, Leh-Ladakh, 901205

This trans-Himalayan icy region, popularly known as cold desert, is characterized by severe, arid conditions (Acharya *et al.*, 2010). In this region, agriculture season is very short (April-May to September-October) and main crops are wheat, barley, gram, potato and some vegetables. In Ladakh region besides poor soil fertility status, water is the major factor limiting crop production. Nearly all the water used in irrigation is from melting snowbanks and glaciers and is therefore most abundant in the spring and summer months. Without irrigation vegetable farming is out of question in Ladakh. Till date assessment of irrigation water quality of Ladakh region have not been carried out. Hence, present study focuses on assessment and comparative study of irrigation water quality of different villages of Indus and Nubra valley.

MATERIALS AND METHODS

Water samples for irrigation water quality assessment were analyzed for chemical constituents. The samples were collected in sterile plastic bottles (500 ml) and stored by adding 2-3 drops of toluene to prevent microbial growth. Sampling was carried out from April to October over two years of investigation (2009-2010) from different canals in Nubra and Indus valley of Ladakh region. Nubra valley lies between two great mountain ranges, i.e. Ladakh (on the south) and Karakoram (on the north) with approximately $34^0$152 453 -$35^0$302 N latitude and $76^0$552 -$78^0$052 E longitude. Study area of Indus valley lies between 33p 592 363 -34p 172 723 N latitude and 077p 122 -077p 452 673 E longitude. Present survey was conducted in 12 villages of Indus valley and 10 villages of Nubra valley. From each source (irrigation canals) 3 samples were collected from each village and altogether, 66 water samples were collected from both the valleys.

Many factors were taken together to determine the quality of water for irrigation. Irrigation water quality was determined by using the following parameters: pH, electrical conductivity (EC), Total dissolved solids (TDS), alkalinity (carbonates and bicarbonates), sodium (Na) hazard (amount of Na in water compared to Ca and Mg), bicarbonate hazard [also called Residual sodium carbonate (RSC)] (Singh *et al.*, 2005). The effect of Na is calculated as the sodium adsorption ratio (SAR). SAR is calculated using the formula:

SAR = Exchangeable {(Na)/ “(Ca + Mg)/2}

Where concentrations are given in mel^{-1}

Soluble sodium percentage (SSP) is another alternative measure of sodium hazard and was calculated to see the damaging effect of Na in the soil.

SSP = Exchangeable {(Na)/ (Ca + Mg + K + Na)} x 100

Salt Index is also used for predicting sodium hazard. It is the relation between Na, Ca and $CaCO_3$ present in irrigation water.

Salt Index = (Total Na – 24.5) – [(Total Ca – Ca in $CaCO_3$) X 4.85]

Presence of bicarbonate (HCO_3^-) is also important parameter for irrigation water quality. It brings about changes in SSP and SAR and therefore, an increase of the sodium hazard. It is expressed as residual sodium carbonate (RSC) using the following formula:

RSC (mel^{-1}) = {(CO_3 + HCO_3) - (Ca + Mg)}

Irrigation water classification based on EC, SAR, SSP, RSC and Salt Index is shown in Table 1.

Table 1. Classification of irrigation water based on EC, SAR, SSP, RSC and Salt Index

Water class	EC (µScm^{-1})	SAR	SSP	RSC	Salt Index
Low	< 250 (C1)	< 10 (S1)	< 20	< 1.25	-24.5 to 0
Medium	250-750 (C2)	10-18 (S2)	20-50	1.25-2.5	
High	750-2250 (C3)	18-26 (S3)	50-80	> 2.5	> 0
Very high	> 2250 (C4)	> 26 (S4)	> 80		

In addition, presence of toxic substances like chloride in irrigation water as well as trace elements (zinc and manganese) was also estimated.

pH, soluble salts (EC) and TDS of irrigation water was measured by pH and EC meter (Model HACH, USA). Calcium and magnesium was measured by versenate titration method using EDTA-disodium salt solution as chelating agent. Carbonates and bicarbonates were determined by titrating known volume of water against standard H_2SO_4 using phenolphthalein and methyl orange indicators, respectively. Sodium, potassium and calcium were measured by flame photometer (Model AFP 100, UK). Chloride was determined by $AgNO_3$ (Mohr’s titration) method and trace elements like zinc and manganese were measured using inductively coupled plasma (ICP) spectrophotometer (Model Optima 7000 DV, Perkin Elmer).

RESULTS AND DISCUSSION

The pH of irrigation water is an important parameter because it will influence the relative solubility of certain nutrients and can impact the solubility of certain chemicals or pesticides used in agriculture. From the table 2a and 2b it was found that average pH of Indus and Nubra valley was 7.93 (range: 7.78-8.10) and 7.90 (range: 7.82-8.02) respectively. Normal range of pH of irrigation water is considered between pH 6.5-8.4 (Ayers and Westcot, 1994).

The excess of salts content is one of the major concerns with water used for irrigation. A high salt concentration present in the water and soil will negatively affect the crop yields, degrade the land and pollute groundwater. Electrical conductivity (EC) of water determines soluble salt content in it. EC was measured 265.9 μScm^{-1} and 156.53 μScm^{-1} for Indus and Nubra valley respectively. In Nubra valley average EC of irrigation water exists in C1 class (low) whereas for Indus valley it is in C2 class (medium) (Table 1). Water salinity hazard is one of the most influential water quality guideline on crop productivity which is measured by EC. The primary effect of high EC water on crop productivity is the inability of the plant to compete with ions in the soil solution for water (physiological drought). The higher the EC, the less water is available to plants, even though the soil may appear wet. Besides EC the other terms that use to report salinity hazard is total dissolved solids (TDS). TDS quantify the amount of dissolved salts (or ions, charged particles) in a water sample. TDS was found 127.3 and 74.39 ppm respectively for Indus and Nubra valley (Table 2a and 2b). From the results it was observed that there is no salinity hazard of irrigation water of Ladakh region.

Total salt concentration of irrigation waters should not be used as a single criteria to prevent its use in irrigation (Kirda, 1997). Sodium hazard is defined separately for irrigation water because of sodium's specific detrimental effects on soil physical properties. The sodium hazard is typically expressed as the sodium adsorption ratio (SAR). This index quantifies the proportion of sodium (Na^+) to calcium (Ca^{++}) and magnesium (Mg^{++}) ions in a sample. Calcium will flocculate, while sodium disperses soil particles. This dispersed soil will readily crust and have water infiltration and permeability problems. Average SAR of irrigation water of different villages

Table 2a. Irrigation water quality of different villages of Indus valley

Name of Villages	pH	EC (μScm^{-1})	TDS (ppm)	Na(mel^{-1})	(Ca + Mg) (mel^{-1})	(CO_3+HCO_3) (mel^{-1})	Cl^-(mel^{-1})	K(mel^{-1})	Zn (ppm)	Mn (ppm)
Chuchot Goma	8.00	334.7±6.5	161.0±8.5	1.00±0.02	3.06±0.07	3.13±0.083	1.40±0.04	0.069±0.002	0.010	0.007
Chuchot Soma	8.09	340.3±6.5	163.3±7.6	1.01±0.05	3.23±0.21	3.30±0.187	1.40±0.14	0.066±0.003	0.009	0.007
Chuchot Yogma	8.10	337.3±6.8	161.6±8.5	1.00±0.04	3.06±0.16	3.27±0.122	1.41±0.06	0.069±0.004	0.009	0.006
Matho	7.92	286.7±6.7	138.1±6.6	0.24±0.03	2.78±0.13	2.93±0.098	1.10±0.09	0.041±0.006	0.008	0.004
Nimoo	8.00	323.6±7.4	154.1±7.4	1.00±0.07	3.08±0.11	3.29±0.042	1.28±0.08	0.067±0.003	0.006	0.008
Phey	7.90	232.3±10.1	111.4±5.8	0.70±0.07	2.42±0.05	2.76±0.090	0.86±0.05	0.035±0.002	0.009	0.005
Phyang	7.82	197.7±6.0	94.6±6.0	0.60±0.03	3.02±0.16	3.32±0.225	1.20±0.16	0.073±0.002	0.007	0.006
Saboo	7.85	141.7±6.5	66.9±7.7	0.97±0.04	1.75±0.07	2.12±0.098	1.10±0.07	0.050±0.003	0.010	0.005
Shey	7.93	288.0±10.0	136.0±6.0	0.83±0.06	2.55±0.11	3.05±0.086	1.11±0.04	0.042±0.002	0.008	0.009
Stoke	7.78	232.0±11.5	111.3±4.0	0.22±0.02	2.60±0.06	2.78±0.155	0.81±0.04	0.018±0.002	0.005	0.012
Taru	7.83	152.0±7.0	73.0±6.8	0.18±0.01	1.76±0.10	2.31±0.082	1.07±0.12	0.046±0.001	0.009	0.010
Thiksey	7.98	325.0±5.0	156.3±7.8	1.01±0.04	3.11±0.18	3.20±0.041	1.40±0.16	0.072±0.004	0.011	0.010
Average	7.93	265.9	127.3	0.73	2.73	2.96	1.18	0.054	0.0084	0.0074

Table 2b. Irrigation water quality of different villages of Nubra valley

Name of Villages	pH	EC (μScm^{-1})	TDS (ppm)	Na(mel^{-1})	(Ca + Mg) (mel^{-1})	(CO_3+HCO_3) (mel^{-1})	Cl^-(mel^{-1})	K(mel^{-1})	Zn (ppm)	Mn (ppm)
Bogdang	7.96	164.43±4.4	78.53±5.2	0.07±0.01	2.71±0.11	2.75±0.05	2.02±0.15	0.044±0.003	0.002	0.003
Diskit	7.90	365.67±4.9	176.10±5.5	1.02±0.03	3.42±0.07	3.50±0.08	2.14±0.25	0.132±0.004	0.010	0.004
Hundar	7.87	77.87±2.9	36.50±4.6	0.60±0.04	0.88±0.07	1.40±0.04	1.40±0.15	0.026±0.002	0.006	0.003
Khalsar	7.79	66.43±4.9	31.17±3.1	0.44±0.02	0.87±0.06	1.30±0.07	1.39±0.16	0.010±0.002	0.005	0.003
Ombe	7.82	94.80±3.1	44.90±3.2	0.50±0.06	1.17±0.05	1.42±0.06	1.56±0.09	0.048±0.006	0.007	0.005
Partapur	7.92	121.77±5.2	57.40±4.4	0.94±0.05	2.10±0.05	2.32±0.10	1.73±0.08	0.099±0.004	0.008	0.009
Skumpook	7.95	86.22±2.9	40.07±3.1	0.41±0.05	1.09±0.05	1.38±0.09	1.43±0.04	0.065±0.006	0.006	0.005
Skuru	7.85	88.83±3.2	41.80±2.9	0.10±0.02	1.14±0.06	1.50±0.08	1.40±0.16	0.023±0.002	0.005	0.008
Sumur	8.02	282.20±5.1	133.83±4.9	1.02±0.04	2.54±0.10	3.32±0.07	2.13±0.21	0.126±0.005	0.006	0.007
Tirche	7.95	217.03±6.3	103.57±3.5	0.83±0.06	2.74±0.09	3.22±0.07	2.08±0.19	0.082±0.004	0.010	0.009
Average	7.90	156.53	74.39	0.59	1.87	2.21	1.73	0.066	0.0065	0.0056

of Indus valley was found 0.89 whereas for Nubra valley it was also recorded as 0.89. In Indus valley, highest SAR was recorded in Saboo village (1.47) whereas in Nubra valley, Hunder (1.28) recorded highest SAR values (Table 3a and 3b).

Table 3a. SAR, SSP, RSC and Salt Index value of irrigation water of different villages of Indus valley

Name of Villages	SAR	SSP	RSC (mel^{-1})	Salt Index (ppm)
Chuchot Goma	1.14	24.2	0.07	-5.2
Chuchot Soma	1.12	23.4	0.07	-6.34
Chuchot Yogma	1.15	24.3	0.22	-5.45
Matho	0.28	7.7	0.15	-19.97
Nimoo	1.14	24.2	0.22	-12.75
Phey	0.90	22.3	0.34	-6.85
Phyang	0.69	16.3	0.30	-11.31
Saboo	1.47	35.1	0.37	-22.78
Shey	1.04	24.3	0.50	-8.85
Stoke	0.28	7.9	0.18	-20.15
Taru	0.28	9.2	0.55	-21.27
Thiksey	1.15	24.2	0.10	-7.09
Average	0.89	20.3	0.25	-12.33

Table 3b. SAR, SSP, RSC and Salt Index value of irrigation water of different villages of Nubra valley

Name of Villages	SAR	SSP	RSC (mel^{-1})	Salt Index (ppm)
Bogdang	0.08	2.5	0.04	-20.57
Diskit	1.10	22.3	0.08	-6.15
Hundar	1.28	40.0	0.52	-14.20
Khalsar	0.95	33.5	0.43	-17.82
Ombe	0.92	29.0	0.26	-13.74
Partapur	1.30	30.0	0.22	-6.31
Skumpook	0.78	26.1	0.29	-18.65
Skuru	0.19	8.2	0.36	-22.70
Sumur	1.28	27.6	0.78	-5.85
Tirche	1.00	22.7	0.48	-10.01
Average	0.89	24.2	0.35	-13.6

The most damaging effects of poor quality irrigation water are excessive accumulation of soluble salts and/or sodium in soil which is expressed by EC and SAR respectively. From the table 1 using EC and SAR values, it was found that irrigation water of Indus valley falls in C2S1 and Nubra valley in C1S1 class which is considered as good quality and there is no sodium hazard persists in irrigation water of this cold arid region.

However, many factors including soil texture, organic matter, crop type, climate, irrigation system and management impact how sodium in irrigation water affects soils. Sodium in irrigation water can also cause toxicity problems for some crops, especially when sprinkler applied. Average soluble sodium percentage (SSP) of irrigation water of Indus and Nubra valley was found in medium range (20.3 and 24.3 respectively).

Residual sodium carbonate (RSC) is another alternative measure of the sodium content in relation with Mg and Ca. When the RSC concentration becomes too high, the carbonates combine with calcium and magnesium to form a solid scale which settles out of the water. The end result is an increase in both the SSP and SAR. Average RSC value of Indus and Nubra valley was found 0.25 and 0.35 mel^{-1} respectively (Table 3a and 3b).

RSC values less than 1.25 mel^{-1} are considered safe (Table 1). Waters with RSC of 1.25-2.50 mel^{-1} are within the marginal range. These waters should be used with good irrigation management techniques. Salt index sometimes used to determine sodium hazard in irrigation water. Salt Index values of Indus and Nubra valley found between 0 to -24.5 which is considered to be good for irrigation purposes. Chloride levels of irrigation water had also been measured and were detected much below the normal range in water (<4 mel^{-1}) (Table 2a and 2b). Beside some trace elements like zinc and manganese were also measured. The levels of Zn and Mn (0.008 and 0.007 ppm for Indus valley; 0.006 and 0.006 ppm for Nubra valley respectively) were found much below the recommended maximum concentration (recommended maximum concentration for Zn: 2.0 ppm; Mn: 0.2 ppm). In conclusion, it can be said that there is no hazard in irrigation water of Ladakh region in terms of salinity, sodium and bicarbonate levels, and Zn and Mn concentration and therefore, can be used safely in agriculture for growing crops.

REFERENCES

Acharya S, Stobdan T and Singh S B. 2010. Seabuckthorn (*Hippophae* sp. L.): New crop opportunity for biodiversity conservation in cold arid Trans-Himalayas. *Journal of Soil and Water Conservation*, 9(3): 201-204.

Ayers R S and Westcot D. W. 1994. Water quality for agriculture. FAO irrigation and drainage paper, 29 Rev. 1, FAO, Rome.

Kirda C. 1997. Assessment of irrigation water quality. Options Mediterraneennes. 367-377.

Singh D, Chhonkar P K and Dwivedi B S. 2005. Manual on soil, plant and water analysis. 200 p. Westville publishing house, New Delhi.

Will E and Faust J E. 2002. Irrigation Water quality for greenhouse production. Agricultural Extension Service, The University of Tennessee. PB 1617.

Journal of Soil and Water Conservation **11**(4): 316-322, October-December 2012
ISSN: 022-457X

Soil moisture, organic carbon and micronutrient dynamics and their interrelationship in drip irrigated mango orchard

S R BHRIGUVANSHI[1], TARUN ADAK[2], KAILASH KUMAR[3], VK SINGH[4], ACHAL SINGH[5] and VINOD KUMAR SINGH[6]

Received: 19 March 2011; Accepted: 31 August 2012

ABSTRACT

A field experiment was conducted in drip irrigated mango (*Mangifera indica* L.) cv *Dashehari* orchard of Central Institute for Sub-tropical Horticulture, Rehmankhera, Lucknow experimental farm to assess the dynamics and interrelationship among soil moisture, organic carbon and Diethylene triamine penta acetic acid (DTPA) extractable micronutrients under differential soil moisture and fertigation regimes. The study revealed that the drip irrigation system was found to be the best in explaining the functional relationship among various components within orchard soils as compared to basin system of irrigation. The functional relationship among soil moisture, organic carbon and micronutrients were statistically significant. The Pearson's correlation coefficient between soil moisture vs micronutrients and organic carbon vs micronutrients indicated that at 1m horizontal distance, Zn, Cu and Fe showed strong association with moisture regime in 70-90% open pan evaporation (OPE) replenishment in drip system of irrigation while Mn availability showed highly significant correlation with moisture more than 90% OPE replenishment irrespective of method of irrigation. Zn and Fe were mostly non-significantly related at 1.5 m distances from the tree trunk. Availability of micronutrients was significantly correlated with organic carbon content at 1 m distance in all the drip irrigation levels. The relationship among soil moisture, organic carbon and micronutrients were mostly non-significant in basin application of irrigation. Linear regression analysis was done using soil organic carbon and soil moisture as independent variables and micronutrients as dependent variable. The degree of variability in micronutrient dynamics as a function of soil moisture could be explained to the tune of 51-69% for Zn, 72-82% for Cu, 41-68% for Mn and 68-74% for Fe as compared to lower degree in basin irrigation. While in case of organic carbon, the magnitude of micronutrient dynamics could be explained of the order 50-61% in Zn, 65-71% in Cu, 52-61% in Mn and 48-51% in Fe as compared to lower degree of basin irrigation application. Thus, the application of irrigation water through drip might be the best technology to be adopted in mango orchards for maintaining optimum soil moisture, organic carbon and their significant correlation with micronutrient dynamics.

Key words: drip irrigation, mango, micronutrient interrelationship, soil moisture, organic carbon

INTRODUCTION

Mango (*Mangifera indica* L.) is an important fruit crop of economic importance. Improper nutrient and water managements along with indiscriminate use of chemical pesticides have led to rapid deterioration in the nutritional balance of orchards leading to low fruit yields and thus, production and productivity of this fruit crop is suffering. Not only macro but also the micronutrients are limiting the fruit yield of mango across the country (Ravishankar *et al*. 2010; Kumar *et al*. 2011).

Soil organic carbon is one of the important ecological indicators of any agroecosystem and has long been recognized as a source of fertility because of its capacity for nutrient storage and release (Tiessen *et al*. 1994; Craswell and Lefroy, 2001; Lal *et*

Division of Crop Production, Central Institute for Subtropical Horticulture, Rehmankhera, P.O. - Kakori, Lucknow-227107, U.P.
[1]Principal Scientist (Soil Science); [2] Scientist (Soil Physics / Soil and Water Conservation, tarunadak@gmail.com); [3]Principal Scientist (Soil chemistry / Fert. / Microb., kailash1952@gmail.com); [4]Principal Scientist (Plant Physiology); [5]Senior Scientist (Agril. Statistics); Technical Officer (T-6)[6]

al. 2004; Sebasti‘ *et al*. 2008; Adak *et al*. 2011a). Soil organic carbon and micronutrients dynamics are interdependent under differential soil moisture regimes. Soil moisture not only controls the microbial activity and organic matter decomposition but also significantly influences micronutrients mobility and uptake by fruit crops. As micronutrients are essential for improving growth as well as fruit yield, understanding of their interrelationships is essentially required in case of fruit crops particularly in mango.

Tree response to chemical fertilizers undoubtedly depends on soil moisture and soil organic carbon status. Both moisture and soil organic carbon are significantly influencing nutrient release pattern and their mobility and interactions with the tree roots. Soils of subtropical regions are mainly deficient in nitrogen and inherently low in organic carbon because of rapid turnover rates of organic material with high soil temperatures and micro-fauna. Therefore, information on soil moisture, organic carbon and micronutrient dynamics and their interrelationship under differential soil moisture and fertigation regimes is essentially required for optimum water and nutrient management for sustainable fruit production (Labanauskas *et al*. 1958; Labanauskas *et al*.1960; Richards *et al*. 1958; Purushotham and Narasimhan, 1981; Guilivo, 1990; Heck *et al*. 2003; Srivastava and Singh, 2005; Sujatha *et al*. 2006; Singh *et al*. 2009; Adak *et al*. 2011b). Lack of information in mango orchards of subtropical regions on the above aspects has led us to undertake the present study to find out the dynamics and relationship among soil moisture, soil organic carbon with micronutrients under differential moisture and nutrient regimes.

MATERIALS AND METHODS

The experiment was laid out at the experimental research farm of Central Institute for Sub-tropical Horticulture (CISH), Rehmankhera, Lucknow, Uttar Pradesh during 1998-2002. The soil of the experimental site was *Typic ustochrept* having a pH of 8.2, EC; 0.27dS / m, bulk density (BD); 1.44 Mg / m^3, water holding capacity (WHC); 30%, infiltration rate; 3.6 cm / hr, organic carbon; 0.27% with available P; 11.25 ppm and available K; 74 ppm. DTPA extractable Zn, Cu, Mn and Fe were 0.71, 2.3, 37.3 and 29.6 ppm respectively. The experiment was conducted in a split-plot design consisting of four irrigations (I_1-90%, I_2-70% and I_3-60% of open pan evaporation (OPE) replenishments through drippers and I_4- basin irrigation as control) as main plot treatments and three N levels (F_1- 750g N / tree; F_2-500g N / tree and F_3-Zero N) as sub-treatments. The irrigation was scheduled on the basis of USWB Class-A Open Pan Evaporation data to create soil moisture regime. Twenty year old trees of mango cv *Dashehari* having spacing of 10 ×10 m were selected. The trees were fertilized with 1000 g P_2O_5 and 1000 g K_2O per tree during the month of September in 30 cm deep trenches while N was applied through fertigation. Soil samples were taken at 25 cm interval up to 100 cm depth (Z_1: 0-25 cm, Z_2: 25-50 cm, Z_3: 50-75 cm and Z_4: 75-100 cm). Soil samples were also collected from horizontal distance of 1.0 m (X_1) and 1.5 m (X_2) from the tree trunk keeping in view the extent of variability under different methods of water application. DTPA extractable Zn, Fe, Mn and Cu (Lindsay and Norvell, 1978) were determined by Chemito AA203D model of atomic absorption spectrophotometer. Organic carbon was estimated using wet digestion method (Walkley and Black, 1934). The pooled data were analyzed in software SPSS version 12.0. The best-fit linear regressions equations were drawn using MS Excel software.

RESULTS AND DISCUSSION

Soil moisture and organic carbon dynamics

It was revealed that the moisture content was higher up to the effective root zone (up to 30 cm) than in lower soil depth. The horizontal moisture content at surface soil depth (Z_1) varied from 16.51-17.12, 16.67-16.85, 16.66-17.36 and 15.9-16.90% in I_1, I_2, I_3 and I_4 respectively at 1 m distance from tree trunk while at 1.5 m distance, the corresponding values were 15.92-16.47, 15.21-16.50, 16.50-17.11 and 16.80-17.40% in I_1, I_2, I_3 and I_4 respectively. Vertical distribution (Z_2 to Z_4) showed 15.09-16.74% across drip irrigated treatments at 1 m horizontal distance as compared to 15.40-16.54% in basin application (I_4). This spatial distribution of irrigation water recognizes the need for drip irrigation system so as to ensure optimum moisture regimes within the root zone and to confine soil moisture within the effective horizontal distance. Higher organic carbon (0.49%) was found at the surface soil (up to 25 cm soil depth) and decreased vertically to 0.26% with increasing depth across irrigation levels at 1 m distance. Relatively lower organic carbon (0.35-0.42%) was recorded at 1.5 m horizontal distance from the tree trunk as compared to 1 m distance. The higher concentration of organic C in surface soil might be due to decomposition of leaf litter, grasses in the surface soil. Further, it was inferred that relatively lower organic C prevailed in soils (0.26-0.33%) where N was not applied than fertilized with N. This may be due to the fact that addition of N increased biomass production and microbial enzymatic activity. The interrelationship between soil moisture and organic carbon indicated that soil moisture had significant impact on organic carbon content variation of the experimental soil; more of it is due to changes in microbial activation and leaf decomposition (Schroth, 2003; Jha and Mohapatra, 2010).

Functional relationship between soil moisture and micronutrient dynamics

Since soil moisture is an important and essential factor controlling mobility and dynamics of micronutrients in soil, it is necessary to determine the functional relationship between soil moisture and micronutrients concentrations. The concentration of 1.38-1.64, 2.23-3.74, 21.81-28.96 and 18.73-27.40 ppm of Zn, Cu, Mn and Fe, respectively were observed in the surface soil (Z_1) at 1m horizontal distance while at 1.5 m distance, the corresponding values were 1.16-1.32, 1.83-2.63, 16.06-25.92 and 12.85-24.10 ppm, respectively. The vertical distribution has showed 1.11-1.37, 1.25-2.27, 13.22-21.15, 10.91-19.49 ppm of Zn, Cu, Mn, Fe respectively, at 1 m horizontal distance and 0.89-1.24, 1.04-1.75, 12.4-20.93, 9.44-14.21 ppm of Zn, Cu, Mn, Fe respectively, at 1.5 m horizontal distance. The regression on soil moisture and micronutrient concentration (Fig. 1 and 2) in X_1 distances, showed that drip irrigated soils showed better response to the functional relation with the micronutrients in general. In case of Zn, the functional relationship was found to be the best (R^2

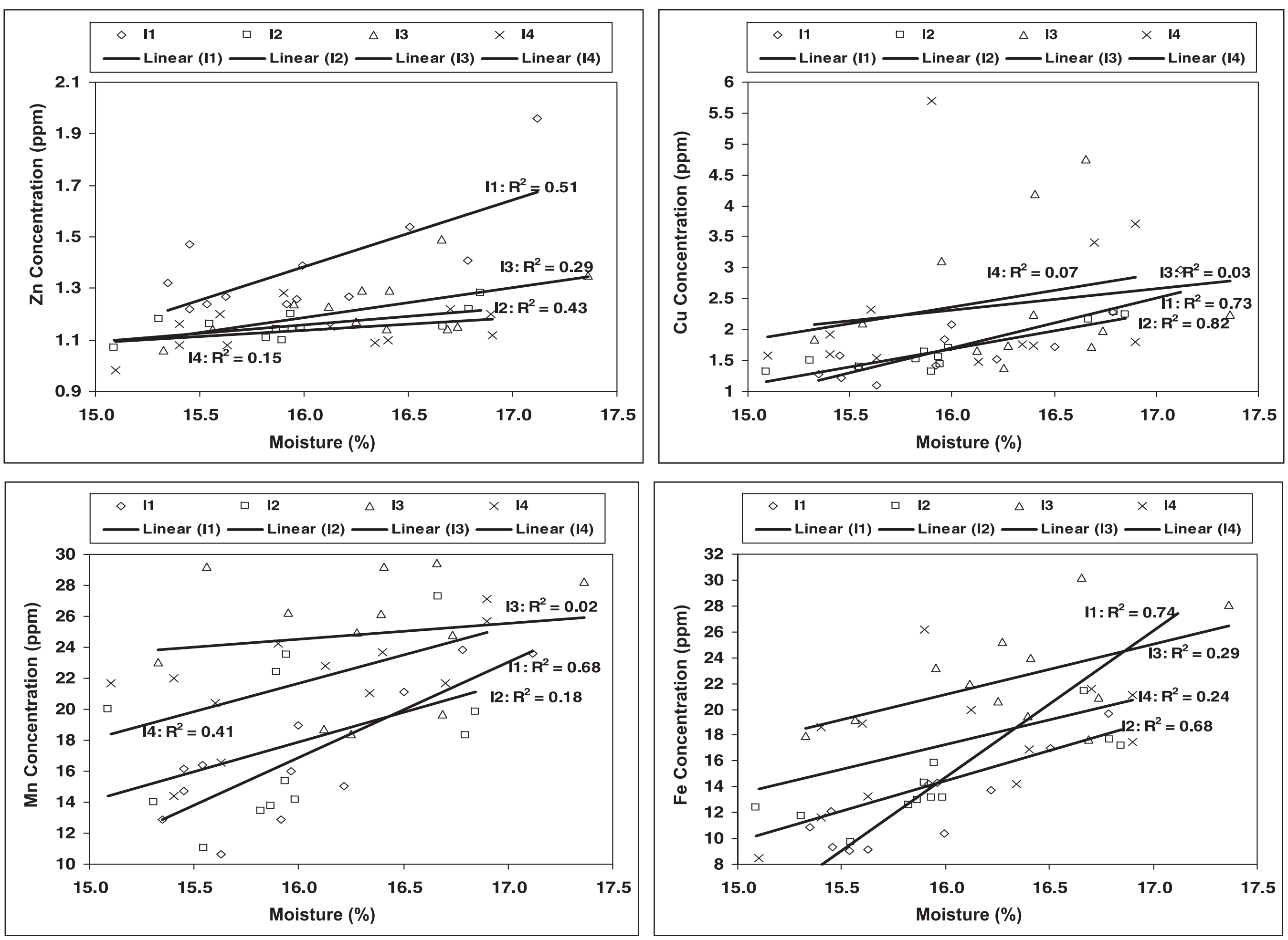


Fig.1. Functional relationship (1 m horizontal distance) between soil moisture (%) and micronutrients (ppm)

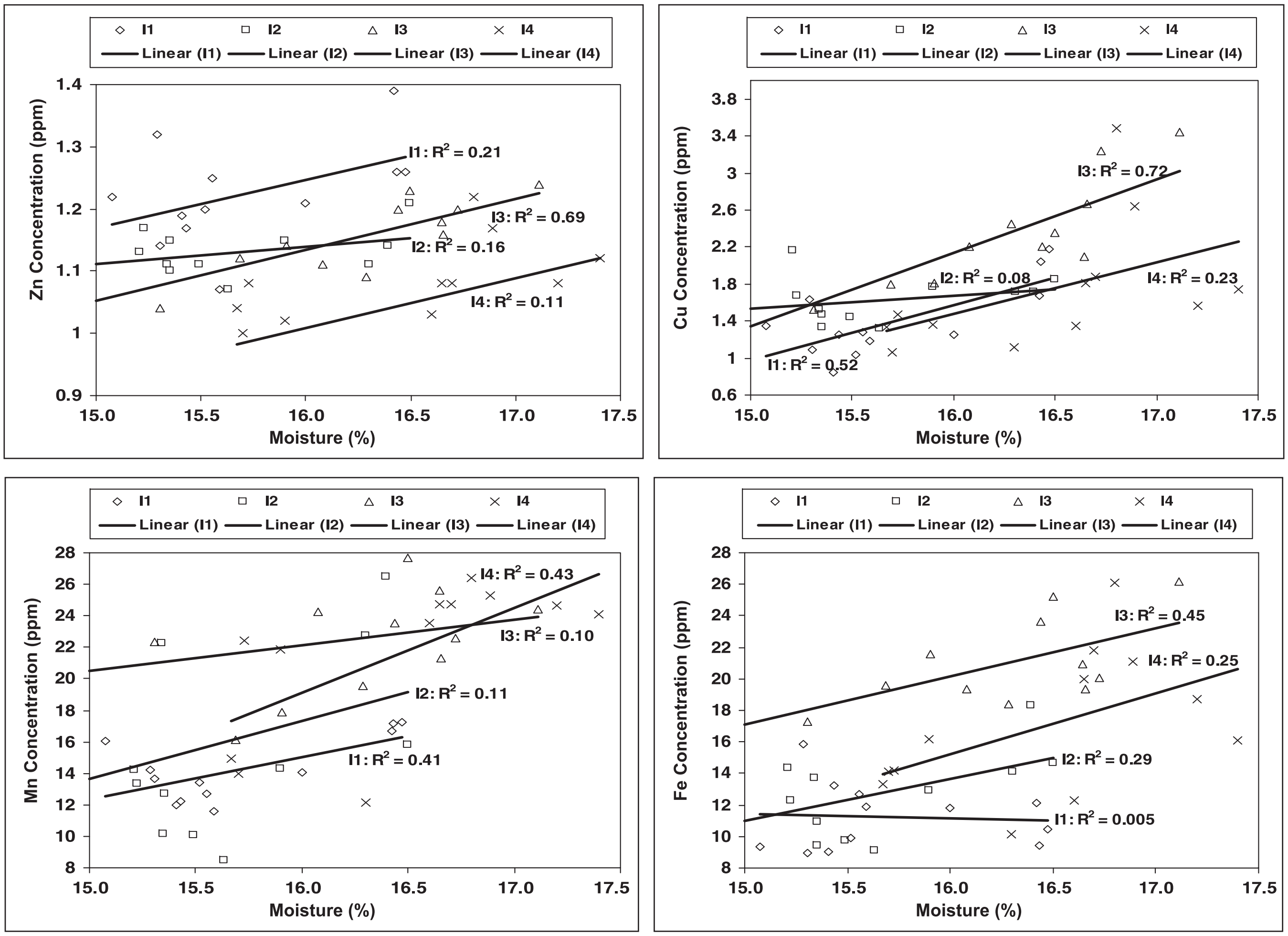


Fig. 2. Functional relationship (1.5 m horizontal distance) between soil moisture (%) and micronutrients (ppm)

= 0.51) in drip irrigated soils (I_1) as compared to the basin irrigation (I_4) (R^2 = 0.15). The dynamics in available Cu could be explained to the tune of 73-82% in drip irrigated soils (I_1 and I_2) as compared to 7.0 % in basin application (I_4). Similarly, Fe (R^2 = 0.68 in I_1) and Mn (R^2 = 0.74 in I_1 and R^2 = 0.68 in I_2) also responded in a way of better root zone moisture regimes than basin application of irrigation water. Interestingly, at X_2 distances I_3 is best (Zn: R^2 = 0.69, Cu: R^2 = 0.72, Fe: R^2 = 0.45) while Mn is R^2 = 0.1. This functional relationship stated that any change in the profile soil moisture will have significant consequences on the micronutrient dynamics.

Functional relationship between organic carbon and micronutrient dynamics

Organic carbon is an important soil property that controls release and dynamics of micronutrients in soil. Linear regression analysis (Fig. 3) showed that the drip irrigated system responded in the best possible way to the functional relationship between organic carbon variations and micronutrient distribution within the soil profile. The degree of variability in micronutrient dynamics as a function of organic carbon could be explained to the order of 50-61% (I_3-I_1) in case of Zn, 65-71% in Cu (I_3-I_1), 52-61% in Mn (I_3-I_1) and 48-51% in Fe (I_3-I_1) as compared to lower degree of basin irrigation application. However, the magnitude of relationship was diminishing when the horizontal direction (X_2) increased (Fig. 4). This information indicated that the micronutrients along with organic carbon were strongly influenced with effective root zone of vertical and horizontal distance of 1m.

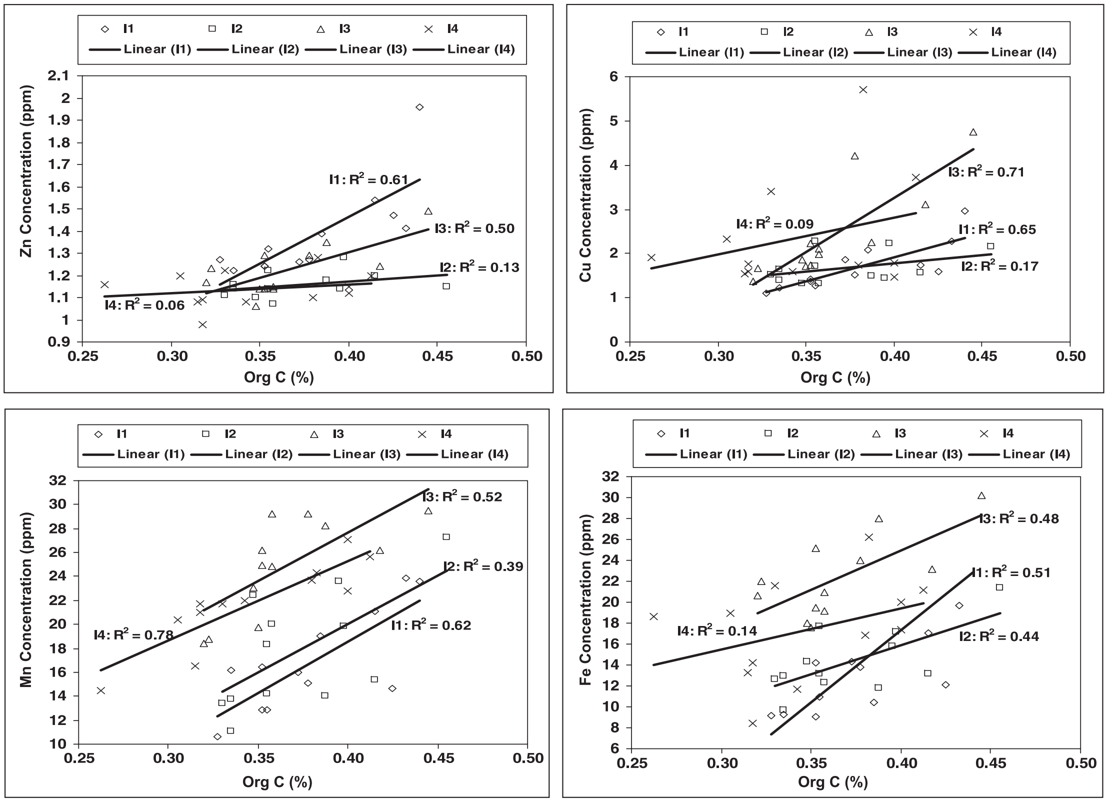


Fig. 3. Functional relationship (1 m horizontal distance) between organic carbon (%) and micronutrients (ppm)

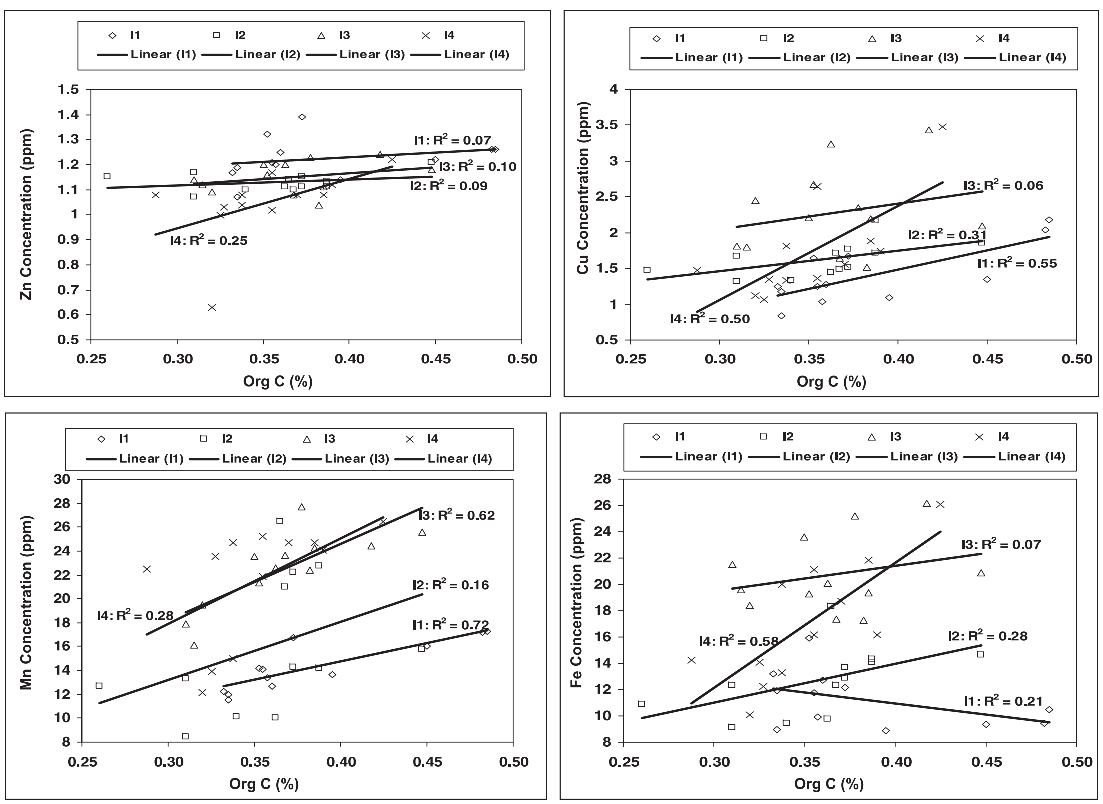


Fig. 4. Spatial relationship (1.5 m horizontal distance) between organic carbon (%) and micronutrients (ppm)

Correlation matrix among micronutrients

The Pearson's correlation coefficient between soil moisture and micronutrients; organic carbon and micronutrients indicated that at 1m horizontal distance, Zn, Cu and Fe showed strong association with moisture regime in 70-90% OPE replenishment in drip system of irrigation while Mn availability showed highly significant correlation with moisture more than 90% OPE replenishment irrespective of method of irrigation. Zn and Fe were mostly non-significantly related at 1.5 m distances from the tree trunk (Table 1). Availability of micronutrients was significantly correlated with organic carbon content at 1 m distance in all the drip irrigation levels. The relationship among soil moisture, organic carbon and micronutrients were mostly non-significant in basin application of irrigation. Analysis of correlation matrix (Table 2a and b) among micronutrient contents under differential soil moisture and nitrogen regimes revealed that some of the micronutrients were significant at 1% level of significance and others at 5% level of significance within the irrigation and fertigation levels. Non-significance was also found in Mn at I_2 in both X_1 and X_2 directions.

Table 1. Statistical significance and Pearson's correlation coefficient among different treatments

Soil moisture (%)	Micronutrients at 1 m horizontal distance (ppm)				Micronutrients at 1.5 m horizontal distance (ppm)			
	Zn	Cu	Mn	Fe	Zn	Cu	Mn	Fe
I_1	0.71**	0.85**	0.82**	0.86**	NS	0.72**	0.64*	NS
I_2	0.65*	0.90**	NS	0.82**	NS	NS	NS	NS
I_3	NS	NS	NS	NS	0.83**	0.85**	NS	0.67*
I_4	NS	NS	0.64*	NS	NS	NS	0.65*	NS
Organic Carbon (%)								
I_1	0.78**	0.78**	0.77**	0.69*	NS	0.72**	0.83**	NS
I_2	NS	NS	0.62*	0.66*	NS	NS	NS	NS
I_3	0.69*	0.84**	0.72**	0.68*	NS	NS	0.79**	NS
I_4	NS	NS	0.88**	NS	NS	0.72**	NS	0.78**

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).
I represent irrigation treatments (I_1-90%, I_2-70% and I_3-60% of open pan evaporation and I_4- basin irrigation system)

Table 2a. Correlation matrix among micronutrients under drip irrigation cum fertigation techniques at 1 m horizontal distance

Micro-nutrients	Irrigation levels	Zn I_1	I_2	I_3	I_4	Cu I_1	I_2	I_3	I_4	Mn I_1	I_2	I_3	I_4	Fe I_1	I_2	I_3	I_4
Zn	I_1	1	0.68*	NS	0.59*	0.82**	0.78**	0.82**	0.65*	0.68*	NS	NS	NS	0.89**	NS	NS	0.61*
	I_2		1	0.66*	0.95**	NS	0.71**	0.90**	0.91**	NS	NS	0.69*	NS	NS	NS	0.58*	0.94**
	I_3			1	NS	NS	0.681*	0.70*	0.73**	0.61*	0.66*	NS	0.71**	NS	0.76**	0.97**	NS
	I_4				1	NS	NS	0.78**	0.79**	NS	NS	0.59*	NS	NS	NS	NS	0.96**
Cu	I_1					1	0.74**	NS	NS	0.85**	NS	NS	0.79**	0.87**	0.75**	NS	NS
	I_2						1	0.82**	0.65*	0.91**	NS	0.80**	0.65*	0.70*	0.77**	0.67*	0.64*
	I_3							1	0.93**	0.64*	NS	0.69*	NS	0.61*	NS	0.63*	0.80**
	I_4								1	NS	NS	NS	NS	NS	NS	0.65*	0.77**
Mn	I_1									1	NS	0.74**	0.79**	0.70*	0.89**	0.66*	NS
	I_2										1	NS	0.76**	NS	0.81**	0.74**	NS
	I_3											1	NS	NS	0.58*	NS	0.67*
	I_4												1	0.65*	0.87**	0.79**	NS
Fe	I_1													1	0.66*	NS	NS
	I_2														1	0.84**	NS
	I_3															1	NS
	I_4																1

* Correlation is significant at the 0.05 level (2-tailed) and ** Correlation is significant at the 0.01 level (2-tailed).
I represent irrigation treatments (I_1-90%, I_2-70% and I_3-60% of open pan evaporation and I_4- basin irrigation system)

CONCLUSION

The study recognized the importance of maintaining optimum soil moisture and carbon storage in the root zone through drip irrigation system. It also indicated that irrigation water applications through drip were essentially required to maintain the highest micronutrient availability and distribution within the soil profile as well as horizontally away from the tree trunk. Drip irrigated soils showed better response to the functional relationships of soil moisture with the micronutrients. Similarly, the degree of variability in micronutrient dynamics as a function of soil organic carbon could be explained of the order 50-61% for Zn, 65-71% for Cu, 52-61% for Mn and 48-51% for Fe as compared to lower degree of basin irrigation application. Thus, it was concluded that application of irrigation water through drip is the best technology for maintaining optimum soil moisture, organic carbon and their significant correlation with micronutrient dynamics in mango orchard soil.

REFERENCES

Adak T, Kumar K, Singha A, Singh VK. 2011b. Soil organic carbon content and moisture dynamics in a mango orchard soil as influenced by integrated nutrient management. *In: Global Conference on Augmenting Production and Utilization of Mango: Biotic and Abiotic Stresses*, June 21-24, 2011, CISH, Rehmanhkeha, Lucknow. pp 96-97.

Adak T, Singh VK, Kumar K, Singha A, Singh VK, Mishra D, Arun SK. 2011a. Addressing soil health issues under high density Mango and Guava orcharding systems. *In: X^{th} Agricultural Science Congress on Soil, Plant and Animal Health for enhanced and sustained agricultural productivity*, 10-12 February, 2011 at NBFGR, Lucknow. pp 3.

Craswell E T and Lefroy RDB. 2001. The role and function of organic matter in tropical soils. *Nutrient Cycling in Agroecosystem* **61**: 7-18.

Guilivo C. 1990. Interactions between mineral nutrition and tree and soil water status. *Acta Horticulturae* **274**: 149-67.

Heck R J, Tiessen H, Salcedo I H and Santos M C. 2003. Soil chemical changes under irrigated mango production in the Central Sa˜o Francisco River Valley, Brazil. *Journal of Environment Quality* **32**:1414-21.

Jha P and Mohapatra P K. 2010. Leaf litterfall, fine root production and turnover in four major tree species of the semi-arid region of India. *Plant Soil* **326**: 481-491.

Kumar K, Bhriguvanshi SR, Adak T, Singh VK. 2011. Micronutrients status in mango orchards of Uttar Pradesh. *In*: *X^{th} Agricultural Science Congress on Soil, Plant and Animal Health for enhanced and sustained agricultural productivity*, 10-12 February, 2011 at NBFGR, Lucknow. pp 60.

Labanauskas C K, Embleton T W, Garber M J and Richards S J. 1958. Effects of irrigation treatments and rates of nitrogen fertilization on young Hass avocado trees. V. Micronutrient content of leaves. *Proceedings of American Society of Horticulture Science* **71**:315-319.

Labanauskas C K, Embleton T W, Richards S J and Handy F M.1960. Effects of nitrogen and irrigation treatments on the micronutrient concentration in Hass Avocado leaves. *California Avocado Society Yearbook* **44**: 97-100.

Lal R, Griffin M, Apt J, Lave L and Morgan M G. 2004. Ecology - Managing soil carbon. *Science* **304**: 393.

Lindsay W L and Norvell W A. 1978. Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of American Journal* **42**:421-428.

Purushotham K and Narasimhan B. 1981. Depletion of soil moisture by young mango trees with and without irrigation. *South Indian Horticulture* **29**:68-69.

Ravishankar H, Kumar K, Singha A, Adak T. 2010. Integrated Nutrient Management in Mango and Guava. *Indian J. Fert*., **6**(11):12-21.

Richards S J, Weeks L V and Johnston J C. 1958. Effects of irrigation treatments and rates of nitrogen fertilization on young Hass avocado trees. I. Growth response to irrigation. *Proceedings of American Society of Horticulture Science* **71**: 292-297.

Schroth G.2003. Decomposition and nutrient supply from biomass. In: Schroth G, Sinclair FL (eds) *Trees, crops and soil fertility-concepts and research methods*. pp 131-150,CABI publishing.

Sebasti‘ M T, Marks E and Poch R M. 2008. Soil carbon and plant diversity distribution at the farm level in the savannah region of Northern Togo (West Africa). *Biogeosciences Discuss*. **5**: 4107- 4127.

Singh R K, Chakraborty D, Garg, R N, Subba Rao Y V, Sharma, D K and Sharma U C. 2009. Soil organic carbon and nutrient uptake vis-à-vis growth and yield of pearl millet as influenced by water and nitrogen in Typic Haplustept soil. *Indian Journal of Agricultural Sciences* **79**: 359-63.

Srivastava A K and Singh Shyam. 2005. Zinc nutrition, a global concern for sustainable citrus production. *Journal of Sustainable Agriculture* **25(3)**: 5-42.

Sujatha S, Rao J V and Reddy N N. 2006. Effect of drip irrigation and nutrient management on mango in alfisols of semi-arid tropics. *Indian Journal of Agricultural Sciences* **76**(10): 618 - 622.

Tiessen H, Cuevas E, Chacon P. 1994. The role of soil organic matter in sustaining soil fertility. *Nature* **371**: 783-785.

Walkley A C and Black T A. 1934. Estimation of soil organic carbon by the chromic acid titration method. *Soil Science* **47**: 29-38.

Journal of Soil and Water Conservation **11**(4): 323-328, October-December 2012
ISSN: 022-457X

Rainwater harvesting in North-Western himalayan region- A case study

ROHITSHAW KUMAR[1], DEEPAK JHAJHARIA[2], D. RAM[3], S. CHAND[4], MUKESH KUMAR[5] and R. M SHUKLA[6]

Received:15 April 2012; Accepted: 14 September 2012

ABSTRACT

IIn North Western Himalayan region, most of the water received through torrential and high intensity rainfall, out of which mostly goes as a surface runoff. The surface runoff causes problems of soil erosion in the hills and flood in downstream. In the region rainfall distribution is uneven and erratic which results in moisture stress for the crop production. The present study revealed that *in- situ* runoff management is most efficient and cheapest way of conserving rainwater, which also reduces soil losses and increases the opportunity time for groundwater recharging. The earthen embankment for rainwater harvesting has cost benefit ratio of 1.38:1. In addition, good results of harvesting and storage also achieved through ferro-cement water storage tanks of different dimensions. The paper describes traditional and new techniques for rainwater harvesting and a case study of Makkowal and Takarla projects.

Key words: *In-situ* runoff management, poly lined farm ponds, water harvesting structures

INTRODUCTION

In North-West Himalayan region of India, the annual rainfall varies 1500-3000 mm with average of 1750 mm. Out of which 71% is received during tropical monsoon period i.e. July-August and 79% of the total rainfall goes as runoff and stream flow. The rainfall distribution is erratic and uneven both spatially and temporally which results into acute water shortage for the use of both domestic and agriculture. To combat this problem, on farm rainwater harvesting is a common practice in the region with traditional and new methods which contribute 10% of water availability for agriculture and 40% for the domestic use. The site specific techniques which include construction of nala bandhan, farm pond, embankment-cum-dug structures/surface ponds, check dams for aquifer recharge and "Johar" or tanks for water storage to increase water potential for the crop production. Water harvested from roof top is stored in small dug out structures which are excavated in the hard rock and are commonly called as "Khattis" or "Dighis". Due to acute shortage of water the crop yields are significantly low and unstable which has adversely affected the socio-economic status of the people. Moreover, due to undulating topography canal irrigation system is not feasible and groundwater is inadequate and not accessible economically in this region.

The average depth of runoff at 80% probability level was found to be about 14 cm. Due to climatic change and increase in population the traditional and new techniques are being upgraded to harvest the maximum rainwater. To combat this acute shortage of water in the region, traditional and new techniques of on farm rainwater harvesting are prevailed, where in the natural rainwater is stored in augmented storage structures and further used for domestic and irrigation purposes, hence such type practices economically can be replicated.

It has also observed that earthen check dam/ reservoirs which are recommended across the streams to regulate runoff for flood control, trapping silt, collecting water for irrigation and fish

[1]Associate Professor & Head, [6]Assistant Professor, Division of Agricultural Engineering [3&4]Assistant Professor, Division of Soil Science, SKUAST- Kashmir, Shalimar Campus, Srinagar (J&K). [2]Assistant Professor, NERIST, Itanagar, [5]Assistant Professor, School of Agriculture, IGNOU, New Delhi-India. Corresponding author: mail- rohituhf@rediffmail.com

production and to recharge groundwater has good potential for replication. The different methods and objectives for rainwater harvesting in different areas vis-à-vis groundwater recharges excellently described by Suraj Bhan (2009). This study revealed traditional and new techniques of on-farm rainwater harvesting and their impact on sustainable agriculture production.

MATERIAL AND METHODS

Taking into account the topography (hilly), climatic conditions and occupation of people of the North Western Himalayan Region of India, traditional and new techniques of on-farm rainwater harvesting play an important role to meet irrigation and domestic water requirement. These include construction of contour bunds, semi-circular hoops, trapezoidal bunds, nala bandhan, graded bunds and different types of check dams. The foothills areas were selected to develop new on farm rainwater harvesting techniques. The study area facing land degradation problem due to high amounts of rainfall received and unscientific way of land and water management. Numbers of researcher has been investigated of various water harvesting techniques carried out at different sites in the region.

2.1 Rainwater Harvesting Techniques

Traditional Techniques

Small Ponds

Locally called "Talabs", these ponds exist as natural depressions, where run-off water from rainfall gets collected which used for irrigation, domestic and livestock requirements. These ponds are also constructed artificially, which are of two types:

a) Dammed Pond

The small soil ponds constructed against a stream of water. These ponds are suitable for steep topography area. These ponds are fed by run-off water. It is suitable in areas having heavy soils that have low percolation rate of water.

b) Cemented / Stoned Ponds

These small ponds are also locally called as "Haug". In hilly areas due to steep slope, it is not easy to construct big ponds. In these areas, rainwater is carried through "Kuhls" to the agriculture fields and stored water in small ponds having storage capacity of 2—35 cum. These ponds are made up by cement and stone masonry. LDPE lined small ponds are also constructed due to their low cost of construction.

c) Construction of "Bauris"

The "Bauris" are actually cemented storage structures, which are used to collect water from natural resources. In this case cemented storage structures are constructed across a natural point of flow of water and automatically considerable qualities of water get collected. The storage water is used for drinking domestic and irrigation requirements.

2.2 New Techniques

2.2.1 Run –off harvesting short-term storage

Contour bunds constructed along the contour lines, trap the water and retain water behind the bunds, whose height and slope determine the water storage capacity. Crops or trees are grown within the bunded area. Height of contour bunds range from 0.3 to 1.2 m and length of the bunds may vary from 10 m to 100 m. This technique has been used especially in hilly areas.

2.2.2 Semi- Circular Hoops

Semi circular hoops consist of earth embankments which are constructed in the shape of a half moon with the tips of the semi-circle on the contour. The water is collected within the hoop from the area just above it and impounded to a maximum depth defined by the height of the bund. In a field, the hoops are staggered in rows so that the water overflowing from the upper row is intercepted in the lower row. The height of bunds ranges from 0.1 to 0.5 m and the radius vary from 5 m to 30 m. Semi-circular bunds generally used for irrigation of grass, fodder, shrubs and trees.

2.2.3 Trapezoidal bunds

The trapezoidal earthen embankments bunds constructed on the tips of the bund of contour. Water is collected from the slopes above the bunded area and excess water overflows around the tips. The rows of bunds are staggered to intercept overflow from the above rows. The layout of trapezoidal bunds follows the same principles as those for semi-circular bunds, but they usually enclose a large bounded area. The height of bunds ranges from 0.3 m to 0.6 m and their width across the tip ranges from 40 m to 160 m. Trapezoidal bunds are used where rainfall intensities are high, causing surface water to flow at high discharges which would cause damage to contour bunds. These bunds are used extensively for irrigation of crops, grasses, shrubs or trees and enable intercropping within the large enclosed areas.

2.2.4 Nala Bandhan (Mini earthen check dams)

Various gullies and ravines originating from hills are transformed into the shape of “nala” small stream at the foothill and divide the agricultural and non-agricultural land in to various segments. These “nalas” could be conveniently converted into series of mini water reservoirs with suitable structures such as earthen check dams. For constructing the check dam’s trenches of size 1 m depth and 0.75 m width are excavated and filled with puddle clay. Stone pitching on the upstream side is done to prevent damage of the dam. To drain out the excess rainwater side spillways at suitable height are provided with stone pitching. The loose boulder wall is constructed between the earthen check dams for strengthening of minimizing the run-off cutting effect due to its velocity.

2.2.5 Off-contour bunds or graded bunds

Off-contour bunds consist of earthen or stone embankments build along 0.5-2% slopes. The contour bunds constructed where rainfall intensity is high and soils are such that large amount of water which require safe drainage through the field is intercepted. The height of the bunds ranges from 0. 3 m to 0.6 m. The off- contour bunds or graded bunds look like an open ended trapezoidal bund and commonly known as modified trapezoidal bund.

a) Rock catchment

Exposed rock surfaces are used for the collection of water. The rainfall on the exposed rock is drained towards the lowest points, sometimes being channeled along low walls. The runoff is collected in a storage tank or reservoir of earth fill embankments; gravel stone fill embankments, stone masonry dams or concrete dams. The storage water used for domestic and irrigation purposes.

b) Ground catchment

The ground surface is used to collect water into storage tanks or reservoirs. The ground is cleared from vegetation, compacted and then reshaped to create a series of channels leading to the reservoir. The surface compacted and sometimes covered with gravel. These are called roaded catchments.

2.2.6 Flood water harvesting-short term storage

Level flooded terraces are re-shaped to form a series of broad level terraces. Water is collected via the valley from the watershed above and it flows by means of stone, gabion or concrete weirs, from one terrace to the next. Terraces are used to grow trees or crops. This system is used to grow trees along the main roads.

2.2.7 Diversion of run-off

In hilly area contour bunding diversion of flood water for direct application on field by flooding is common practice. Water may be diverted by a diversion dam and led through channels to basins where the crops are irrigated by flooding.

2.2.8 Check dams for aquifer recharge

Small rocks or concrete dams are built across the depressions to slow down the velocity of flow to enable a large amount of water to infiltrate into the soil under the channel bed. This added infiltration helps replenish the aquifers. Water is stored in the aquifers and utilized through wells or borehole. This system permits less evaporation losses than a surface reservoir, less problem of siltation and cheaper construction as the peak flows are not intercepted but are allowed to discharge over the check dam.

2.2.9 Sub-surface dams

Sub-surface vertical barriers are constructed across the channel in downstream to intercept water flowing within the alluvium. This water flows along the surface and it is collected in sub-surface reservoir created by the barriers. Barriers are constructed of clay stone masonry, concrete or steel sheet and piles. Water is utilized by gravity or by shallow wells or boreholes. It is common practice to construct sub-surface dams together with sand dams.

2.2.10 Roof top water harvesting

To encourage rainwater harvesting and its supplementary use for irrigation and domestic purpose, a technique of roof top harvesting has been evolved. Under the scheme all the Government and private buildings must have the provision of roof top harvesting and its storage. With these practices rainwater collected from the roof tops is stored in the dug wells / ponds and used for washing, drinking of livestock and irrigation.

2.3 Reservoirs /Tanks/Ponds

2.3.1 Earthen check dam reservoirs

At some places, there are big gullies and ephemeral streams in watersheds originating from hills and flowing down through cultivated lands. Earthen check dams across these gullies / streams can be constructed at suitable sites to store runoff with multi-purpose benefits like:

- to regulate runoff for checking land damage and flood downstream,
- to trap silt and for safe disposal of runoff,
- to collect water for irrigation /fish production, and
- to recharge groundwater.

The earthen dam reservoirs to be constructed in the watershed may be designed for fulfilling one or more of the objectives based on the location specific situations.

2.3.2 Excavated tanks

Excavated / dug- out tanks are most suitable for storage of runoff in cultivated lands but seepage losses are very high and thus need lining.

3. Makkowal project- A case study

Makkowal is situated in the state of Punjab (India) about 30 km from Hoshiarpur at the foothills of Shivaliks. The village has a habitation of 300 houses and an area of 243 ha. On Northern side of the village there is hilly area and western part of the village has leveled lands with moderate slope. Soils are sandy to sandy loam and are good for agriculture, but because of scarcity of irrigation water, the production of agriculture crops was very low. Although the average rainfall is about 1000 mm, its distribution is erratic and uneven. About 80% of the rainfall is received in three monsoon months. Heavy soil erosion due to flash floods and torrential rain and there are frequent crop failures due to drought are common. The problem of water scarcity can be judged from the fact that a 100 m deep open well was dug in the village long ago, could not provide enough water for drinking. The villagers had to traverse 2 to 3 km in the hilly terrain to fetch water from wells located along the side of streams, where perennial flow existed for most part of the year. A sketch layout map of drainage line treatment of Mokkowal watershed has been shown in Figure 1.

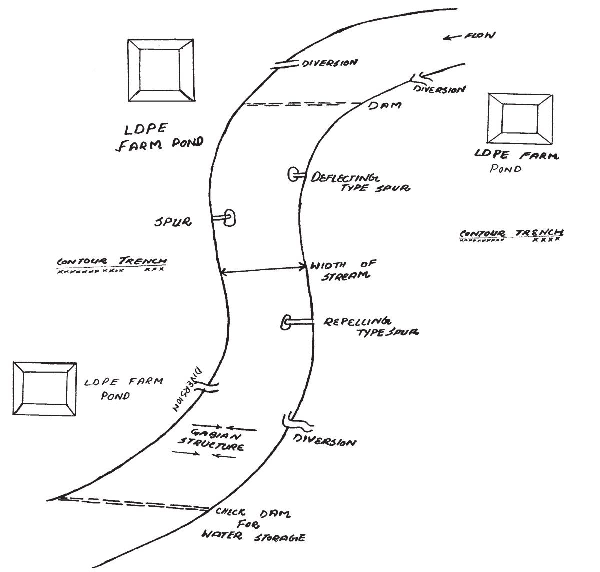


Fig. 1. Layout map of drainage line treatment of Mokkowal and Takaral Watersheds

The project was launched in the year 1986 for seven years function for tapping of surface flow in the stream bed emanating from hill seepage from a point located at 3 km from village. Three existing shallow open wells on the bank of the stream were charged with seepage water connected with each other by cement concrete pipes. The village pond was deepened, widened and renovated to have a storage capacity of 2.4 ha-m. From the pond a network of underground pipeline of cement concrete was laid to convey water to the agricultural fields for irrigation. Just before the village pond, separate taps were also provided for drinking, bathing washing and for cattle. Surplus arrangement was made on the other side of the pond. The entire catchment area of choes was treated with different engineering and biological conservation measures. The cost of construction of earthen check dam and is effective life depend upon the location, proper design and proper maintenance. The earthen dams constructed in the area cost about Rs 2.5 to Rs 27.0 per m^3 of capacity.

Prior to the implementation of the project, the farmers did not use fertilizer, high yielding varieties and weedecides etc. Only FYM was applied to the individual farmers. After the project, the farmers have started using seed of high yielding verities of maize and wheat. Use of chemical fertilizers, weedecides and pesticides has also been started after the project. The fertilizer use, yield of major crops *viz*. wheat, maize, gram, fodder and gross returns has been increased due to implementation of project (Figures 2-3).

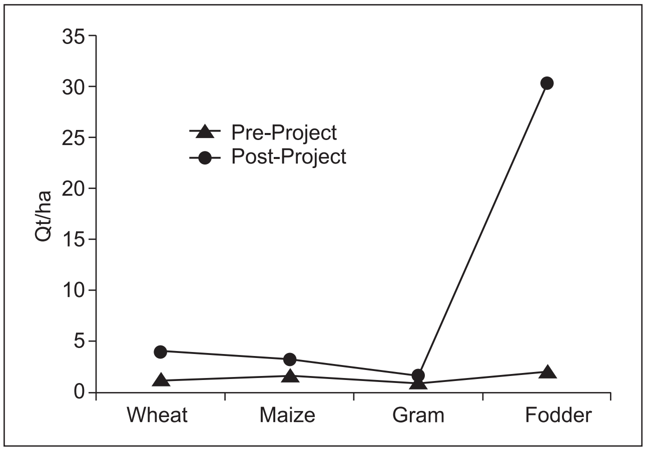


Fig. 2. Pre and post-project average yields (Qt ha^{-1})

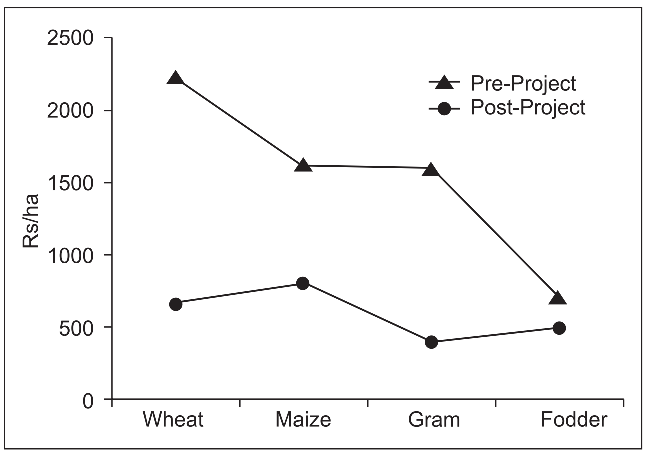


Fig. 3. Pre and post-project average returns (Rs. ha^{-1})

4. Takarla project-A case study

The Takarla, surface flow harnessing project has been designed on the similar lines of Makkowal project but with slight modification. This project is located in foothills of Indian Shiwaliks at a distance of 13 km from Balachaur; district Nawashahar in the state of Punjab and the project was functioned for seven years. The area is sloppy and undulating. The soils are loamy sand to sandy loam in texture and at some places silt loam, sub angular to angular blocky in structure, very deep and erodible. The area is totally rainfed. The area is affected from torrential rain and the surface runoff flow is due to seepage from the side hills. The flow remains 3-4 month even after the rainy season and thereafter flow rate decrease but remains in the sub-surface sand bed of choe. In the channel a concrete toe wall was constructed at the stream bed. A weir of suitable section was made on the barrier wall and flow released over the structure close to the water pool. On one side of the stream, a stilling basin was constructed to create head of water. The inlet was connected to the stilling basin through a pipe. Above the weir, a filter of local stones and grits was provided in the choe bed to facilitate infiltration of water when surface flow diminishes during the lean period. An underground pipeline has been laid from the stilling basin to the agricultural fields located at lower level. Therefore, the system works on gravity flow. This system is providing supplemental irrigation to about 100 ha farm lands of the village. The major crops grown in the study area and their pre and post project yields and return have shown in Table 1 and Figure 4 &5. The gross returns from major crops have shown increasing trends due to adoption of new water saving techniques. Similarly studies of water resources in Shaheed Bhagat Singh Nagar- A Case Study was concluded by R. Agrawal *et al.* (2010).

Table 1: Pre and post project average yields of major crops

Name of Crop	Pre-project yield (Q ha^{-1})	Post-project yield (Q ha^{-1})
Wheat	10.0	25.0
Maize	5.0	12.5
Gram	2.5	7.5
Fodder	40.0	100.0

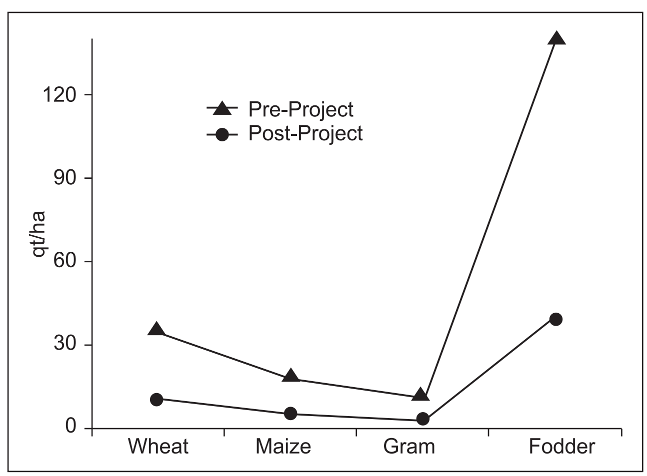


Fig. 4. Pre and post-project average yields (q ha^{-1}) of major crops

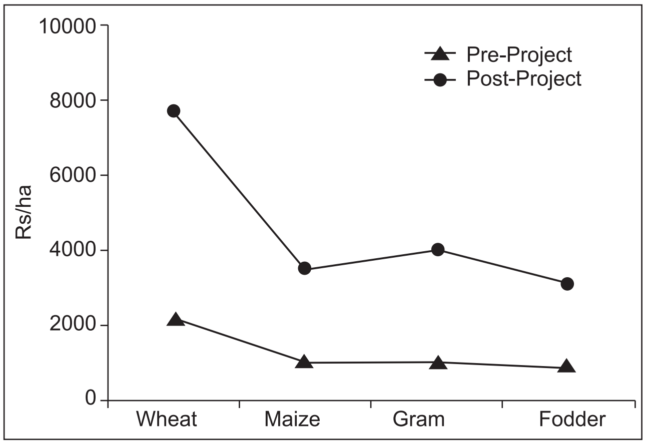


Fig. 5. Pre and post-project gross returns (Rs. ha^{-1}) of major crops

RESULT AND DISCUSSION

Tradition and new techniques is tool of on farm rainwater harvesting in Northern Himalayan region. In lower Himalayan regions, it is viable to design and construct earthen dams, gully plugging, and loose stone check dam at suitable locations for multipurpose uses fulfilling numbers of objectives. Following results have emerged from the detailed studies on earthen dams in the Northern Himalayan region

- Drainage line treatment should be designed and developed in the catchment first and then the runoff and silt should be estimated at the site for treated catchments /sub watershed for development of land, crop and vegetation.
- The storage volume should be designed for 60 to 80% probability level of lowest assured runoff.
- There is no economically viable method to reduce seepage from porous bed of the reservoir area except self sealing by silting.
- It is not economically viable to construct earthen dams for irrigation purpose only.

The research investigation carried out in Kandi area on excavated tanks emerged as:

1) Tanks with inverted truncated pyramid shape having 1:1 side slope and lined with polyethylene sheet of 200 micron, buried under 20 cm thick soil at bottom and brick cement on side found suitable.
2) The tank capacity should be designed on the basis of lowest assured monsoon runoff at 50 to 80% probability in such a way that it gives full capacity water in the end of monsoon considering seepage and evaporation losses during collection period.
3) The stored water in tank is used for life saving irrigation of wheat crop during pre-sowing irrigation for maximum returns per unit of storage capacity of tank.

CONCLUSION

The erratic and uneven distribution of rainfall both spatially and temporally, necessitates rainwater harvesting to increase and sustain the agricultural productivity. Excavated dug-out pond tanks are found most suitable for storing runoff in cultivated lands with inverted truncated pyramid shape having 1:1 side slopes with lining of polyethylene sheet of 200 micron buried under 20 cm thick soil at bottom and pitched with bricks. The earthen embankment for rainwater harvesting has cost benefit ratio of 1.38:1. The rainwater harvesting during monsoon and its use for irrigation during scarcity period was found to increase the crop yield by 25-35% during Rabi season and additional water for domestic use by 55% population of the area. There is urgent need for flood protection and irrigation on farm lands below the hills through control and utilization of runoff. Rehabilitation of upper watersheds through reduced run off and erosion from the hills through soil conservation measures. For successful implementation of traditional and new on farm rainwater harvesting techniques, strengthening of project implementing agency's capacity should be done for undertaking investigations and research of surface hydrology, groundwater and micro-watershed studies.

ACKNOWLEDGEMENT

Authors are thankful to Dr. Tej Pratap, Vice-Chancellor, SKUAST- Kashmir and Head CSWCRTI, Chandigarh for encouraging and providing information about the case study.

REFERENCES

Aggrawal, R., Kaur, S. and Pamela M. (2010). Assessment of water resources in Shaheed Bhagat Singh Nagar- A case study. Journal of Soil and Water Conservation.9:288-292.

Suraj Bhan (2009). Rainwater harvesting. Journal of Soil and Water Conservation.8:42-48.

Journal of Soil and Water Conservation **11**(4): 329-333, October-December 2012
ISSN: 022-457X

Effect of low nitrogen on productivity and nitrogen economy of maize (*Zea mays*) cultivars

MAHENDRA SINGH PAL[1]

Received: 27 March 2012; Accepted: 20 September 2012

ABSTRACT

A field study was carried out during kharif season 2006 and 2007 at Crop Research Centre, G.B. Pant University of Agriculture & Technology, Pantnagar (Uttarakhand) with the objective to screen out higher nitrogen efficient maize cultivars under low nitrogen fertilization in Mollisols of Uttarkhand. The experiment consisted of 3 nitrogen levels in main plot i.e. 40 (N_{40}), 60(N_{60}) and 80(N_{80}) kg/ha and four maize cultivars i.e. 'VL Amber' (Pop corn), 'Him -129' (Hybrid), 'Vivek-1'1 (Hybrid) and 'Pragati' (Composite) in sub plot, was planted on 25th July, 2006 and 25th June, 2007 under split plot design and replicated thrice. Besides nitrogen, basal application of 60kg P_20_5 and 40kg K_20/ha was also made. Application of 80 kg N recorded 14.3 and 44.7% higher grain yield compared to 60 and 40 kg N, respectively, while 60 kg N gave 26.6% higher grain yield than 40 kg N level. Hybrid 'Him-129' also gave 16.4 and 26.2% higher grain yield than 'ViveK-11' and 'Pragati', respectively. N_{40} had the highest NUE 76.9 kg grain yield/kg N applied and reduced with increasing N rates as N_{60} had 51.3 and N_{80} 38.3 kg/kg N applied. Similarly, hybrids had better NUE as 'Him-129' and 'Vivel-11' had 66.67 and 57.9 kg/kg N applied, respectively. The research findings revealed that maize hybrids 'Him-129' and 'Vivek-11' might be grown with application of 80 kg nitrogen/ha in addition to 60 kg P_20_5 and 40 kg K_20/ha for higher productivity and nitrogen economy under low nitrogen environments including Mollisols of Uttarakhand.

Key words: zea mays, cobs, tasseling, silking, leaf area index, nitrogen economy

INTRODUCTION

Maize (*Zea mays)* is the third most important cereal of the country with 8.17 m ha area, 19.73 m t production and 24.15 q/ha productivity. It is a fast growing very exhaustive C_4 plant and also very responsive to inputs including nutrients and water. Maize, in general, removes 161kg N, 34 kg P and 110 kg K from one hectare land per season, hence, it requires higher doses of balanced fertilization but higher application of chemical fertilizers have shown deleterious effect on soil health leading to unsustainable productivity particularly in intensive cropping systems of irrigated environments in Indo-Gangetic plains of India (Swarup, 2002). Among the essential plant nutrients, nitrogen is the most important one and farmers invariably apply nitrogenous fertilizers in imbalanced manner with little or almost no amount of phosphatic and potassic fertilizers that leads negative NPK ratio in the soil. In the present scenario of soaring fertilizers cost, the emphasis is required to have crop cultivars of higher nitrogen use efficiency. Further, higher application of nitrogen leads to loss of nitrogen with poor nitrogen use efficiency and wastage of energy. Therefore, the present study has been made to screen out high nitrogen use efficient maize cultivars under low nitrogen fertilization environments.

MATERIALS AND METHODS

The experiment was carried out during *kharif* season 2006 and 2007 at Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) with the objective to find out the effect of low nitrogen on productivity and nitrogen economy of maize (*Zea mays*) cultivars in *Tarai* region of Uttarakhand, India. The experimental

[1] Department of Agronomy, College of Agriculture, G. B. Pant University of Agriculture & Technology, Pantnagar-263145 (Uttarakhand), India (Email: drmspal1@gmail.com)

site was sandy loam in texture having soil pH 7.33, organic carbon 0.57 % and available P and K 19.9 and 147.8 Kg / ha, respectively. The experiment consisted of 3 nitrogen levels in main plot i.e. 40 (N_{40}), 60(N_{60}) and 80(N_{80}) kg / ha and four maize cultivars i.e. 'VL Amber '(Pop corn), 'Him -129' (Hybrid), 'Vivek -11' (Hybrid) and 'Pragati'(Composite) in sub plot, was planted on 25th July, 2006 and 25th June, 2007 under split plot design and replicated thrice. The crop was harvested on 31th October, 2006 and 21st September, 2007, respectively. The planting geometry 60cm x 30cm was mainlined during both years. Full amount of P and K was applied as basal but the nitrogen was applied as 20% basal, 25% at 4 leaf, 30% at 8 leaf, 20% at tasseling and 5% at early grain filling stage. The crop was irrigated at knee height, silking and grain filling stages. The uniform spray of Endosulphan @ 0.2 % was made twice in all experiments at silking and 15 days after silking.

The randomly selected samples of five plants were taken from every plot at all growth stages for analysis of growth and yield parameters. The net plot was harvested for grain yield and expressed in kg / ha. The nitrogen use efficiency was calculated as grain yield divided by applied nitrogen and expressed in kg grain yield / kg N applied.

RESULTS AND DISCUSSION

Effect of nitrogen levels

Growth attributes

The plant height increased with crop age and significantly tallest plants were observed at harvest during both years except at harvest in 2006 (Table.1). The plant height increased with increased level of nitrogen and the tallest plants were also noticed at highest N level i.e. N_{80} that remained significantly similar to N_{60} level during both years. The dry matter accumulation was also affected significantly by nitrogen levels and improved with increment of N levels during both years. The maximum dry matter per plant was recorded at N_{80} level and the lowest at N_{40} during both years. The plant dry matter was weighed significantly highest at N_{80} at 30 days after sowing (DAS) during both years, while at 60 DAS and also at harvest, N_{80} level had significantly similar dry matter compared to N_{60} level during both years except in 2006 where the dry matter was observed significantly highest at N_{80} level. The leaf area index was also increased up to 60 DAS and then reduced, therefore, the lower leaf area index was recorded at harvest during both years. The leaf area index was measured significantly highest at N_{80} level at 30 and 60 DAS during both years but at harvest, the N_{80} and N_{60} levels had significantly same leaf area index during both years. The higher plant height, dry matter and leaf area index at higher N levels might be due to better N availability that improved the growth and development of the plant (Pathak, *et al*., 2005).

Yield and yield attributes

Nitrogen level did not influence the days taken to 50% tasseling as well as silking during both years (Table.2). The cob length was significantly affected by nitrogen levels and the largest cobs were found at N_{80} levels that did not differ with N_{60} level during both years. The cob girth, however, did not differ significantly with N levels but the highest cob girth was measured at N_{80} level. The cob yield was weighed significantly higher at N_{80} level that had significantly equal cob yield at N_{60} level during both years. The pooled average indicated that N_{80} had 8.2 and 23.4% higher cob yield than N_{60} and N_{40}, respectively, while N_{60} had 14.1% higher than N_{40} level. The 100 grain weight was also influenced by N levels and the highest values were recorded at N_{80} levels that gave significantly equal 100 grain weight to N_{60} level during both years. Singh *et al*. (2003) also concluded that higher dose of fertilizers improved the values of yield contributing attributes. The grain yield was also affected significantly by N levels during both years and N_{80} recorded two year pooled average of 14.3 and 44.7% higher grain yield than N_{60} and N_{40} levels, respectively, while N_{60} gave 26.6% higher than N_{40} level. Khanday and Thakur (1990) also reported that grain yield of maize increased significantly with increase in N levels up to 80 kg / ha. The higher dose of N improved the growth and yield attributes resulted in to more sink translocation from source and finally bolder seed and greater grain yield and supported by Kumar (2008). However, Sutaliya and Singh (2005) noticed improvement in yield and yield attributes of maize up to 180 kg N / ha.

Effect of cultivars

Growth attributes

The cultivars had significant effect on plant height only at 30 DAS during both years (Table 1). Hybrid 'Vivek-11' had the tallest plants at 30 DAS but at

Table 1. Effect of nitrogen levels and cultivars on plant height, dry matter and leaf area index (LAI) of maize during 2006 and 2007

Treatment	Plant height (cm)						Dry matter accumulation (g/plant)						Leaf area Index (LAI)					
	30 DAS		60 DAS		harvest		30 DAS		60 DAS		harvest		30 DAS		60 DAS		harvest	
	2006	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
A. Nitrogen levels (kg/ha) (N)																		
N_{40}	96	91	188	178	208	196	11.2	20.6	64.8	59.3	165.6	155.2	1.21	2.55	2.49	2.55	1.19	0.91
N_{60}	102	99	195	183	209	200	14.4	24.0	70.9	67.9	186.4	174.8	1.41	2.81	2.79	2.81	1.35	1.00
N_{80}	104	103	198	187	207	204	18.5	27.1	74.6	70.5	199.9	182.6	1.66	3.05	3.16	3.05	1.44	1.08
SEM ±	1.5	1.5	2.6	3.1	1.4	1.9	0.4	0.8	1.3	1.8	3.3	4.2	0.03	0.06	0.03	0.06	0.04	0.05
CD (p=0.05)	04	04	08	09	ns	06	1.2	2.5	3.8	5.3	10.0	12.3	0.08	0.20	0.09	0.20	0.11	0.15
B. Cultivars (C)																		
VL-Amber	99	97	194	184	202	202	16.2	22.3	61.7	62.1	164.9	152.7	1.64	1.93	2.90	2.59	1.12	0.89
Him-129	97	94	191	179	209	199	13.6	20.7	68.4	67.2	194.3	183.2	1.53	2.53	2.73	2.93	1.43	1.16
Vivek-11	108	105	193	181	208	197	14.8	28.2	74.8	63.9	192.4	177.4	1.48	1.99	2.45	2.91	1.40	1.03
Pragati	99	94	196	185	214	201	14.1	24.3	75.4	70.3	184.3	170.2	1.32	2.03	3.19	2.80	1.35	0.90
SEm ±	02	1.6	03	3.4	04	2.2	0.5	0.5	1.5	2.1	3.8	4.6	0.03	0.05	0.03	0.07	0.09	0.05
CD (p=0.05)	05	05	ns	ns	ns	ns	1.4	2.9	4.4	6.1	11.6	13.4	0.09	0.16	0.11	0.23	0.28	0.17
Interaction (N x C)	ns	ns	ns	ns	ns[1]	ns	ns[1]	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

harvest, 'Pragati(composite)' produced the tallest plants during both years. The plant dry matter was affected significantly by cultivars at all growth stages during both years. The highest dry matter was recorded under 'VL Amber' in 2006 and 'Pragati' in 2007 at 30 DAS, while at 60 DAS, 'Pragati' gave the highest values during both years, however it did not differ significantly with 'Vivek-11' and 'Him 129' during 2006 and 2007, respectively. At harvest, 'Him-129' had significantly higher dry matter that remained non significant with 'Vivek-11' and 'Pragati' cultivars during both years. The leaf area index was also influenced by cultivars at all the growth stages during both year. The cultivar 'VL Amber' and 'Him-'129' gave significantly highest leaf area index at 30 DAS during both years, while at 60 DAS, 'Pragati' and 'Him-'129' produced the highest leaf area index in 2006 ad 2007, respectively. At harvest, 'Him-129' had the highest leaf area index during both years, however, it remained non significant with 'Vivek-11' and 'Pragati' in 2006 and Vivek-11 in 2007. Both hybrids had higher leaf area index than composites at harvest indicating that hybrids utilized natural resources better than composites and converted energy in form of grain yield. Similarly, Pop corn 'VL Amber' gave the lowest leaf area at harvest during both years.

Yield and yield attributes

The days taken to 50% tasseling and silking stages differed greatly with cultivars during both years. 'VL Amber' took maximum days to 50% tasseling and silking during both years followed by 'Vivek-11'.The cob length did not influenced significantly by the cultivars, however the largest cobs were recorded in 'Him-129' followed by 'Vivek-11'. The cob girth was affected significantly by cultivars during both years. The highest cob girth was noticed under 'Pragati' that had significantly equal values to 'Him-129' and 'Vivek-11'.

Significantly maximum cob yield was recorded in 'Him-129' that did not differ significantly with 'Vivek-11' and 'Pragati' during both years. The pooled average of two years revealed that 'Him-129' gave 3.6 and 10.5% greater cob yield than 'Vivek-11' and 'Pragati', respectively but 'Vivek-11' had 6.2% higher cob yield than 'Pragati'. Similarly, the 100 grain weight also differed significantly with cultivars with on an average the highest value was recorded in 'Pragati' followed by 'Hime-129'. The cultivars had significant effect on grain yield of maize as evidenced with significantly highest grain yield under 'Him-129' during both years. Hybrid 'Him-129' also gave on an average 16.4 and 26.2% higher grain yield than 'ViveK-11' and 'Pragati', respectively. 'VL Amber' produced significantly lowest grain yield during both years due to low values of cob length, cob girth, cob yield and also 100 grain weight. The interaction effect between nitrogen rates and cultivars on growth and yield attributes and also on grin yield remained non significant during both years.

Nitrogen Use Efficiency (NUE)

The nitrogen use efficiency (N Economy) was affected significantly by both nitrogen rates as well as cultivars during both years (Table 2). Significantly highest NUE was found at N_{40} and followed by N_{60} and the lowest at N_{80} levels during both years. The pooled data indicated that the N_{40} had the highest NUE of 76.9kg grain yield of maize per kg nitrogen applied. The NUE was reduced at higher levels of applied nitrogen as evidenced with NUE of 51.3 and 38.3 kg grain yield / kg N applied at N_{60} and N_{80} kg / ha, respectively (Fig.1).

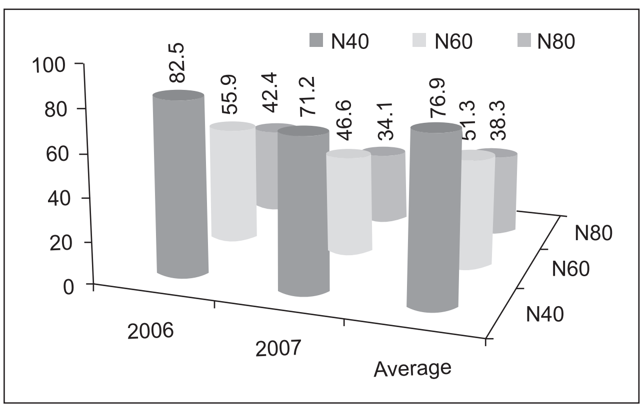


Figure 1. Effect of nitrogen rates on nitrogen economy (kg / ha)

Nitrogen use efficiency varied significantly with maize cultivars during both years (Table 2 and Fig.2). Significantly highest NUE was observed under hybrid 'Him 129' followed by hybrid 'Vivek-11', composite 'Pragati' and the lowest in VL Amber (pop corn) during both years. The average NUE was also recorded maximum under 'Him-129' with 66.6 kg grain production per kg nitrogen applied followed by 'Vivel-11' with 57.9 , 'Pragati' with 53.4 and 'VL Amber' with 44.6 kg / kg N applied. The hybrids had higher nitrogen economy because of better utilization

Table 2. Effect of nitrogen levels and cultivars on yield attributes, grain yield, moisture content and nitrogen use efficiency of maize during 2006 and 2007

Treatment	Days to 50% Tasseling		Days to 50% Silking		Cob length (cm)		Cob girth (cm)		Cob yield (kg / ha)		100-grain weight (g)		Grain yield (kg / ha)		N yield (kg grain / Kg N applied)	
	2006	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
a) Nitrogen levels (kg / ha) (N)																
N_{40}	47	45	49	47	14.2	13.2	11.4	11.1	6146	5060	21.48	18.34	2732	2238	82.5	71.2
N_{60}	46	44	49	47	15.7	14.9	11.9	11.2	6840	5945	22.56	19.41	3434	2858	55.9	46.6
N_{80}	46	44	49	48	16.3	15.5	11.9	11.4	7299	6530	23.86	20.78	3864	3325	42.4	34.1
SEM ±	0.4	0.2	0.3	0.2	0.4	0.4	0.4	0.3	207	312	0.60	0.49	57	104	0.8	0.7
CD (p=0.05)	ns	ns	ns	ns	1.3	1.3	ns	ns	620	905	2.00	1.45	170	405	2.5	2.2
b) Cultivars (C)																
VL-Amber	48	45	49	49	15.6	14.6	9.7	9.7	4552	3810	16.61	14.64	2900	2068	'52.2	36.9
Him-129	46	43	48	46	16.4	14.6	11.8	11.8	7808	7048	24.29	21.58	3994	3410	72.2	61.0
Vivek-11	46	44	49	47	15.6	14.6	11.6	11.6	7453	6532	23.64	20.53	3437	2925	62.2	53.6
Pragati	47	45	48	47	15.4	14.4	11.9	11.9	7232	6209	26.00	21.29	3044	2824	55.8	51.0
SEm ±	0.7	0.2	0.6	0.2	0.6	0.5	0.4	0.4	240	336	0.77	0.51	66	105	0.6	0.7
CD (p=0.05)	ns	0.7	ns	0.7	ns	ns	1.2	1.1	716	975	2.30	1.6	196	311	1.9	2.0
Interaction(N x C)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	s	s

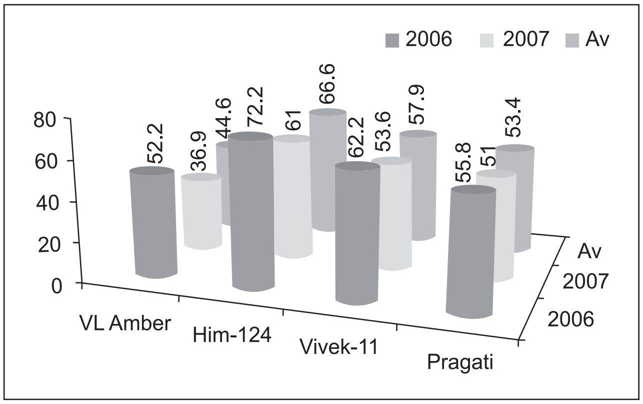


Figure 2. Effect of cultivars on nitrogen economy (kg/ha)

of inputs due to its genetic make up compared to composites. The interaction effect between N rates and cultivars found significant on N economy during both years.

CONCLUSION

The research findings revealed that maize hybrids 'Him-124' and 'Vivek-11' had higher nitrogen use efficiency, hence, these hybrids might be grown with application of 80 kg N/ha in addition to 60 kg P_20_5 and 40 kg K_20/ha for higher productivity and nitrogen economy under low nitrogen fertilization environments including Mollisols of Uttarakhand.

REFERENCES

Khanday B A and Thakur R C. 1990. Response of rain fed maize to fertilization. *Indian J. Agric. Res*. **60**: 631-633.

Kumar Ashok. 2008. Direct and residual effect of nutrient management in maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system. *Indian J Agron*. **53**: 37-41.

Pathak S K, Singh S B, Jha R N and Shrma R P. 2005. Effect of nutrient management on nutrient uptke and changes in soil fertility in maize (*Zea mays*)- wheat (*Triticum aestivum*) cropping system. *Indian J. Agron*. **50**: 269-273.

Singh R N, Sutaliya R, Ghatak R and Sarangi S K. 2003. Effect of higher application of nitrogen and phosphorus over recommended level on growth, yield and yield attributes of late sown winter maize (*Zea mays* L.). *Crop Res*. **26**: 71-74.

Sutaliya R and Singh R N. 2005. Effect of planting time, fertility level and phosphate-solubilizing bacteria on growth, yield and yield attributes of winter maize (Zea mays) under rice (Oryza sativa)- maize cropping system. *Indian J. Agron*. **50**: 173-175.

Swarup A. 2002. Lessons from long term fertilizer experiments in improving fertilizer use efficiency and crop yields. *Fertilizer News* **47**: 59-66 & 71-73**.**

Journal of Soil and Water Conservation **11**(4):334-338, October-December 2012
ISSN: 022-457X

Influence of value added fertilizer on production and productivity of wheat (*Triticumaestivum L.*) in Indo-gangetic plains of eastern Uttar Pradesh

A.K. JHA[1], K.K. SINGH [2] and MAYANK RAI[3]

Received: 18 March 2012; Accepted: 26 September 2012

ABSTRACT

Beneficial effect of value added fertilizers on production and productivity of rice is well established. There is a need to test the applicability of neem coated urea in irrigated wheat to obtain maximum yield in minimum input without impairing soil fertility. In view of above facts, field experiments were conducted at ten locations in Faizabad, Ambedkar Nagar, Sultanpur and Barabanki districts of eastern Uttar Pradesh during the year 2005-06 and2006-07 to evaluate the effect of neem coated urea on growth, yield and nutrient uptake of wheat and residual fertility of soil. Seed germination of wheat was not affected significantly by the levels and doses of nitrogenous fertilizers. However, plant population after 90 days of sowing increased by 1.04-4.43% due to substitution of prilled urea (PU) by neem coated urea (NCU). NCU was found to be superior over PU in augmenting height of the plants at different stages of plant growth. Grain and straw yields of wheat also increased by 6.47% and 7.56% respectively when PU was substituted by NCU. Grain yield obtained with NCU_{80}(4.18 t ha^{-1})was at par with that recorded with PU_{100}(4.19 t ha^{-1}). Total uptake of nitrogen (81.0 Kg ha^{-1}), phosphorus (16.47 Kg ha^{-1}) and potassium (66.2 Kg ha^{-1}) by wheat crop withNCU_{80} was at par with those recorded with PU_{100} at harvesting stage of the crop. Available nitrogen and phosphorus content in experimental soil increased by 3.7% and 2.8% respectively whereas available potassium content decreased by 0.17%when crop was treated with NCU_{80}.

Key words: wheat, neem coated urea, prilled urea, growth and yield attributes of wheat, nutrient uptake by wheat, change in soil fertility

INTRODUCTION

Nitrogenous fertilizers have the kingpins of green revolution which transformed the Indian agriculture from subsistence to surplus. But, there is a negative balance between consumption and production of nitrogenous fertilizers in India. The poor nitrogen use efficiency (30-40% only) due to higher loss of nitrogen through runoff, leaching, denitrification and ammonia volatilization is an important factor answerable for this negative balance (Masthanareddy, 2009). Huge nitrogen requirement of major cereals of India is another vital cause of this negative balance. Both economic and ecological ground of chemical fertilizer application invites introduction of slow release nitrogenous fertilizers in Indian agriculture.

Production and productivity of wheat has shown declining trends in past few years and it is probably due to deterioration in soil health (Tomar, 2008). So, application of slow release nitrogenous fertilizers may be considered as a component to sustain crop yield by restoring soilfertility (Kabat and Panda, 2009). As this material releases the nitrogen slowly, so it becomes available to the crops for longerperiod and assures nutrient availability throughout the growing period. Fertilizer related soil, water and environmental pollution also emphasizes the use of value added fertilizers and organic sources of plant nutrients in agriculture(Tiwari, 2008). Thus, there is a need to test the applicability of slow release nitrogenous fertilizers in wheat crop under assured irrigated condition.

[1] & [2] Bihar Agricultural University, Sabour-813210, Bhagalpur, Bihar
[3] Krishi Vigyan Kendra, Murad Nagar-201206, Ghaziabad, Uttar Pradesh

In view of above facts, an effort was made to study the effect of levels and types of nitrogenous fertilizers on growth, yield and nutrient uptake of wheat. Effect of applied fertilizers on available N, P and K status of the experimental soil was also studied.

MATERIALS AND METHODS

To study the relative suitability of NCU and PU for wheat crop, experiment was conducted in normal and salt affected soilsof eastern Uttar Pradesh.Exact location of field along with characteristics of experimental soil has been depicted in table 1. The present investigation was carried out in randomized block design (RBD) with four treatments and ten replications. Area of each plot was 0.2 hectare. Treatment details are as under:

T_1: PU_{80}- 80% of recommended N through prilled urea

T_2: NCU_{80}- 80% of recommended N through neem coated urea

T_3: PU_{100}- 100% of recommended N through prilled urea

T_4: NCU_{100}- 100% of recommended N through neem coated urea

Wheat cv. PBW-343 was selected for field experiment at Auliapur, Gopalpur, Jaraikala and Kumarganjand cv. PBW-154 forRaghupur and Madhupurwhereas cv. PBW-373, UP-2425 and HD-2285 was grown atTahwapur, Haidergarh and Haliapur respectively. At most of the locations, sowing was done in between last week of November to first week of December but atKumarganj and Haidergarh crop was sown in second fortnight of December.

Half dose of nitrogen along with full doses of phosphorus and potassium was applied at the time of sowing. However, one fourth of recommended N along with 25 Kg $ZnSO_4ha^{-1}$ was applied after first irrigationand remainingone fourth of recommended N was top dressed after second irrigation at proper soil moisture.

To study the effect of value added fertilizer on seed germination and tillering, number of plants available in one meter length of sample row was counted at three different places (after 15 and 90 days of sowing) and averaged. Vertical length from ground surface to top of the randomly selected five plants from every experimental unit was measured after 30 and 60 days of sowing and averaged to determine the plant height. Spike length, number of spikelets per spike, number of grains per spikelet in five randomly selected plants were recorded and averaged. Weight of 1000 grains was also recorded to determine the test weight. Grain and straw yields were recorded on net plot basis and expressed in term of tonne per hectare.

Nitrogen content in grains and straw was determined by colorimetric method developed by Linder (1944) and these values were multiplied by grain and straw yields to find out N uptake. Phosphorous and potassium contents in plants were determined by colorimetric and flame photometric methods respectively(Tandon, 1993) and these contents were multiplied bygrain and straw yields of wheat to find out uptakes. Available nitrogen, phosphorus and potassium contents in experimental soil were determined as per AOAC (1970). Rest properties of experimental soil Viz. p^H, E.C., ESP and Organic Carbon were determined by the slandered methods discussed by Jackson (1973).

Table 1. Location of experiment and properties of experimental soils

Repl. No.	Location	p^H(1:2.5)	E.C. (dsm^{-1})	Organic Carbon(%)	ESP (%)	AvailableN (Kg ha^{-1})	Available P_2O_5 (Kg ha^{-1})	Available K_2O ($Kgha^{-1}$)
R_1	Auliapur, Ambedkar Nagar	7.03	0.34	0.489	12.8	167.2	29.2	287.2
R_2	Raghupur,Ambedkar Nagar	7.12	0.37	0.426	13.6	141.0	18.8	265.8
R_3	Gopalpur,Faizabad	9.76	0.43	0.315	18.4	117.8	19.6	280.4
R_4	Madhupur,Faizabad	9.45	0.40	0.222	17.1	113.6	16.4	190.0
R_5	Masodha,Faizabad	7.05	0.35	0.259	13.1	115.4	15.7	210.7
R_6	Kumarganj,Faizabad	9.08	0.48	0.462	21.6	165.3	20.8	285.2
R_7	Haliyapur,Sultanpur	9.63	0.49	0.482	18.2	152.0	17.3	272.6
R_8	Jaraikala,Sultanpur	9.41	0.38	0.444	15.8	150.6	16.8	255.6
R_9	Haidergarh,Barabanki	7.08	0.36	0.389	13.8	138.2	17.0	185.4
R_{10}	Tahwapur,Barabanki	7.16	0.32	0.296	14.6	122.4	15.2	192.6

RESULTS AND DISCUSSION

Neem coated urea had no significant effect on seed germination where astillering was enhanced by the application of value added fertilizer and consequently, plant population per running meter in NCU_{80} treated plot was significantly higher after 90 days of sowing(79.61) than that recorded in PU_{80} treated plot(76.23). Plant population recorded with NCU_{80} and PU_{100} were statistically at par. It was probably due to slow but continuous supply of nitrogen to the plants treated with NCU (Blaise and Prasad, 1996).Levels and type of nitrogenous fertilizer also affected height of the plants significantly (Table 2). NCU was found significantly superior over PU in increasing plant height. Plant heights recorded with NCU_{80}after 30 and 60 days of sowing (60.5 cm and 81.5 cm respectively) were significantly higher than those recorded with PU_{80} (56.5cm and 79.1cm respectively). Height of the plants recorded with PU_{100} after 30 and 60 days of sowing(60.9cm and 82.6cm respectively) was at par with those recorded with NCU_{80}.It was probably due to continuous supply of mineral N to the plants in NCU treated plots (Nayyar,2002).

Table 2. Effect of neemcoatedurea on population and height of wheat plants

Treatment	Plant population (m^{-1} row length)		Plant height (cm)	
	15 DAS	90DAS	60DAS	90DAS
PU_{80}	45.2	76.2	56.5	79.1
NCU_{80}	45.8	79.6	60.5	81.5
PU_{100}	45.7	80.9	60.9	82.6
NCU_{100}	45.7	81.8	61.4	82.8
SEm±	0.5	1.1	0.9	0.6
LSD (P=0.05)	NS	2.3	1.9	1.3

DAS= Days after sowing

Number of effective tillers, spike length, spikelets per spike, test weight, grain and straw yields of wheat were also affected greatly by the levels and type of nitrogen sources. Slow release nitrogenous fertilizer was found to be superior to PU in augmenting yield and yield attributes (Table 3). NCU_{80} resulted statistically equal number of effective tillers per meter, spike length(6.72cm), spikelets per spike(10.07), test weight(36.97 g), grain yield (4.18 t ha^{-1}) and straw yield (5.28 t ha^{-1}) of wheat compared to those obtained with PU_{100} (77.6, 6.77 cm, 10.08, 36.99 g, 4.19t ha^{-1} and 5.37 t ha^{-1} respectively). NCU_{80} was found significantly superior to PU_{80} in

Table 3. Effect of value added fertilizer on number of effective tillers, yieldattributing characters and yield of wheat

Treatment	No. of effective tillers (m^{-1} row length)	Spike length (cm)	No. of spikelets $spike^{-1}$	Test weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
PU_{80}	71.7	6.1	8.5	35.4	3.93	4.91
NCU_{80}	76.6	6.7	10.1	37.0	4.18	5.28
PU_{100}	77.6	6.8	10.1	37.0	4.19	5.37
NCU_{100}	78.9	6.9	10.6	37.5	4.29	5.45
SEm±	1.1	0.2	0.4	0.5	0.48	0.39
LSD (P=0.05)	2.3	0.4	0.9	1.0	0.98	0.80

augmenting yields and yield attributes. The highest values of yields and yield attributes were recorded with NCU_{100}, but, these values were at par with those obtained with NCU_{80}.These findings were in the close conformity with the results of Gandeza*et al.* (1991).

Nitrogen uptake by grain and straw of wheat increased by >12 % when PU_{80} was replaced by NCU_{80}(Table 4). Total uptake of nitrogen recorded with NCU_{80} (80.8 $Kgha^{-1}$) and PU_{100}(82.0 $Kgha^{-1}$) were found at par. This finding was in the close conformity with the results of Kabat and Panda (2009).Total uptake of phosphorus by PU_{100} treated crop (16.92 Kg ha^{-1}) was at par with phosphorus uptake by NCU_{80}treated wheat (16.47 Kg ha^{-1}) and 9.6% lesser than that by NCU_{100}treated crop. It was probably due to synergistic effect ofN availability on production of wheat and availability of phosphorus in soil.This finding is similar to the result obtained by Ramamoorthy and Velayutham (1976). In contrast of nitrogen, phosphorusand potassiumconcentration in grain & strawof wheat did not varysignificantly due to thevariation in levels and type of nitrogenous fertilizer.However,uptake of potassium increased significantly due to higher yield of wheatin case of NCU treatment.

Available nitrogen and phosphorus status of experimental soil improvedat cropharvest due to the application of higher doses of chemicalNand substitution of PU by NCU(Table 5). However, available potassium in experimental soil remained unaffected even after the application of value added fertilizer. N status of experimental soilincreased by 3.69 % due to application ofNCU_{100}, however, NCU_{80} could only sustain N status of experimental soil. Similar kind of result was obtained by Blaise and Prasad (1996)when working with polymer coated

Table 4. Influence of value added fertilizer on nitrogen, phosphorus and potassium uptake by wheat at maturity stage

Treatment	Nutrient content in grain (%)			Nutrient content in straw (%)			Nitrogen uptake (Kg ha^{-1})			Phosphorus uptake (Kg ha-1)			Potassium uptake (Kg ha-1)		
	N	P	K	N	P	K	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
PU_{80}	1.48	0.29	0.54	0.293	0.02	0.68	57.6	14.4	72.0	11.41	0.98	12.38	21.1	33.4	54.6
NCU_{80}	1.55	0.33	0.58	0.306	0.05	0.75	64.7	16.3	81.0	13.83	2.64	16.47	24.3	41.8	66.2
PU_{100}	1.57	0.34	0.60	0.307	0.05	0.79	65.6	16.6	82.2	14.22	2.69	16.92	25.2	42.6	68.0
NCU_{100}	1.68	0.36	0.65	0.328	0.06	0.83	71.7	18.1	89.8	15.31	3.25	18.55	27.9	45.2	73.2
SEm±	0.03	0.02	0.06	0.005	0.01	0.06	3.239	0.809	4.97	0.731	0.239	0.941	1.513	1.610	3.121
LSD (P=0.05)	0.07	0.04	NS	0.011	0.02	NS	6.64	1.66	8.40	1.51	0.49	1.93	3.1	3.3	6.4

Table 5. Effect of levels and type of nitrogenous fertilizer on availability of nitrogen, phosphorus and potassium in experimental soil

Treatment	Available nitrogen (Kg ha^{-1})	Available phosphorus (Kg ha^{-1})	Available potassium (Kg ha^{-1})
PU_{80}	131.48	19.3	242.8
NCU_{80}	139.05	18.5	242.2
PU_{100}	139.84	18.2	242.4
NCU_{100}	143.54	18.4	242.6
Initial value	138.35	17.9	242.6
SEm±	0.93	0.09	0.13
LSD(P=0.05)	1.91	0.23	0.28

urea. NCU_{80} increased available phosphorus content of experimental soil by 5.59%. NCU_{80}, $NCU_{100}$and PU_{100} were found equally effective to Increase available P content of experimental soil. It was probably due to synergistic effect of available N on availability of phosphorusin soil Ramamoorthy and Velayutham, (1976). Availability of potassium in experimental soil remained unaffected even after harvesting of the crop. It was probably due to lack of direct relationship between availabilities of nitrogen and potassium. This result was in close conformity with the findings of Dargan (1979).

CONCLUSION

It is concluded that, 20% of chemical Ncan be saved during wheat cultivation if prilled urea is substituted byneem coated urea. Both, vegetative and reproductive growth of wheat treated with NCU_{80} was at par with that obtained with PU_{100}. $NCU_{80}$was found slightly inferior to PU_{100}but, superior to $NCU_{80}$to increase nitrogen, phosphorus and potassium uptake by the crop at maturity stage.Uptake of nitrogen by wheat crop at maturity stage increased by >12 % when PU_{80} was substituted by NCU_{80}. NCU_{80} was found superior over all other treatments to improve available nitrogen and phosphorus status of experimental soil. Available N and P_2O_5statusof experimental soil improved by 3.7% and 2.8% respectivelywithin two years due to replacement of $PU_{80}$by NCU_{80}. $PU_{100}$and NCU_{80}were found to be equally effective to improve nutritional status of experimental soil.

REFERENCES

AOAC 1970. *Official Methods of Analysis*, Association of Official Analytical Chemists. 11th Edition, AOAC P.B. No. 540, Washington D.C., pp. 19-20.

Blaise, D. and Prasad, R. 1996. Mineralization pattern of different urea sources under flooded soil condition. *Fertilizer News* **41(11)**: 67-69.

Dargan, K.S. 1979. Agronomic and cultural practices for crop productionin salt affected soils. *Curr. Agric.*, **3(1-2)**:1-20.

Gandeza, A.T., Shoji, S. and Yamuda, I. 1991. Simulation of crop response to polyolfin coated urea, 1.Field dissolution. *Soil Science Society of American Journal* **55**: 1462-1467.

Jackson, M.L. 1973. *Soil Chemical Analysis*, Prentice Hall India Pvt. Ltd., New Delhi, India.

Kabat, B. and Panda, D. 2009. Nitrogen release characteristics of controlled release N fertilizer and their effect on yield and N nutrition of rice in alluvial and laterite soils. *Journal of the Indian Society of Soil Science* **57(2)**:154-160.

Linder, R.C. 1944. Rapid analytical methods for some of the more common inorganic constituents of plant tissues. *Plant Physiology* **19**:76-89.

Masthanareddy, B.G., Manjunath, H., Patil, V.C. and Patil, S.G. 2009. Response of transplanted rice to levels, splits and timing of NPK application. *Journal of the Indian Society of Soil Science* **57(2)**:183-190.

Nayyar,V.K. 2002. Soil fertility management. In Fundamentals of Soil Science, *Indian Society of Soil Science publ.* pp 489-498.

Ramamoorthy, B. and Velayutham, M 1976. Nitrogen, Phosphorus and potassium in soil-Chemistry, forms and availability. *Soil fertility- theory and practice* (Ed. J.S. Kanwar): 156-201.

Tandan, H. L. S. 1993. *Methods of Analysis of Soils, Plants, Water and Fertilizers*. Fertilizer Development and Consultation Organization, 204-204 A, Bhanot Corner, 1-2 PamposhEnclave, New Delhi.

Tiwari, K.N. 2008. Future plant nutrition research in India, *Journal of the Indian Society of Soil Science* **56(4)**: 327-336.

Tomar, S.S. 2008. Conservation agriculture for rice- wheat cropping system. *Journal of the Indian Society of Soil Science* **56(4)**:358-366.

Journal of Soil and Water Conservation **11**(4): 339-345, October-December 2012
ISSN: 022-457X

Reservoirs – Sink or sources of greenhouse gases?

SOMEN ACHARYA[1*], TARUN ADAK[2] and R.B. SRIVASTAVA[3]

Received: 1 May 2012; Accepted: 26 October 2012

ABSTRACT

Reservoir surfaces were widely viewed as a carbon-free source of energy during past few centuries because of non availability of data on CO_2 and CH_4 emissions from reservoirs. However, recent development and research studies indicated that greenhouse gas production per unit of power generated is not zero and should depend on the amount of organic carbon flooded to create the electricity. Henceforth, global effect of all types of reservoirs surfaces (both tropical and temperate reservoirs) on the atmosphere needs to be evaluated and these fluxes should be included in greenhouse gas inventories by each country and in models of global carbon cycling. A first estimate indicated that for a global large dams area of $1.5x10^6$ km^2, about $10x10^{14}$ g/yr of CO_2 and 69.3 Tg CH_4 (1 Tg=10^{12}g) can be annually released by bubbling and diffusive processes. Based on a theoretical model, bootstrap resampling and data provided by the International Commission on Large Dams (ICOLD), it was estimated that global large dams might annually release about 104±7.2 Tg CH_4 to the atmosphere through reservoir surfaces, turbines and spillways. In view of novel technologies to extract CH_4 from large dams, it was further estimated that roughly 23±2.6, 2.6±0.2 and 32±5.1Tg CH_4 could be used as an environmentally sound option for power generation in Brazil, China and India, respectively. For the whole world this number may increase to around 100±6.9 Tg CH_4. Although there are uncertainties in both flux measurement and surface area information, however based on initial available data globally, these emissions may be equivalent to 7% of the global warming potential of other documented anthropogenic emissions of these gases. Therefore, a thorough rethink is essentially required for a newly established reservoirs and the process of reservoir development for the mitigation options available. Innovative engineering technologies are essentially needed to avoid these emissions, and to recover the non-emitted CH_4 for power generation.

Key words: Reservoirs, global emission estimates, Indian scenario, techniques of flux measurements, emission process and dominant factors

INTRODUCTION

Global climate is changing and is believe to be changing slowly yet progressively than our imagination. Although, the green house effect makes the Earth suitable for living, release of excessive amount of greenhouse gases (GHGs) into the atmosphere due to anthropogenic activities cause global warming. According to an estimate (Sharma et al., 2006), total amount of GHGs emitted in India, was 1228 million tonnes, which accounted for only 3% of the total global emissions, and of which 63% was emitted as CO_2, 33% CH_4, and the rest 4% as N_2O. Moreover, the projected trends of GHGs emissions in India in 2020 will be below 5% of global emissions and the per capita emissions will still be low compared to most of the developed countries as well as the global average. However, the problem lies in Indian estimate is that emissions from reservoirs and large dams are not included as these sources were thought to be emission free resources.

The general impacts of climate change on water resources indicate an intensification of the global hydrological cycle affecting both ground and surface water supply (Gosain et al., 2006). Significant changes in total amount, frequency, intensity and distribution of precipitation have also been

[1] Address: Scientist, Defence Institute of High Altitude Research (DIHAR), DRDO, C/o 56 APO, Leh Ladakh-901205.
[2] Address: Scientist, Division of Crop Production, CISH, Rehmankhera, Lucknow; email: tarunadak@gmail.com).
[3]Address: Director, Defence Institute of High Altitude Research (DIHAR), DRDO, C/o 56 APO, Leh Ladakh-901205.
*Corresponding author: someniari@gmail.com

predicted. Such spatio-temporal changes may create drought-like situations and will have drastic impact on ground water recharge, reservoir storage capacity and thereby emissions of gases.

Reservoirs or dams are generally man-made bodies of open water serving as public water supply sources, as winter storage for crop irrigation or as flood storage facilities in association with river corridors. Upland reservoirs are commonly known as impounding reservoirs since they are built across river valleys. A common form of lowland reservoir is known as a pumped storage reservoir since water is pumped from a nearby river source rather than filling naturally as in the case of an impounding reservoir. Water supply reservoirs have developed into important nature conservation assets.

Reservoirs are believed to be the sources of greenhouse gases to the atmosphere and their surface areas have increased to the point where they should be included in global inventories of anthropogenic emissions of GHGs (Keller and Stallard, 1994; Fearnside, 1997; Duchemin et al., 1999). Recent research indicates that reservoirs and hydroelectric dams (Table 1) may be significant sources of GHGs

Table 1. Global warming impact of various electricity options

Power plant type	Emissions (g CO2-eq/kwh)
Hydro (tropical)	200 – 3000*
Hydro (temperate/boreal)	10 – 200*
Coal (modern plant)	790 - 1200
Heavy oil	690 - 730
Diesel	555 - 880
Combined cycle natural gas	460 - 760
Natural gas cogeneration	300

*Represents gross emissions and does not include emissions produced when water is released from the reservoir
Source: International River Network (IRN)

since these gases are emitted from both natural aquatic (lakes, rivers, estuaries, wetlands) and terrestrial ecosystems (forest, soils) as well as from anthropogenic sources (Cole et al., 1994; Lima, 2005). Hydropower is generally considered “clean” in comparison with fossil fuel combustion which since well ago is acknowledged an important source of GHGs (IRN, 2002). However, dams are know to produce large environmental and social problems, particularly the larger ones (Rashad and Ismail, 2000). Dams may emit considerable amounts of GHG as CO_2 and CH_4 (Fearnside, 2004; Bambace et al., 2007).

The first studies of greenhouse gas fluxes from reservoirs focused on hydroelectric generation (Kelly et al., 1994; Duchemin et al., 1995) because it was, and still is, widely viewed as a carbon-free source of energy (Hoffert et al., 1998). This view likely originated because before 1994, there were no data available on CO_2 and CH_4 emissions from reservoirs, even though it was well known that oxygen depletion resulting from active decomposition of flooded organic matter was common in waters of newly constructed reservoirs (Baxter and Glaude, 1980). The first discussion of greenhouse gas emissions from reservoirs pointed out that greenhouse gas production per unit of power generated (e.g., in kWh) is not zero and should depend on the amount of organic carbon flooded to create the electricity.

Estimation of global flux of GHGs from reservoirs

Estimation of the global surface area of reservoirs and average flux of GHGs is itself a very difficult task due to incomplete databases of the International Commission on Large Dams (ICOLD, 1998). Non registering of dams and reservoirs by different countries is attributed to the possibility of fair estimation of surface area. However, considering both the incomplete listing of large dams in many countries and the overall lack of data on small reservoirs, the global surface area of all reservoirs today is estimated to be approximately 1.5 million km^2, or approximately three times the documented area behind large dams and this area is equivalent to the estimated global surface area of natural lakes (Shiklomanov, 1993). Thus, combining the average areal fluxes with the estimated surface area of reservoirs in temperate and tropical regions yields annual global fluxes of 10×10^{14} g/yr of CO_2 and 0.7×10^{14} g/yr of CH_4 (Abril et al., 2005; Soumis et al., 2005). It was estimated that a total of approximately 70% and 90% of global reservoir fluxes of CO_2 and CH_4, respectively, occurred from tropical reservoirs even though these reservoirs were only accounted for approximately 40% of the global surface area. On a global basis, the CO_2 flux from reservoirs was only equivalent to 4% of other anthropogenic emissions of CO_2, but the CH_4 flux was equal to approximately 20% of other anthropogenic CH_4 emissions. These large estimated CH_4 fluxes from reservoirs exceed estimated fluxes from rice paddies or biomass burning worldwide. When CO_2 and CH_4 fluxes are combined and converted to a flux of total carbon to the atmosphere, the fluxes from reservoir surfaces are equal to 0.3 Gt / yr of carbon, or 4% of other documented anthropogenic fluxes of carbon as CO_2 and CH_4. Average emission fluxes of GHGs from different ecosystems are tabulated in the table 2 and 3 to indicate the mean emission rate, net emission and net consumption by the ecosystem (Aselmann and Crutzen, 1989; Kelly et al., 1997).

Table 2. Average emissions of CH_4 from natural areas (Kelly et al., 1997)

Category	Emission mean rate (mg CH_4-C / m^2 / day)	Period of production (days)
Wetlands with decomposing vegetation	11 (11-38)*	178
Marsh	60 (21-162)	169
Swamp	63 (43-84)	274
Bog	189 (103-299)	249
Floodplains	75(37-150)	122
Lakes	32(13-67)	365

* the numbers in brackets are the range

Table 3. Average fluxes of CO_2 and CH_4 from the surfaces of different ecosystems

Ecosystem	Areal flux (mg / m^2 / d)	
	CO_2	CH_4
Temperate reservoirs	1500↑	20↑
Tropical reservoirs	3000↑	100↑
Boreal / temperate forests	2100↓	1.0↓
Tropical forests	710↓	0.2↓
Northern peatlands	230↓	51↑
Lakes (worldwide)	700↑	9↑

[a]Downward arrows indicate net consumption by ecosystem. Upward arrows indicate net flux to the atmosphere. [b]Averaged over 365 days assuming 1.5 million km^2 of lake surface area globally.

(Kelly *et al*, 1997)

Indian scenario

Indian reservoirs represent the whole spectrum of different reservoir types found in the world. Some are located in alpine environments and shares the same features that are typical of northern temperate reservoirs, i.e., can be assumed to release insignificant amounts of greenhouse gases. On the other extreme one finds reservoirs in arid environments, where sequestration probably dominates over release of carbon. Between these extremes are reservoirs located in wet, humid or dry tropical environments**.**

The major dams and water reservoirs in India include:

- Nagarjuna Sagar Dam, Andhra Pradesh
- Sardar Sarover Project build on river Narmada, Gujarat
- Bhakra Nangal Dam build on river Sutlej, Himachal Pradesh
- Maharana Pratap Sagar Dam, Himachal Pradesh
- Krishna Raja Sagara Dam on Cauvery River, Karnataka
- Tunga Bhadra Dam
- Neyyar Dam, Kerala
- Narmada Dam Project, Madhya Project
- Hirakund Dam Build on Mahanadi River, Orissa
- Farakka Barrage

Ocular inspections of satellite photos (Google Earth) in combination with information on prevalent climatic conditions indicate that reservoirs in Uttarakhand, Tamil Nadu, Sikkim, Rajasthan, Punjab, Karnataka, Jammu / Kashmir, Himachal Pradesh, Gujarat, and Arunachal Pradesh represent categories of surface waters where net emissions of greenhouse gases, to judge from experiences from other parts of the world, are generally low, and probably comparable to those from natural lakes. These reservoirs represent about 40 percent of the total storage capacity occupied by reservoirs in the country.

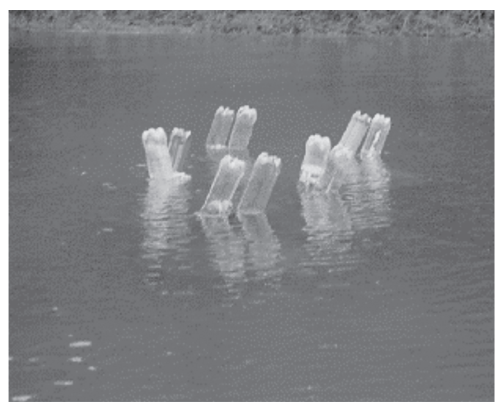
On the other hand, latest scientific estimates show that large dams and reservoirs in India are responsible for about a fifth of the countries' total global warming impact (Lima et al., 2008). Study conducted by National Institute for Space Research, Brazil estimates that total methane emissions from India's large dams could be 33.5 million tonnes (MT) per annum, including emissions from reservoirs (1.1 MT), spillways (13.2 MT) and turbines of hydropower dams (19.2 MT). Total generation of methane from India's reservoirs could be 45.8 MT. The difference between the figures of methane generation and emission is due to the oxidation of methane as it rises from the bottom of a reservoir to its surface. The methane emission from India's dams is estimated at 27.86 % of the methane emission from all the large dams of the world, which is more than the share of any other country of the world. Brazil comes second with the emission of methane from Brazil's reservoirs being 21.8 MT per annum, which is 18.13% of the global figure. Looking at the available figures for dams in India, total emission of methane from Indian dams may be somewhat over estimated, but it is still likely to be around 17 MT per annum. Even this more conservative figure means that India's dams emit about 425 CO_2 equivalent MT (considering that global warming potential over 100 years of a T of methane is equivalent to GWP of 25 T of CO_2, as per the latest estimates of IPCC). This, when compared to India's official emission of 1849 CO_2 MT in year 2000 (which does not include emission from large dams), the contribution of methane emission from large dams is 18.7% of the total CO_2 emission from India. Based on a theoretical model, bootstrap resampling and data provided by the International Commission on Large Dams, it was estimated that global large dams might annually release about 104 ± 7.2 Tg CH_4 to the atmosphere through reservoir surfaces, turbines and spillways. In view of novel technologies to extract CH_4 from large dams (Table 4), it was further estimated that roughly 23 ± 2.6, 2.6 ± 0.2 and 32 ± 5.1 Tg CH_4 could be used as an environmentally sound option for power generation in Brazil, China and India, respectively (Lima et al., 2008). For the whole world this number may increase to around 100 ± 6.9 Tg CH_4. Researchers are in opinion that Indian dams are the largest global warming contributors compared to all other nations. The problem lies in Indian estimate is that emissions from reservoirs and large dams are not included even in the IPCC estimation as these sources were thought to be emission free sources. Henceforth, there is an urgent need to set up a coordinated research programme and its implementation owing to have an idea of GHGs emission from our own reservoirs so that any discrepancies / claims by other sources are sorted out effectively and in an efficient scientific manner.

Techniques for Measuring Emissions from Reservoirs

Fluxes of greenhouse gases from water surfaces can be quantified using a number of techniques:

1. Gas Sampling Method for Bubbles Using Funnels

Funnel Bubble Collector Coupled to a Gas Collecting Bottle



Group of Collecting Funnels Placed in a Shallow Region

Table 4. Estimation of CH_4 production (emission + oxidation) and potential recovery from large dams in the world, Brazil, China and India

Country	Upstream Tg CH_4	Downstream Tg CH_4	Total Production Tg CH_4	Potential Recovery Tg CH_4
Brazil	8.28 ± 0.72	25.12 ± 3.027	33.41 ± 3.752	23.38 ± 2.626
China	0.45 ± 0.06	3.248 ± 0.235	3.703 ± 0.300	2.592 ± 0.210
India	5.33 ± 1.91	40.49 ± 5.402	45.82 ± 7.312	32.07 ± 5.118
World	17.4 ± 1.15	125.9 ± 8.730	143.4 ± 9.880	100.4 ± 6.916

Tg- Terra gram (10^{12} gram)

2. Sampling of Gases by Diffusion Chambers

A static floating chamber measuring the rate of buildup of CO_2 and CH_4 gases over time inside the chamber

Floating static chambers have been used to estimate the diffusive flux of CO_2 and CH_4 from the surface of reservoirs by calculating the linear rate of gas accumulation in the chambers over time. Diffusive flux of CO_2 and CH_4 from reservoir surfaces has also been estimated using the thin boundary layer method.

Gas emission process in tropical reservoirs

The pattern of gas emissions from a hydroelectric reservoir is totally different from a fossil-fuelled power plant. While CO_2 emissions from the combustion of fossil fuels in a thermal power plant are released uniformly over the entire period of operation of the plant, important part of the production of both CH_4 and CO_2 from the bacterial decomposition of organic matter in a hydroelectric reservoir can be concentrated in time and can decay over a period much shorter than the lifespan of the reservoir. There will also be CH_4 and CO_2 long-term emissions due to the (Delmas et al., 2004)

1. decomposition of residual stored biomass remaining in the reservoir after an initial intense degradation,
2. new biomass produced over time inside the reservoir
3. alocthonous organic matter from the watershed.

The bottom of the reservoir contains flooded biomass that after decomposition emitted principally CO_2, CH_4 and N_2 resulting from anaerobic decomposition. In aerobic decomposition only CO_2 and N_2 are emitted. Along with the gases emitted, during decomposition biologically inert residues are formed (humus, humic and fulvic acids) can be leached out and carried by the water. These inert compounds (phenol polymers) originate principally from lignin, present in woody material. Thus part of the carbon is emitted as gas, and another part is carried by the water as humic and fulvic acids. There is also the insoluble and inert phenol residue, the humus, that can be incorporated into the bottom of the reservoir as sediment, and which, together with the silica and clay sediments, can proceed to fossilization.

At the bottom of the reservoir, there are the flooded terrestrial biomass, the organic matter that coming from the watershed and some fresh sediment formed by plankton detritus. The decomposition of sediment, carried out principally by bacteria, demands oxygen at higher rates than diffusion can supply, and an anaerobic regime is established. In the first stage of decomposition, organic acids released, which are then decomposed leading to the formation of CH_4 and CO_2, as can be exemplified with acetic acid subject to methanogenesis.

$$CH_3 - COOH = CH_4 + CO_2$$

The gas emitted from the decomposition of flooded biomass constitutes only a fraction of the total of gas emitted by the reservoir, because there is another source of gas emissions: the zooplankton and phytoplankton contained in the water of the reservoir. Phytoplankton, consisting principally of algae, carries out photosynthesis using carbon dioxide dissolved in the water. The phytoplankton biomass grows at a typical rate of 80 mg of carbon per m^2 per day, a value confirmed in the large Amazon reservoirs.

The decomposition of the flooded biomass progressively reduces the stock of carbon, and because of the resulting biological inertia, its proportion of the emissions of gases diminishes over time. The gas emitted as a result of plankton has an essentially constant rate over time because its source is constantly renewing.

Factors affecting emissions from existing reservoirs

The range of average fluxes from reservoirs around the world is expected because fluxes of CO_2 and CH_4 depend on a number of factors (Bastviken et al., 2004), including the amount of organic carbon flooded, age of the reservoir, mean annual temperature etc.

1. Organic carbon: The flux per unit area of GHGs from reservoir surfaces should be proportional to the amount of decomposable organic carbon that is flooded to create the reservoir. The largest

amounts of organic carbon per unit area are found in peatlands. CH_4 fluxes in temperate regions were highest in reservoirs that flooded at least 80% peatlands.

2. Age: The age of reservoirs also affect GHGs fluxes because newly flooded labile carbon, such as that found in leaves and litter, should decompose rapidly, followed by slow decomposition of older, more recalcitrant organic carbon such as soil carbon and peat (Kelly et al., 1997).
3. Water temperature: Higher rates of decomposition in tropical reservoirs because of annual water temperatures are much higher as compared to temperate environments.
4. Water residence time
5. Size and nature of watershed
6. Climate and hydrological fluctuations
7. Primary production
8. Operating regime of dam
9. Depth of the reservoir
10. Size and shape of reservoir (bathymetry)
11. Anthropogenic activities around the reservoir and in the catchments

Alternative energy generation options

Alternative future energy sources for electricity generation have become an increasingly popular subject as more emission of GHGs into the atmosphere due to anthropogenic causes. Many sources of alternative energy have been proposed due to global concern for cleaner electricity production. The most important of these are solar, wind, geothermal and nuclear energy. According to recent projections, alternative energy will become increasingly more important over the next 50 to 100 years. For developing countries, nuclear energy promise to produce the most electricity with practically no CO_2 emissions. For rural parts of developing and undeveloped countries wind, solar, wave and tidal channel power are the most viable alternatives to fossil fuels for electricity production. These simple technologies can be implemented cheaply and quickly without the investment and planning required for nuclear and hydroelectric.

CONCLUSION

Reservoirs were widely viewed as a carbon-free source of energy since most reservoirs are developed not for hydroelectric production but rather for flood control, water supply, irrigation, navigation, recreation and aquaculture purposes. However, a recent concern is whether reservoirs emits significant amount of GHGs and contributing to global climate change; is of practical significance. The slow yet steady accumulation of scientific data on GHGs emissions indicates that reservoirs can emit GHGs due to the anaerobic decomposition of biomass and CO_2. Tropical reservoirs that are shallow and unclear of biomass appear most at risk. The uncertainty lies in the estimates; the main scientific controversy centres on the extrapolation of measured emissions per m^2 in selected parts of the reservoir to the whole reservoir area. Emissions almost certainly vary according to depth and the distribution of the submerged biomass. They also vary through time, with a rapid peak occurring shortly after submersion after which they tail off at an unknown rate. Studies have not yet been carried out over long periods to characterize the full life-cycle curve of the emissions. Thus, this has to be assessed on a case by case basis. Although, the science base is not yet able to give accurate guidance to planners on whether a new reservoir will or will not emit GHGs. More research is needed in order to be able to do this, and this should focus on the following areas: i) spatio-temporal variability of CO_2, CH_4 and N_2O fluxes in reservoirs, ii) correlation of trace gas emissions with the major environmental variables (water levels, temperature, air pressure, nutrients) and the key biogeochemical process (primary production, denitrification, methane generation and oxidation), iii) application of remotely sensed data and new techniques to evaluate trace gas fluxes and biogenic chemical process from reservoir and lake ecosystems and finally iv) to build a GHG emission network including reservoirs and lakes in different agro-climatic zones involving study on carbon budgeting in reservoirs.

REFERENCE

Abril G, Gue´rin F, Richard S, Delmas R, Galy-Lacaux C and Gosse P. 2005. Carbon dioxide and methane emissions and the carbon budget of a 10 year old tropical reservoir (Petit Saut, French Guiana). *Global Biogeochem Cycles* **19:** 1-16.

Aselmann I and Crutzen P. 1989. Global Distribution of Natural Freshwater Wetlands and Rice Paddies, Their Primary Productivity, Seasonality and Possible Methane Emissions. *Journal of Atmospheric Chemistry* **8:** 307-358.

Bambace L A W, Ramos F M, Lima I B T and Rosa R R. 2007. Mitigation and recovery of methane emissions from tropical hydroelectric dams. *Energy* **32:** 1038-1046.

Bastviken D, Cole J, Pace M and Tranvik L. 2004. Methane emissions from lakes: Dependence of lake characteristics, two regional assessments, and a global estimate, *Global Biogeochemical Cycles* **18:** 1-12.

Baxter R M and Glaude P. 1980. Environmental effects of dams and impoundments in Canada: Experience and prospects. *Canadian Bulletin of Fisheries and Aquatic Sciences* **205:** 1-34.

Cole J J, Caraco N F, Kling G W and Kratz T K. 1994. Carbon dioxide supersaturation in the surface water of lakes. *Science* **265:** 1568-1570.

Delmas R, Richard R, Guérin F, Abril G, Galy-Lacaux C, Delon C and Grégoire A. 2004. Long term greenhouse gas emissions from the hydroelectric reservoir of Petit Saut (French Guiana) and potential impacts. In: Greenhouse Gas Emissions: Fluxes and Processes. Hydroelectric Reservoirs and Natural Environments. A. Tremblay, L. Varfalvy, C. Roehm and M. Garneau (Eds) Environmental Science Series, Springer-Verlag, Berlin, Heidelberg, New York. pp 293-312.

Duchemin E, Lucotte M and Canuel R. 1999. Comparison of static chamber and thin boundary layer equation methods for measuring greenhouse gas emissions from large water bodies. *Environmental Science and Technology* **33:** 350-357.

Duchemin E, Lucotte M, Canuel R and Chamberland A. 1995. Production of the greenhouse gases CH4 and CO2 by hydroelectric reservoirs of the boreal region. *Global Biogeochemical Cycles* **9:** 529-540.

Fearnside P M. 2004. Greenhouse gas emissions from hydroelectric dams: controversies provide a springboard for rethinking a supposedly 'clean' energy source. *Climatic Change* **66:** 1-8.

Fearnside P M. 1997. Greenhouse-gas emissions from Amazonian hydroelectric reservoirs: The example of Brazil's Tucuruí Dam as compared to fossil fuel alternatives. *Environmental Conservation* **24:** 64-75.

Gosain A K, Rao S and Basuray D. 2006. Climate change impact assessment on hydrology of Indian river basins. *Current Science* **90:** 346-353.

Hoffert M I et al. 1998. Energy implications of future stabilization of atmospheric CO2 content. *Nature* **395:** 881-884.

ICOLD. 1998. International Commission on Large Dams. World Register of Dams, Paris: International Committee on Large Dams.

IRN. 2002. Flooding the land, Warming the Earth. Greenhouse gas emissions from dams. International River Network (IRN).

Keller M and Stallard R F. 1994. Methane emission by bubbling from Gatun Lake. *Panama. J Geophys Res* **99:** 8307-8319.

Kelly C A, Rudd J W M, St. Louis V L and Moore T. 1994. Turning attention to reservoir surfaces, a neglected area in greenhouse studies. *EOS* **75:** 332-333.

Kelly C A, Rudd J W M, Bodaly R A, Roulet N P, St. Louis V L, Heyes A, Moore T R, Schiff S, Aravena R, Scott K J, Dyck B, Harris R, Warner B and Edwards G. 1997. Increases in fluxes of greenhouse gases and methyl mercury following flooding of an experimental reservoir. *Environmental Science and Technology* **31:** 1334-1344.

Lima I B T. 2005. Biogeochemical distinction of methane releases from two Amazon hydroreservoirs. *Chemosphere* **59:** 1697-702.

Lima I B T, Ramos F M, Bambace LW A and Rosa R R. 2008. Methane Emissions from Large Dams as Renewable Energy Resources: A Developing Nation Perspective. *Mitig Adapt Strat Glob Change* **13:** 193-206.

Rashad S M and Ismail M A. 2000. Environmental impact assessment of hydro-power in Egypt. *Applied Energy* **65:** 285-302.

Sharma S, Bhattacharya S and Garg A. 2006. Greenhouse gas emissions from India: A perspective. *Current Science* **90:** 326-333.

Shiklomanov I A. 1993. World fresh water resources. Pages 13-24 in Gleick PH, ed.Water in Crisis: A Guide to the World's Fresh Water Resources. Oxford University Press.

Soumis N, Lucotte M and Canuel R. 2005. Hydroelectric reservoirs as anthropogenic sources of greenhouse gases. In: Lehr JH, Keeley J (eds) Water encyclopedia: Surface and agricultural water. Wiley-Interscience, Hoboken, N. J. pp 203-210.

Journal of Soil and Water Conservation **11**(4): 346-355, October-December 2012
ISSN: 022-457X

Addressing social and gender issues –A key to exploit full potential of watershed development programmes in rehabilitating Shivalik ecosystem-Northern India

SWARN LATA ARYA[1] AND R. P. YADAV[2]

Received: 19 September 2012; Accepted: 31 October 2012

ABSTRACT

A field experiment was conducted during the rainy (*kharif*) season of 2010 at the research farm of the IARI, New Delhi to study the influence of methods of rice transplanting and varieties on crop growth, methane emission pattern in soil and to determine the correlation between different genotypic and phenotypic characters and yield. The experiment was laid out in factorial randomized block design (FRBD) with nine treatments combinations comprising three methods of crop establishment viz., conventional transplanting (CT); system of rice intensification (SRI) and double transplanting (DT) and three rice varieties viz., 'Pusa Basmati 1401'; 'Pusa 44' and 'PRH 10'. In CT, SRI and DT seedlings of 21, 12 and 41 days, respectively were transplanted in puddled fields. Results showed that water management through alternate wetting and drying (AWD) in SRI led to one week early maturity compared to CT in all the three cultivars. Rice hybrid 'PRH 10' in SRI gave the highest grain yield (5.36 t/ha) and per day productivity (46.2 kg/day/ha). Rice grain yield had significant positive correlations with root volume (r = 0.816), effective tillers (r = 0.917), dry weight (r = 0.432) and filled grain (0.412). Crop growth rate (CGR) at 60-90 DAT was higher in 'Pusa Basmati 1401'compared to other varieties. Significant temporal variations in the individual methane ûuxes were observed during rice growing period. Flux of methane was higher in early stage of crop and peaked about 21 days after transplanting coinciding with tillering stage of crop. Methane flux was drastically increased when observation was taken after N fertilizer (urea) application. However, methane flux declined gradually from 75 days after transplanting and stabilized at the harvest stage of rice in all the 3 methods of transplanting.

Key words: correlation, methane emission pattern, per day productivity, phenology, rice yield, SRI

INTRODUCTION

In fact, the concept of integrated and participatory watershed development has emerged as the corner stone of rural development in entire dry and rainfed region of the country. The country has so far, made massive investment on the watershed management programmes through own and external resources. Drought Prone Area Programme (DPAP), Desert Development Programme (DDP), National Watershed Development Programme for Rainfed Areas (NWDPRA), Integrated Watershed (IWDP) and Wasteland (IWDP) Development Programme are the few implemented over large areas (Sharda et al. 2006). Till March 2005, 45.48 m ha has been treated under various watershed programmes with a total investment of about Rs.170 billion (GOI 2006). Even more ambitious plans are there in pipeline for the future.

During the first generation of watershed projects, we have realized gains in the forms of increase in productivity, cropping intensity, ground water recharge and employment coupled with favorable crop diversification and reduced soil loss. As we enter second generation of watershed based developmental projects with such massive investment and high targets and expectations,

[1] Principal Scientist (Agricultural Economics) and [2] Principal Scientist (Soils), respectively, Central Soil and Water Conservation Research and Training Institute, Research Centre, Sector 27-A, Madhya Marg, Chandigarh, INDIA-160019

lessons learnt from first generation widely implemented watershed developmental projects needs to be well understood and policy guidelines and mechanisms be redrawn. People's participation is the key to sustainability of natural resources management projects. Hence, the issues influencing their participation level becomes more important. Aspects like social and gender equity need to be addressed to ensure involvement of all sections of the society for fair participation as well as to seek sustainability in the projects. Success of Sukhomajri and similar other watershed management programmes has led to implementation of 170, 130 and 60 numbers of projects in Shivalik region of Haryana, Punjab and Himachal Pradesh, respectively (Arya and Samra 2001). The present paper argues for certain basic re-thinking in the policy options for viable watershed management on the basis of experiences gained from the study of 53 water harvesting structures in 27 villages covering 2070 families of Haryana Shivaliks, Northen India, during past 24 years. The study examined different aspects of integrated watershed management projects including social, institutional and the most important, gender issues. In the last, some approaches and strategies for resolving these issues and integrating them into national policies have been suggested.

MATERIALS AND METHODS

To draw useful inferences regarding social and gender issues, the study was conducted during 2005-2009 in 27 villages representing entire Shivalik region in Haryana state (Fig. 1). In these villages, 53 water harvesting structures were constructed in 1980s by Haryana Forest Department on the pattern of Sukhomajri. In depth interviews, informants and observations were used to study impact of watershed management projects. Farmer respondents were selected on the basis of land holding from each village for the impact since inception of watershed projects *i.e.* for 20-25 years. Background information about villages and watershed project details were taken from implementing agencies and related state agencies.

Qualitative information on user's perception was also solicited. PRA and RRA techniques were utilized wherever needed to quantify benefits accrued from private as well as common property resources like water harvesting structures, forest and pasture lands.

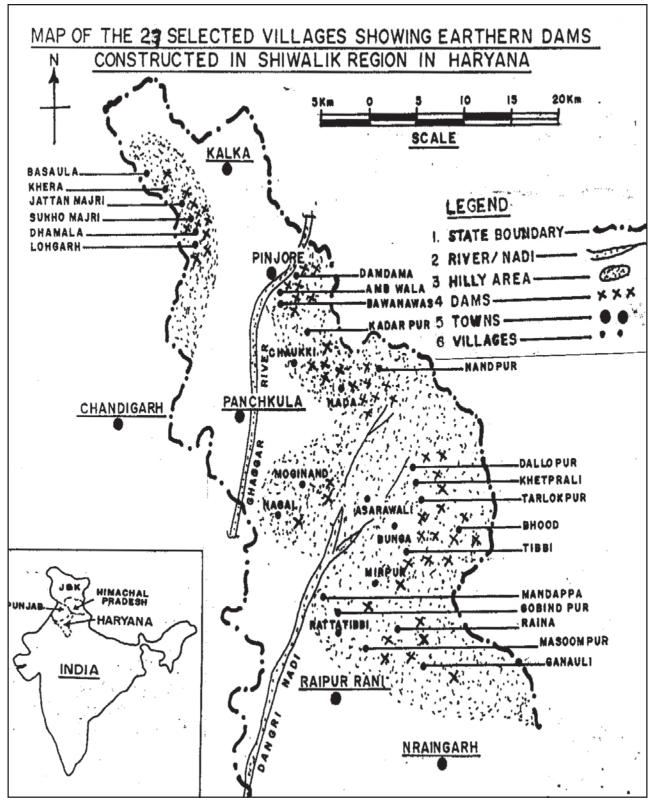


Fig. 1. Location map of studied villages

Separate information on various activities in which women participated predominantly were collected from all households and their proportional contribution was worked out. Labour utilisation in different operations of crop cultivation and livestock management was computed on the basis of average working hours spent on different operations by male and female labourers. A labour day of 8 hours for female was converted into men equivalent day. One day's work of women was taken as equivalent to 0.75 of a man's work day (Singh *et al.* 1981). This also matched the ratio of their respective wage rates. The collected information was synthesized scientifically to draw conclusions from the study in the following section.

RESULTS AND DISCUSSION

Profile of the project villages

Table 1 presents demographic characteristics of the villages covered under these projects. In thirty percent of the cases, projects were highly successful. Hill Resource Management Societies formed in these villages are still working efficiently since their

Table 1. Socio-economic characteristics of the households (No. of villages-27)

Variables	Categories	Frequency	Percentage
Overall effectiveness(Scale of 0-10)	Unsuccessful (0-3)	14	51.9
	Moderate (4-6)	5	18.5
	Successful (7-10)	8	29.6
Distribution of households	< 50	7	25.9
	50-100	14	51.9
	> 100	6	22.2
Land holding wise distribution of families	Landless	395	19.1
	< 1 hectare	749	36.2
	1-2 hectare	447	21.5
	2-3 hectare	210	10.1
	3-4 hectare	181	8.8
	> 4 hectare	88	4.3
Number of affected communities	< 22	8	29.6
	-5	12	44.5
	> 5	7	25.9
Irrigated area as percentage to total operated area	Unirrigated	7	25.9
	< 25%	5	18.5
	25-50%	6	22.2
	50-75%	7	25.9
	>75%	2	7.4
Occupational distribution of the working population	Agriculture and animal husbandry	Service Business	Daily wages
Average farm income per hectare of operational holding (Rupees)	< 4000	13	48.1
	4000-8000	9	33.3
	>8000	5	18.6
Contribution of animal husbandry towards total income in the selected villages (%)	< 40 %	4	14.8
	40 to 60 %	12	44.5
	> 60 %	11	40.7
Average per capita income (per annum)	< 4000	12	44.1
	4000-8000	10	37.1
	> 8000	5	18.5
Present status of Hill Resource Management Societies	Not constituted	13	48.2
	Successfully working	10	37.4
	Not working	4	14.8

inception. In case of nineteen percent of the projects, moderate level of success was achieved, whereas in fifty two percent of the cases projects turned out to be failures.

Total cultivated area in all the 27 villages was 2980.33 ha. Nineteen per cent of the total families were reported to be landless. The households having agricultural land less than 2 ha constituted 57.7 per cent of the total number, whereas only 4.3 per cent possessed more than 4 ha of land. Remaining 18.9 per cent of the households were operating agricultural land between 2 to < 4 ha. The data revealed that most of the farmers in the Shivalik foothill region belonged to small and marginal category. Occupational distribution of working population was also worked out which indicated that 60 percent of the working population was exclusively engaged in agriculture and animal husbandry activities. Eighteen percent of the working population was engaged in either private or government jobs, which was their regular source of income. Proportion of the working force employed outside the village varied widely from village to village from as low as 14 percent to as high as 58 percent. This seems to indicate that village economies were highly influenced by outside income, though inter-village differences in economic structure may also exist. In case of majority of the villages (44 percent) per hectare farm income was less than Rupees 4000. Only five out of 27 villages had farm income more than Rupees 8000 per annum. Average per capita income (per annum) also followed the same pattern.

However, by and large, agriculture cultivation was the mainstay of economic living in these villages supplemented by dairying. Economic activities in these villages were influenced by the caste biases on one hand and by the ecological and economic conditions prevailing in the region on the other. Wherever irrigation facilities were not available or insufficient, large number of cattle migration was also prevalent. Apart from these land- based activities, there were no major cottage or household level activities within these villages. In certain villages, which are quite near to cities, large numbers of men were employed either on regular or casual basis. The village life in a way was influenced by both the cultural and social identities within the village and by the urban links through the employment opportunities available in nearby cities

Organizing ‘inequity’: the key to sustainability

Judicious distribution of the economic benefits from the project among various stakeholders has been the most challenging issue. So far, the projects have aimed at bringing equity at enterprise or the segment level. At the most, water rights were established for landless in the initially implemented projects, which however, could not sustain for too long. The data from 27 villages revealed that the proportion of landless households towards total was 21 percent whereas their representation in the Hill Resources Management Societies was only 9 percent (Fig. 2) The review established that watershed development favours the landed and the downstream lands as well as those who have the wherewithal to invest in wells and pump (Arya and Samra 1995; Adolph and Turton 1998; Kerr *et al.* 1998; Arya and Samra 2001; Reddy *et al.* 2001). In some cases, measures like bans on grazing and cutting trees, closing of commons, ban on keeping goats, which are imposed from above, have hit the rural

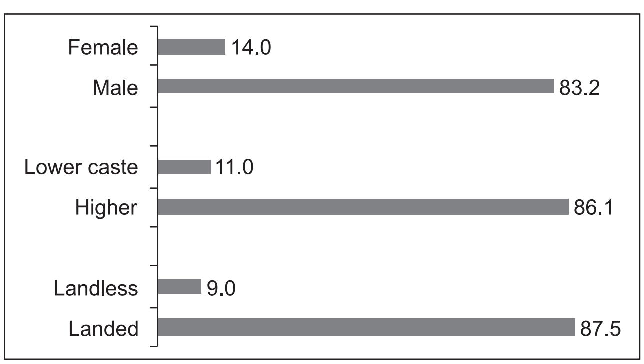


Fig. 2. Membership of Hill Resource Management Societies

poor very hard, especially the backwards and landless lot. To cite another example from the two most successful watersheds named Dhamala and Bunga villages, it was reported that number of livestock units kept by landless reduced considerably in comparison with landed after the implementation of the projects (Fig. 3). The equity has to be achieved at portfolio level and not at the enterprise level or at a segment level because the latter is neither feasible nor viable and sustainable. The portfolio approach to participative watershed development implies attention to inter-sect oral linkages, which manifest in the form of interactions among enterprises and social classes over time and space. The portfolio will include land and non-land based investments, farm and non-farm activities, and short term and long term based transfers of benefits. Thus equity may also have to be achieved over time (Gupta 1996).

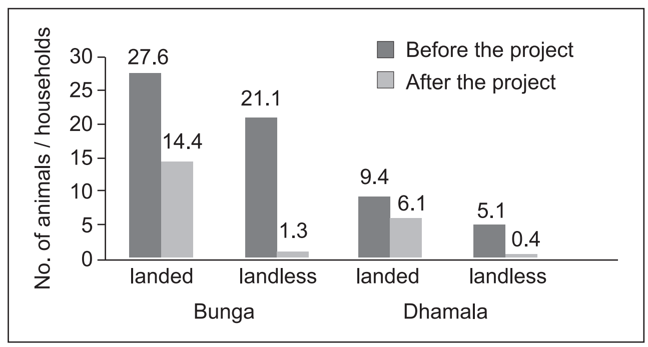


Fig. 3. No. of animals with landed and landless households

Livestock is a key component of the household economy in rural India. It is a source of additional income to farming households especially the poorest of poor. About 70 million households (73 percent of rural households) in India keep and own livestock of one kind or other and drive on average 20 percent of their income from this source (Walker and Ryan 1990). Landless and marginal farmers constitute almost two-thirds of total population in Shivalik foothill villages. Animal husbandry sector was contributing more than 50 percent towards total income in more than 50 percent of the selected villages (Table 2). Seasonal migration of pastoral migratory graziers, which constitutes a major proportion of human population in this region is being practiced since long, still continue in many of the villages as a survival mechanism. It was found that even in most successful watershed development projects namely Bunga and Gobindpur -Mandappa, the contribution of income from cattle migration was 11 and 21 percent, respectively towards the total income of these villages and cattle are being migrated for 6 to 8 months in a year mainly due to lack of market infrastructure, fragmented and small size of land holdings and lack of fodder (Table 3). Thus, one should aim at generating 'iniquitous' situation by providing greater access and share to such livestock dependent communities in the biomass produced in the Common as well as Government lands. The NGO or another agency may help trigger experiments with regard to decentralized fodder banks at least in each watershed so that stake of landless communities in the conservation can be institutionalized. The common water points, particularly, for drinking purpose have to be inalienable feature of watershed projects. It is pity that National Drinking Mission does not seem to coordinate well with the watershed wing of Department of Rural Development as well as Ministry of Agriculture to ensure this. The credit, input and marketing support for non-farm employment opportunities once integrated in the watershed projects can also be used to offset some of the inequities linked with land based investments.

Table 2. Contribution of various sectors (sources) towards total income (gross) in selected villages

Villages	Percentage income from various sources			
	Agriculture	Animal husbandry	Outside village sources	Within village sources*
Sukhomajri	11.8	49.9	35.3	3.0
Dhamala	25.2	35.1	35.9	3.8
Nada	11.6	23.9	62.2	2.3
Bunga	32.2	55.0	11.3	1.5
Lohgarh	21.0	44.1	31.5	3.4
Gobindpur & Mandappa	19.5	74.8	4.1	1.6
Chowki	26.0	44.8	24.9	4.2
Masoompur	22.5	64.6	10.8	2.1
Raina	24.0	64.0	7.0	5.0
Nandpur	14.8	49.0	30.3	5.9
Kedarpur	36.5	46.6	13.9	3.0
Ambwala	28.5	58.9	10.6	2.0
Damdama	19.7	45.3	31.3	3.7
Bhud	46.5	42.0	8.9	2.6
Rattantibbi	23.7	62.8	10.9	2.6
Trilokpur	26.0	30.6	35.5	7.9
Ganouli	27.4	59.1	10.7	2.8
Bhavana	34.1	47.7	15.2	3.0
Jattanmajri	25.5	55.8	16.2	2.5
Kera & Basaula	18.0	34.5	41.8	5.7
Tibbi	13.0	71.2	13.6	2.2
Aasrewali	3.3	80.0	10.2	1.5
Dullopur	31.2	49.1	16.3	3.4
Moginand-Naggal**	6.1	59.0	32.2	2.7
Khetparali	28.4	43.0	25.3	3.3
Mirpur	18.6	63.5	14.7	3.2

* Within village sources does not include income from animal husbandry and agriculture
** Moginand and Naggal have been combined

Institutions

The economic benefits are necessary but not the sufficient inducement for triggering chain reactions of watershed projects. The institutions provide the self-regulating character to any human endeavour. Institutional building for watershed management has been one of the most neglected parts of all the watershed projects. The very concept of 'handing over' of the project to people implies that the ownership has changed. Contrary to this, if officials were to participate in people's plans, the question of 'handing over' would not arise. The institutional building process involves generation of self-renewing capability in the organization and also ability to align mission and goals with the emerging changes in the overall environment without losing basic ethics and spirit. During the present study, it was found that of the 53 micro-watershed

Table 3. Income (Rs) from cattle migration activities

Villages	Gross income from all sources	Gross income from animal husbandry	Income during migration period	% income from migration
Bunga	25,657,972	14,106,297	2,819,114	11.0
Gobindpur-Mandappa	6,577,823	4,915,774	1,373,710	21.0
Rattatibbi	3,426,910	2,153,594	862,896	25.0
Masoompur	4,421,358	2,733,215	871,007	20.0
Raina	8,934,648	5,746,891	1,822,668	20.0
Tibbi	5,754,888	4,102,574	1,671,683	29.0
Aasrewali	3,298,822	2,200,120	1,468,860	45.0
Ambwala	3,306,350	1,948,232	471,808	14.0
Dullopur	709,876	320,218	100,827	14.0
Khetpurali	5,943,304	2,555,265	919,201	16.0

development projects implemented in 27 villages, local institutions were constituted only in 14 cases. Only 10 were functioning at the time of survey. However, there is lack of modus operandi in almost all the communities. These institutions lack the training and technical know-how regarding repair and maintenance of dams and pipelines. Dam maintenance is costly, requiring access to financial resources greater than that generated through the sale or auctioning of irrigation water. To fully exploit the potential of the water-harvesting dams, farmers must have the economic information on which they can make rational and informed decisions. Farmers must have the institutional mechanisms to acquire, process and transform (calculate) the information. Information is required from different sources on crop profitability, crop water use, animal productivity and fodder production. Availability of economic information will allow the farmers to determine which irrigation models, they wish to opt for, and finally, relationships to existing administrative structure and issues of land tenure need to be explored and developed.

Gender issues

It has been noticed that women carry out much of the increased agricultural, dairying and fodder collection tasks whereas men have control the income generated (Arya and Samra 2006; Gopalan 1993; Rani 2004; Arya 2007; Hiraway 1996; Singh 1996; Visaria 1999). Further, stall feeding takes more of the women's time than grazing; consequently, their labour inputs into livestock have increased since the watershed projects were initiated. A survey of seven villages revealed that female participation increased from 163 to 418 hrs / annum / acre of cropped area after watershed implementation. The figure 4 reveals

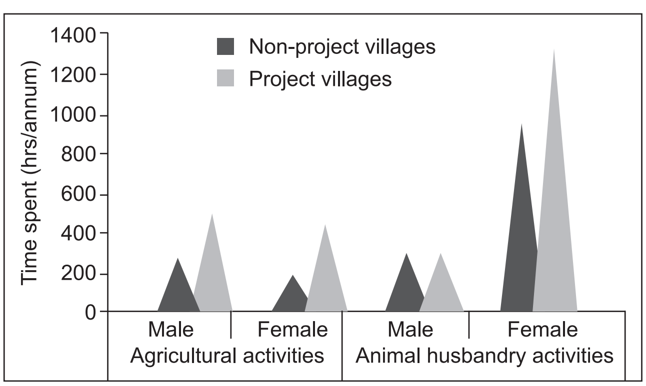


Fig. 4. Relative contribution of farm men and women in various activities in project and non-project villages

that female contribution increased by 157 percent whereas of men by only 85 percent in agricultural activities. The time spent on social and leisure activities decreased by 32 percent. About 71 percent of animal related activities were performed by women which increased by 38 percent after the project period whereas of men increased by 6 percent.

It has been observed from the experience of even most successful watershed management projects that women participation is synonymous with their training in sewing and embroidery, carpet weaving and other art and craft activities. Even in nursery trainings, women are used as labour and rarely allowed to contribute to the selection of species to be raised in nursery. Knowledge and skills determine an individual's position in the hierarchy set up to implement project activities. Unfortunately, training programme in watershed management target men rather than women.

Even if the presence of women in meeting is considered as criteria for their participation in project, the study revealed that on an average, 6 to 22 male members participated in a meeting whereas female member's participation varied from 0.3 to 2 per meeting (Table 4).

Table 4. Details of meetings held by Hill Resource Management Societies (HRMS)

Name of HRMS	No. of meetings held	Period	Attended by	
			Male	Female
Sukhomajri	42	1992-99	936 (22.0)	97 (2.0)
Dhamala	28	1993-99	518 (18.0)	40 (0.4)
Bunga	712	1985-99	8494 (12.0)	Nil
Lohgarh	131	1984-99	1834 (14.0)	102 (0.8)
Gobindpur	35	1990-99	496 (15.0)	22 (0.6)
Masoompur	75	1987-99	1220 (16.0)	Nil
Raina	64	1993-99	1302 (24.0)	15 (0.3)
Mirpur	66	1993-99	905 (14.0)	114 (1.7)
Khera & Basaula	45	1995-99	992 (22.0)	89 (2.0)
Nada	12	1994-99	196 (16.0)	Nil

Note: Figures in parenthesis indicate average participation of male and female per meeting

In the nutshell, it is quite common to find the following gaps in watershed development projects in relation with gender issues:

1. Lack of clear understanding of the concept of gender and lack of an analysis of gender roles and responsibilities.

2. Lack of policies and strategies, which foster a gender sensitive approach and affirmative gender action in favour of women.
3. Misconceptions on development issues relating to women as;
   (a) that economic and environmental development automatically mean an improvement in the quality of life and status of women.
   (b) that specific activities targeted purely at women are likely to succeed.
   (c) that the women's development is synonymous with material benefits or physical project outputs such as the creation of assets.

Reasons for failure of watershed projects

An attempt was made to find out various reasons for non-functioning / partial functioning of various watershed structures, which can be broadly, put under three categories namely technical, administrative and organizational. The same have been discussed in detail in the following section.

Technical issues: The major reason behind the poor performance of water harvesting structures was the clogging of inlet well (tank) and thereby choking the main outlet pipe with silt coming heavily from the catchment area. Out of 53 structures covered under the study, in 31 cases, silt entered into the inlet pipe and in the other nine cases the reservoirs were filled with silt in the first year itself. The main reason being that the catchment area was not treated either with vegetative or mechanical measures before constructing water harvesting dams.

Next important factor was the poor performance of spillways provided in the bodies of dams. Out of 53, in 24 cases the spillways broke (and continued to break) every year even after expensive repairs either by the society or by the department. In 15 cases the spillways were damaged beyond repair. The other reason for heavy damage to spillways was the clogging of inlet well and outlet pipeline due to deposition of silt as the catchment areas were hardly treated except in a few cases. In another 14 cases, the distribution pipelines for providing water to the farmers' agricultural fields were not laid down at all whereas in 9 cases, the pipelines were not provided to the required length. Since very few farmers were getting the irrigation benefits, majority who were denied the facility intentionally damaged the pipelines beyond repair and also took away the sluice valve. In 9 of the cases, the reservoirs were filled with silt in the first year itself because the catchment areas were not treated with either vegetative or engineering measures, which further clogged the inlet tanks and main pipelines. The other important reasons included were, high seepage losses and the level of agricultural fields being at higher elevation as compared to the body of the dam.

Administrative issues: The most typical of all the administrative problems faced by the forest officials, when contacted was that they did not get funds for repair and maintenance of previously constructed structures or left in between. Once the existing funds exhausted, they were not able to lay down the pipelines for distribution of water to the farmers' fields. Next time, when the department got more funds under a different scheme and from different source, it was always for the construction of new dams. In most of the cases, the local labour was not utilized for the construction purposes, while in others, labour was not paid fully. The labourers even had to go to the court to recover their payments.

Selection of sites, designing and execution of drainage line works is a specialized activity and should have received closed co-ordination of experts in the fields. Most of these programmes were implemented by State Forest Department because of territorial consideration. They had no prior experience and the field functionaries especially trained for the purpose Soil and Water Conservation Programme encompass a wider range of disciplines, whereas in the present case study, the watershed management activity was taken as a sectoral activity, without giving any consideration to other fields. Neither the catchment areas were treated nor did the arable land get any attention.

Organizational issues: In all the villages, where water-harvesting structures were constructed by the Haryana Forest Department, constitution of Hill Resource Management Societies (HRMS) was considered imperative to manage and distribute the resources equitably. However, HRMS were constituted and registered only in few cases. About 102 water-harvesting structures were constructed during 1976 to 1996 in 60 villages. The results revealed that out of 27 villages surveyed, HRMS were constituted in 14 villages. In some of the villages where one structure was serving the irrigation purpose of two adjoining villages, only one HRMS was formed for both the villages. Out of 14 societies constituted, 10 were working at the time of survey, which very clearly indicated the active, positive and continuous interest of the village community in these societies.

HRMS's also could not be formed and registered in those cases where the farmers could not get even a drop of water. On the other hand, wherever people were taken into confidence, HRMSs had shown remarkable initiative and resilience in keeping or making their dams functional despite poor delivery by the service-providing department. In such cases, the farmers seeing the benefits of irrigation, tried to clear the blocked outlets with little bit of technical knowledge they had, repaired faulty sluice valves and replaced damaged sections on their own. It was only when the dams finally breached and needed an investment of two to three lakh rupees, that they had to give up.

At many places, farmers were not even consulted before the selection of dam sites as well as for construction. These villagers repeatedly suggested the officials that the selection of sites was wrong, as they have been staying in these villages since ages and water cannot be stored at the selected sites.,. Dam sites were largely selected even without assessing their potential for motivating villagers living near them to protect their catchments in return for getting the water. The principle of linking equal rights to water with equal responsibility for protecting the dam watersheds was not even discussed; leave aside being used as a precondition for the dams being built. Obviously, in such cases, where the authors visited, most of the villagers did not have the knowledge about the dams in their villages. The limited success achieved in the matter raises serious questions about the ability of the implementing agencies to function with accountability to community institutions, which is a pre-condition for initiating durable Joint Forest Management partnership with villagers.

Policy implication

The present study examined different aspects of integrated watershed management projects and institutions related with the management, protection and distribution of common property resources. The findings very clearly revealed that communities with functioning societies established social fencing, water harvesting and grass lease agreements which raised both biomass production as well as income from private agricultural holdings and state forest lands. However, where communities were not able to develop effective management system, the desired goals could not be attained. Based on experiences gained from Sukhomajri, Nada, Bunga, Relmajra villages and lessons learnt from evaluation studies over a period of 30 years, certain thumb rules for ensuring People's Participation in watershed development programmes have been framed and are listed here.

Integrating benefits to resource conservation: Highest priority needs to be given to 'water resource development' as it provides immediate and direct economic benefits to local people. Economic factors hold the key to generate momentum in conservation works. The poorest of the poor dare to improve their land and participate only when it pays for them to do so. Watershed development is essentially a resource-base approach to environmental protection and livelihood enhancement. Unless adequate safeguards can be built in, the danger is that, as the commons become more productive, better-off farmers are tempted to take control of them and customary access rights of the poor are denied (Farrington et al 1998).

Issue of equity: A resource system need to be designed so that all community members benefit. Considerable attention need to be given to developing water sharing arrangements so as to allow landless families to benefit from it. Given the pressure of landless families and uneven spatial distribution of land holdings in the region, it was however, difficult to achieve equitable arrangement for sharing benefits from irrigation development for private lands, but in cases, where this arrangement could be worked out; a great amount of success was achieved.

Institutional arrangements/ formation of society: Transferring to grass roots organization, the responsibility of running the participating process within their communities is a key requisite for ensuring the sustainability of Integrated Watershed Management process. Community awareness, knowledge, support and public participation in the decisions that affect the environment and economic outcomes are equally important. This is, best secured by creating centralized systems of regulation, use and management of resources upon which local communities depend and giving these communities an effective control over the use of these resources (WCED 1987).

Integrating local knowledge and culture into improved system: Formulation of resource based development policies should take into considerable local people's knowledge and culture for its sustainable use. Our evaluation studies' results revealed that water-harvesting structure failed wherever the local people's wisdom and experiences were not taken into consideration. Rural people have a strong capacity to make sound judgment about their work and results. Thus, special attention need be paid to establish a synergy between departmental and indigenously evolved practices.

Gender issues: Women carry out much of the increased agricultural, dairying and fodder collection tasks. Further stall feeding takes more of the women's time than grazing; consequently their labour input into agricultural and livestock activities has increased since the projects were initiated. More representation need to be given to women in order to gain leadership positions in the local institutional set up especially where women are the primary users of grass and forest lands. At the same time, project authorities need to understand the difference in women's and men's roles and responsibilities related to the use of forest produce for sustaining livelihood systems.

Holistic and sustained development: Long term continuity is a vital ingredient in the strategy for sustainable development. Comprehensive small watershed management should be an integration of overall planning and development of hilly lands, water resources, farmlands, forest, agriculture, livestock and fisheries. It should facilitate combination of forest and grasses as vegetative measures along with the engineering measures to control surface and gully erosion and to protect soil and water resources for short as well as for long term economic benefits to the farmers.

Sharing of income/benefits from CPR: Participation is basically a political process concerned with redistribution of power in a society. This usually involve transfer of administrative and financial powers from 'haves' to 'have not' and sharing of benefits with local people whose participation is sought.

The basic philosophy behind the super success of Sukhomajri Model was to tie the economic interests of villagers, living adjacent to forestland for sustainable management of CPRs. This was achieved by identifying water, fodder, bhabbar grass and trees as the catalyst which motivated the villagers to improve the productivity of forest areas while forest department agreed to give HRMS a major share in the increased production resulting from their participation in management.

Insensitive handling of these issues is likely to jeopardize the successful functioning of any local system, as this only holds the key to ensure sustainability and productivity of the hilly ecosystem, which could lead to fulfillment of longterm social objectivity. The strength of Joint Forest Management is that it should be organized from which the community has been and will continue to derive benefits either in cash or in kind. Given the right environment and encouragement, the local communities have the potential to emerge into strong institutions with a high level of financial and institutional sustainability.

CONCLUSION

The present study examined different aspects of integrated watershed management projects and institutions related with the management, protection and distribution of common property resources. The findings very clearly revealed that communities with functioning societies established social fencing, water harvesting and grass lease agreements which raised both biomass production as well as income from private agricultural holdings and state forest lands. However, where communities were not able to develop effective management system, the desired goals could not be attained. More representation need to be given to women in order to gain leadership positions in the local institutional set up especially where women are the primary users of grass and forest lands. At the same time, project authorities need to understand the difference in women's and men's roles and responsibilities related to the use of forest produce for sustaining livelihood systems. Long term continuity is a vital ingredient in the strategy for sustainable development. Failure of watershed management projects was due to many technical reasons *viz.* clogging of pipeline, malfunctioning of spillway, heavy siltation *etc.* administrative issues *viz.* lack of maintenance funds, technical know how, non-treatment of catchment or organizational hindrances. Sustainability can be ensured by integrating benefits to resource conservation, addressing social and gender equity issues, strengthening grass root level institutions, blending indigenous technical knowledge with modern technology and sharing benefits among all from common property resources.

REFERENCES

Adolph, B. , Turton. C. 1998. *Community Self-help Groups and Watersheds Partnerships and Policies Programme Series.* Overseas Development Institute, London.

Arya Swarn Lata. 2007. Women and watershed development in India: issues and strategies. *Indian Journal of Gender Studies*, 14 (2): 199-230.

Arya, Swarn Lata, Samra, J.S. 1995. Socio-Economic Implications and Participatory Approach of Integrated Watershed Management Project at Bunga. Technical Bulletin No. T-27/C-6, Central Soil and Water Conservation Research and Training Institute, Research Centre, Chandigarh, India.

Arya Swarn Lata, Samra, J.S. 2001. *Revisiting Watershed Management Institutions in Haryana Shiwaliks, India*. Central Soil and Water Conservation Research and Training Institute, Research Centre, Chandigarh, India.

Arya, Swarn Lata , Samra, J. S. 2006. Impact analysis of watershed development projects in Shiwalik foothill villages in Haryana State. *Agricultural Situation in India.* 62 (2): 711-722.

Arya, Swarn Lata, Agnihotri Y, Samra, J.S. 1994. Watershed management: change in animal population structure, Income and cattle Migration, Shiwaliks, India. *Ambio* , 23 (7): 446-450.

Farrington J, Gilbert E H, and Khandelwal R. 1998. *Process Monitoring in India Agriculture: Implications of a Rajasthan Case Study*, Chapter 8, In Mosse, D., Farrington, J. and Rew, A. (eds.), *Development as Process*, Routledge, London.

Gopalan Sarala. 1993. *Women and Employment in India*. Har-Anand Publications. New Delhi.

GOI (Government of India). 2006. *Report of the Technical Committee on Watershed Programmes in India* . Department of Land Resources, Ministry of Rural Development, New Delhi, India.

Grewal, S.S. , Mittal, S.P., Singh, G. 1990. Rehabilitation of degraded lands in the Himalayan foothills: People's participation. *Ambio* 19 (1): 45-48.

Gupta, A.K. 1996. *Rethinking Policy Options for Watershed Management by Local Communities: Combining Equity, Efficiency and Ecological-Economic Viability*. IIMA Working Paper No. 1341.

Hiraway, I., 1996. Economic reforms and gender issues in India. *Indian Journal of Labour Economics.* 39 (8): 577-590.

Kerr, J.M., Pangare, G., Lokur- Pangare, V., George, P.J., Kollavalli, S. 1998. *The Role of Watershed Projects in Developing India's Rainfed Agriculture.* Report submitted to the World Bank. IFPRI, Washington.

Rani, K.U. 2004. *Empowering Women through Natural and Social Resource Management* MANAGE CYBERARY, 7. Available at *http://www.manage.gov.in/managelib/faculty/uma.htm;* accessed on 3.8.2006.

Reddy, V., Ratna, M., Gopinath, G.S., Springate-Baginski, O. 2001. *Watershed Development and Livelihood Security: An Assessment of Linkages and Impact in Andhra Pradesh, India*. Draft Report, CESS / University of Leeds.

Sharda, V.N., Sikka, A.K., Juyal, G.P. 2006. *Participatory Integrated Watershed Management – A Field Manual*. Central Soil and Water Conservation Research and Training Institute, Dehradun.

Sidhu, G.S., Walia, C.S., Sachdeva, C.B., Rana. K.P.C., Dhankher, R.P., Singh, S.P., Velayutham, M. 2000. *Soil resources in N-W Shivaliks for perspective land use planning*. In: *Fifty Years of Research on Sustainable Resource Management in Shivaliks* (Eds. S.P. Mittal, R.K. Aggarwal and J.S. Samra), Central Soil and Water Conservation Research and Training Institute, Research Centre, Chandigarh, pp 23-34.

Singh, S. 1996. Occupational participation of women in Punjab: 1961 – 1981. *Indian Journal of Labour Economics*, 39 (4) : 817-826.

Singh, C.B., Dhaka, J.P, Sharma, S.P. 1981. Labour absorption and factors influencing levels of employment in crop, dairy and poultry enterprises. *Indian Journal of Agricultural economics.* 36 (4): 1-14..

Visaria, P. 1999. *Level and Pattern of Female Employment : 1911-1994.* In: *Gender and Employment in India.* (eds.) T.S. Papola and Alakh N. Sharma, Indian Society of Labour Economic Growth in association with Vikas Publishing House Pvt. Ltd, New Delhi. pp. 23-51.

Walker, T., Ryan, J. 1990. *Village and Household Economies in India's Semi-arid Tropics.* John Hopkins University Press.

WCED (World Commission on Environment and Development). 1987. *Our Common Future,* Oxford University Press, Oxford.

Journal of Soil and Water Conservation **11**(4): 356-364, October-December 2012
ISSN: 022-457X

Farmers' perception about climate change and its impact on agriculture in Panna distrct of Bundelkhand region (Madhya Pradesh), Central India

RAJENDRA PRASAD[1], A. K. PANDEY[2], S. K. DHYANI[3], N. K. SAROJ[4] and V. D. TRIPATHI [5]

Received: 24 May 2012; Accepted: 12 October 2012

ABSTRACT

In present study we assessed farmer's perception about climate change and its impact of on agriculture and allied activities by conducting survey of 10 selected villages in Panna district of Bundelkhand region. The findings revealed that the farmers of Panna district have clear perception of changing climatic scenarios and realized wide scale impact of climate change on agriculture and related activities. The deviation in weather pattern, on set and withdrawal monsoon rain, wind and dust storm, and increase in unusual weather extremes was unanimously felt by farmers. Change in phenology of crops manifested by deviation in flowering time & intensity, fruit-bearing pattern, and shape, size and quality of grain was perceived by surveyed respondents in Panna. Livestock productivity was perceived to be at risk and became more vulnerable due to change in climate. Conclusively, it is reported that the local farmers of Panna district of Bundelkhand appears to have a clear cut perception about climate change and its impact on agriculture. Their mindset is ready for climate resilient adaptations.

Key words: climate resilience, adaptations, climate impact assessment, indigenous knowledge

INTRODUCTION

In spite of green revolution in post- independence era leading to five times increase in food grain production, India still continues to face a persistent challenge of feeding growing population amidst climatic uncertainties. Climate is one of the key components influencing agricultural production and overall economy in India. The impact of climate change on agriculture is an issue of great significance to the lives and livelihoods of millions of poor people in India who depend on agriculture for food and livelihood. Today, Climate change has been recognized globally as the most pressing critical issue affecting the mankind survival in the 21st century. The most obvious manifestation of climate change is the rising of average worldwide temperature, popularly termed as global warming. The mean global annual temperature increased between 0.4 to 0.7 ^{o}C (Singh, 2008). Most of the countries are facing the problems of rising temperature, melting of glaciers, rising of sea-level leading to inundation of the coastal areas, changes in precipitation patterns leading to increased risk of recurrent droughts and devastating floods, threats to biodiversity, an expansion of plant diseases and a number of potential challenges for public health. Several global studies have indicated that India is particularly vulnerable to climate change, and is likely to suffer with damage to agriculture, food and water security, human health and cattle populations.

The realization and understanding of climate change is pre-requisite to take appropriate mitigation and adaptation initiatives at local level (Prasad *et al*, 2011). Local communities have been coping with environmental change since millennia and have considerable knowledge about environmental change and means to cope up with its consequences (Salick and Byg, 2007). Documentation of such knowledge can propel scientific inquiry and at the same time help design mitigation and adaptation

[1-5] National Research Centre for Agroforestry, Pahuj Dam, Gwalior Road, Jhansi-284 003 (U.P.)
E-mail: drrajendraprasad2@yahoo.co.in

measures for resilience. In Bundelkhand, there is scarce documentation of traditional knowledge concerning the impact of climate change on agriculture and related activities. Thus, the present study was undertaken in Panna district of Bundelkhand region of Madhya Pradesh to assess farmers' perception about changes in climate and potential impact of such changes on agriculture and livelihoods at local level.

METERIALS AND METHODS

The present study was conducted in Panna distrct of Bundelkhand region of Madhya Pradesh, central India. The average annual rainfall of Bundelkhand in Madhya Pradesh is 990.9 mm with a range of 767.8 to 1086.7 mm. For Panna district the normal rainfall in 1069.6 mm. About 90% of the rainfall is received in the monsoon season of July to September in about 30-35 events or spells (Samra, 2008). Rainfall variation within the season is important for crop production and rain in September is crucial for the maturity of Kharif crops and sowing of Rabi crops. Delayed on set of rains, early withdrawal or long dry spells in between also lead to drought like situation (Table 1).

Panna is located in north-eastern part of Madhya Pradesh with its head quarter at Panna city / town.

Table 1. Distribution of recent meteorological drought in Panna district and Bundelkhand region of Madhya Pradesh

District Region	Normal rainfall (mm)	2004-05	2005-06	2006-07	2007-08
		% Devia-tion	% Devia-tion	% Devia-tion	% Devia-tion
Panna	1069.6	12.0	33.0	-46.0	-67.0
Region Total	0990.9	-16.5	10.0	-37.0	-46.0

(Source: Samra, 2008)

Panna is known as diamond city of India. The total geographical area is 702924 ha out of which 59535 ha is arable land, and 299647 ha is forest. Administratively, it is divided in to five Tehsils viz. Ajaygarh, Panna, Gunar, Pawai and Shahgarh. The main crops grown in the district are wheat, paddy, sorghum, maize, chick pea, pigeon pea, urd, lentil, til, groundnut, mustard, soybean and sugarcane. Among the domestic animals cattle, buffalo, goat and sheep are the dominant.

For survey and collection of data, descriptive survey research design was utilized. Panna district representing Bundelkhand region was purposively selected for the study. Out of five, two tehsils viz Panna and Ajaygarh, and from each tehsil five villages were selected for assessing potential impact of climate change in the area. The sample respondents were drawn from above selected ten villages randomly. In Ajaygarh thesil, Ramnai, Kharoni, Jigni, Chandora and Rajpur villages were selected. In Panna tehsil, Hardua, Janakpur, Purshottam pur, Rajapur and Sunhera villages were selected. General information on number of households, their economic status, animal population, and literacy status of selected villages was collected from secondary sources (Block headquarter) and given in Table 2, 3 and 4.

Door-to-door survey was done through personal interview with individual households

Table 2. Economic status households in selected villages of Panna district in Bundelkhand

Village	Distribution of households			
	Total	SC	ST	BPL
Sunehara	242	22	103	212
Janakpur	314	74	80	267
Purushottampur	241	16	36	74
Rajapur	437	106	20	88
Hardua	205	18	81	90
Jigni	286	70	-	140
Chandaura	387	70	-	197
Kharoni	231	30	-	156
Ramnai	251	75	5	187
Rajpur	326	92	18	290

Table 3. Livestock population in selected villages of Panna district in Bundelkhand

Village	Cows	Buffaloes	Sheep / Goat
Sunehara	610	302	301
Rajapur	1398	342	241
Purushottampur	382	124	142
Janakpur	687	218	166
Hardua	445	236	38
Ramnai	374	244	55
Jigni	480	256	45
Chandaura	442	521	64-14
Kharoni	361	379	40-
Rajpur	510	374	160-

Table 4. Literacy of studied blocks of Panna district in Bundelkhand

Block	Rural Literacy (%)			Urban Literacy (%)			Total		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Ajaygarh	67.42	37.72	53.59	79.13	58.64	69.48	66.43	39.78	55.18
Panna	65.22	39.03	52.92	87.60	69.02	79.45	72.26	49.69	61.00

(N = 50) covering various age groups and gender mixes, with emphasis on older persons. An open-ended questionnaire was designed to identify the evidences of changes in weather and climate for the past decade, impact of climate change on agriculture and animal husbandry. The respondents were interviewed with help of a well structured interview schedule. Besides, in all these villages 2 or 3 focused group consisting of at least five elderly farmers were interviewed to analyze and refine the perception on climate change. The collected information was based on farming status and its history, past memory of extreme climate events and their impact, and management responses to those adverse situations, present-day scenario and likely future consequences. In focused group discussion which, consisted of at least five elderly farmers of the village, other farmers were allowed to participate and involve freely for refinement of information recorded on interview schedule. All the refined information was compiled / analyzed and interpreted for results.

RESULTS AND DISCUSSION

Before presenting and discussing results, some caveats of perception studies are mentioned. Caution is necessary in conducting surveys and interpreting the results of participant surveys and responses. Both sampling (selection of sites and sampling of respondents) and non-sampling (phrasing of questions, choosing interview tools, and consistency in delivering questions and recording responses) errors can occur. Hence, efforts were made to minimize the errors by drawing the sample randomly from a larger population, including maximum possible households in discussion, framing questions in a manner to reduce the probability of respondents making certain presumptions or showing biases, and minimizing interviewing bias in recording information.

1.1 General farming status

The data pertaining to general status of farming in studied area revealed (Table 5) that majority (64%) of respondents owned 1.0 to 2.0 ha land. Only 12% farmers had land holding of more than 5.0 ha. Maximum respondents (56%) had less than 5 domestic animals and only 8% farmers had more than 20 animals on their farm. Among livestock, cows and goats were most common and accounted major shares. Wide range of food grain production among respondents was observed. Maximum farmers (56%) produced 5.0 to 10.0 q of food grain annually. Only 4% respondents had annual production of more than 40 q food grain. All the respondents have planted trees on their farm land. However, majority (56%) of farms had less than 5 trees. More than 40 trees were present on only 4% farms. Among fruit trees ber, mango and guava were most common and provided fruits for sustenance of farm families. Majority of farmers (68%) harvested less than 1.0q fruit annually whereas, more than 5.0 q fruits were

Table 5. Distribution of respondents according to their farming status in Panna district of Bundelkhand

Farming Characteristic	Distribution	% of total respondents
Size of farm holding (ha)	0 to 1	4
	1 to 2	64
	2 to 5	20
	Ã5	12
Number of animal / farm (buffalo, cow, oxen, goat and sheep)	Â5	56
	5 to10	24
	10 to 20	12
	Ã20	8
Annual food grain production (q / farm)	2 to 5	20
	5 to10	56
	10 to 20	8
	20 to 40	12
	Ã40	4
Total numbers of trees / farm	Â5	64
	5 to10	20
	10 to 20	8
	Ã20	8
Total fruit yield from farm trees (q / farm)	Â1	68
	1 to 2	8
	2 to 5	20
	Ã5	4
Total fuel wood yield from farm trees (q / farm)	Â1	52
	1 to 2	8
	2 to 5	32
	Ã5	8

harvested by only 4% respondents. Trees also provided fuel wood to farmers and majority (52%) received less than 1.0 q fuel wood annually from their farms. Only 8% farmers received more than 5q fuel wood annually from their farm. The dominant crops and trees grown in the area are listed in Table 6. Among cereals wheat and paddy are the main crops while chickpea pigeon pea, lentil, black gram and green gram are the pulses. Among oil seed, groundnut mustard and soybean are dominant. Among fruit trees, ber, mango and guava are the main fruits.

3.2 Perception about climatic change and its impact

Table 6. Dominant crops and agroforestry tree species on farmers field in Panna district of Bundelkhand

Crops	Tree species
Paddy *(Oryza sativa*)	Ber (*Zizphus mauritiana*)
Wheat (Triticum astivum)	Babool (*Acacia nilotica*)
Chick pea *(Cicer arietinum)*	Mango (*mangifera indica*)
Ground nut (*Arachis hypogea*)	Guava (*Psidium guajava*)
Sorghum *(Sorghum bulgaris*)	Koha (*Terminalia arjuna)*
Pearl millet (Pennisetum glaucum)	Aonla (*Emblica officinalis*)
Pigion pea *(Cajanus cajan)*	Neem(*Azadirachta indica*)
Sugercane *(Secarum officinerum*)	Mahua (*madhuca indica*)
Green gram *(Vigna radiata*)	Sissoo(*Delbergia sissoo*)
Barley *(Hordeum vulgare)*	Katahal (*Atrocarpus heterophyllus*)
Lentil (*Lens esculenta*)	
Soybean *(Glycine max)*	Bamboo *(Dendrocalmus strictus)* Peepal *)*
Black gram *(Vigna mumgo)*	
Mustard *(Brassica species)*	*(Ficus religiosa*
Battery *(Mentha pipertia)*	Ashok *(Polyalthia lougifoua*)
Sesame *(Sesanum indicum)*	Teak *(Tectona grandis)*

Perception about change in weather pattern: The result of respondent's perception regarding change in rainfall temperature, winds etc. are presented in Table 7. All respondents have perceived changes in rainfall pattern. In comparison to past, 68% respondents believed that onset of monsoon is delayed. However, 16% perceived that now monsoon sets in early, while another 16% perceived no change in arrival of monsoon season. On withdrawal, majority (84%) of respondents agreed for early withdrawal of monsoon rains, whereas 8% for late withdrawal and another 8% find no change. Except 12% of respondents, all perceived that the number of rainy days and their distribution over season have changed. Reduction in number of rainy days is perceived by 44% while 32% believed that the difference in rain events or intermittent dry spell has increased. On rainfall intensity, respondents were

Table 7. Distribution of respondents according to perceived change in rainfall, temperature and wind in Panna district of Bundelkhand

S.No.	Perceived impact by respondent	% of total respondents
1.	Deviation in onset of monsoon	
	Early	16
	Late	68
	Normal / no change	16
2.	Deviation in withdrawal of monsoon	
	Early	84
	Late	8
	Normal / no change	8
3.	Deviation in rainy days and distribution over season	
	No variation	12
	Variation	12
	Rainy days reduced	44
	More difference in rain events / intermittent long dry spell	32
4.	Change in rainfall intensity and frequency	
	No Change	4
	Slow / less intensity	36
	Fast / more intensity	8
	Alternate slow and fast	52
5.	Change in droughts / dry spells years	
	Drought for 1 year	0
	Consecutive drought for 2 year	0
	Consecutive drought for 3year	64
	Consecutive drought for 4year	36
6.	Change in pattern of winter rain	
	Normal rain / no change	40
	Low rain	36
	Very low	4
	No rain	20
7.	Variation in winds speed and direction	
	Normal Easterly wind	44
	High speed Easterly wind	20
	High speed western wind	8
	Normal wind	12
	North-east wind	16
8.	Change in pattern of dust storms	
	Dust storm increased	76
	Dust storm decreased	0
	Normal / no change	16
	Other	8
9.	Variation in seasonal winds	
	No change	48
	Hot wind blow in summer	20
	Very hot wind blow in summer	28
	Other	4
10.	Unusual variation in seasons	
	No Change	0
	Very hot summer	24
	Temperature in summer increasing	72
	More hot summer and more cold winter	4
11.	Event of weather extremes	
	Increasing summer	88
	Increasing winter	12
	No change	0
12.	Harmful effect of weather extremes	
	Disease increase	48
	Tree / crop is badly affected	40
	No change	12
13.	Beneficial effect of extreme weather events	
	No beneficial effect	100
	Beneficial effects	0

divided and 36% felt that rainfall intensity has reduced while 8% perceived increase in it. All the respondents perceived increase in drought and 64% opined consecutive drought for 3 years while, 36% felt drought for 4 years. Regarding change in pattern of winter rain, the respondents were divided in their perception and 40% felt no change. However, 36% respondents perceived that rain in winter has reduced and 4% opined negligible rain in winter. Considerable section of respondents (20%) says that there was no rain in winter. The farmers of the study area have also perceived changes in wind pattern. Majority of respondents (44%) felt normal easterly winds continued in monsoon while, 20% perceived increase in speed of easterlies. Shift in pattern of dust storms was perceived by 76% of respondents while 16% felt no change in dust storms.

Variation in seasonal wind was perceived by majority of respondents, however, 20% perceived no change. For summer wind, 28% respondent perceive blowing of very hot wind while 20% say it was just hot. All farmers unanimously perceived unusual variation in seasons. Maximum respondent (72%) perceived that temperature in summer is increasing due to which this season has become unbearable. Only 4% believed that both winters and summers are increasing in severity. Majority of respondent (88%) perceived that events of hot weather extremes have increased while 12% believed increase in winter. On harmful impact of weather extremes, majority (48%) perceived increase in diseases, while 40% felt bad effect on trees and crops. Only 12% respondents believe that extreme weather events have no effect on human or plant ecosystem. None of the respondents perceived beneficial effect of extreme weather events.

The results on perceived impact are consistent across the space and in conformity with many previous scientific findings. The farmers of Panna have clearly perceived changes in weather and climate. Delayed onset and early withdrawal of monsoonal rains, decrease in number of rainy days, increase in dust storm and droughts, temperature and extreme weather events in summer as well as in winter have multitude of impacts on livelihood and bio diversity of the region. As per historical records there have been only twelve drought years in Bundelkhand during the whole of 19th and 20th century i.e. once in 16 years (Samra, 2008). Frequency of drought increased from one to three in 16 years during 1968-1992. Tiwari et al., (1998) analyzed rainfall data of the region and found that in a cycle of 5 years, 2 are normal, 2 drought years and 1 in excessive rainfall year. However, with the analysis of fifty years (1946-1995) rainfall data of Jhansi district of Bundelkhand region, it was observed that 18% of the years were drought, 68% normal and 14% were surplus years, implying that there is likelihood of one drought year in a span of 5 year (Singh et al., 2002). Out of last 8 years, 6 are severe drought years (2002, 2004-07 and 2009) in the region (Palsaniya et al., 2012). In a study conducted in Kangchenjunga Himalayas, for assessing farmers' perceptions about climate and weather change, Chaudhary et al (2011) reported that overall temperature is increasing with a multitude of impacts on weather and precipitation, snowfall and retreat, and water availability. Similarly, Dhaka et al (2010) reported that most farmers perceived a shift in temperature distribution and its overall increase in Bundi district of Rajasthan. Ecological knowledge in relation to climate held by the indigenous people has also been documented from other parts of the world, mainly North America and Europe. These studies have looked at "native oral tradition" or indigenous knowledge to assess changes in local climate.

Perception about impact on phenological behavior of crops/plants: The farmers of the study area perceived many effects on phenological behavior of crops / grasses and trees (Table 8). A large section of respondents perceived that flowering initiation does not occur timely but, not sure whether initiation was early or late. Contrary to this, 32% respondents perceived that there is no change in time of flower initiation. Only 12% respondents favored early and another set of 12% respondents perceived late initiation in flowering of various crops / plant species. Majority of the respondents perceived, shift in flowering intensity as well. Reduction in flowering intensity was perceived by 36% respondents, while 20% perceived the increase or more flowers. A sizeable number of respondents (16%) perceived more flower drop even though flowering intensity was satisfying. Some respondents (24%) perceived that flower intensity was normal and no change occur.

There was a general perception about the change in flower's shape, size and smell in study area. Decrease in fragrance of mustard flower was perceived by 40% respondents, while 16% believed

Table 8. Perception of farmers' about impact of climate change on phenological behavior of crops / plants

S. No.	Perceived impact	% of total respondents	Remark
1.	Deviation in flowering time		
	Early	12	
	Late	12	
	Normal / no change	32	
	Not timely	44	
2.	Deviation in flowering intensity		
	Low / less flower	36	Flowering in guava is heavy but fruit set is minimum due to flower drop
	Heavy / more flower	20	
	Normal / No change	24	
	More flower but fall down	16	
3.	Change in flower shape / size / smell		
	No difference	12	Earlier smell of mustard flower was very intense but now-days it became very light Fragrance of mustard flower is reduced
	Shape / size and smell changed	32	
	Small flower	16	
	Less smell	40	
4.	Deviation in fruit bearing pattern		
	No change	40	In summer early and in winter late bearing.
	Changed	60	
5.	Deviation fruit shape / size / taste		
	No change	8	Mango, guava and ber became less sweet. The taste of jamun is changed and now it gives more dryness in throat
	Small size	52	
	Bad taste	28	
	Change in taste	12	
6.	Deviation in maturity duration of crop		
	No Change	28	wheat and chick pea mature early due to increase in temperature and water stress
	Early	28	
	Late	44	
7.	Change in keeping quality of fruit / vegetables		
	No Change / normal	32	Easily decay of tomato and pea within 6 to 8 days Less decay of potato and onion
	Easily decay	52	
	Less decay	12	
	other	4	
8.	Change in grain quality of grain / pulses / cereals / oil seeds		
	Grain size reduced	72	Grain size of wheat and mustard reduced The grain of wheat shrinkReduction of oil content in mustard
	Changed grain shape	8	
	Decrease in oil content	12	
	Increase in oil content	4	
	Normal	4	
9.	Change in sowing or harvesting time of crop		
	Normal sowing	20	Late sowing & late harvesting of paddy due to rainfall variation
	Early sowing & late harvesting	8	
	Late sowing & early harvesting	44	
	Late sowing & late harvesting	28	
10.	Change in germination time of crop		
	Normal	36	Germination time of maize reduced
	Early	12	
	Late	52	
11.	Change in productivity of crop / fruits / vegetables		
	Normal / no change	0	Production of wheat, rice and tomato is declining
	Food grain decreasing	92	
	Vegetable decreasing	8	

that flower size has become small. Only 12% of respondents did not perceive any change in flower's shape, size and smell. There was a general perception among respondents (60%) that the fruit bearing patterns has been affected while 40% perceived no change in fruit bearing pattern. The reduction in fruit sized is perceived by 52% respondent while 12 % felt that taste has altered. A sizeable number of respondents (28%) perceived that taste of fruits has gone bad while 8% believed that there was no deviation in shape size or taste of fruits.

In respect of maturity duration of crops, 44% respondents perceived delay in maturity time while 28% said that crop mature early. About 28% respondent did not feel any change in maturity time of crops. The keeping quality of fruits and vegetables is undergoing a shift as perceived by majority of farmers. Easy decaying in tomato and pea was perceived by 52% respondents. However, 32% respondent did not see any change in keeping quality of vegetable or fruits. Except 4% of respondents, all other have perceived changes in grain quality of cereals, pulses and oil seeds. Reduction in grain size of wheat and mustard was perceived by 72% of respondents while 8% realized that wheat grain shrinks. Decrease in oil content in mustard was perceived by 12% of respondents, while 4% perceived the increase. Farmers in study area perceived shift in sowing and harvesting time of crops. The majority of respondents (44%) perceived delayed sowing and early harvesting while 28% opined late sowing and late harvesting of crops. Farmers perceived that germination time of crops is getting altered. Majority (52%) felt that germination get delayed while 12% perceived early germination. About 36% respondent did not perceive any shift in germination time. The general perception of farmers is that the productivity of crops, fruits and vegetable is decreasing. The decrease in yield of wheat and rice is perceived by 92% while in tomato by 8% .

Impact of climate change on phenological behavior plants was reflected in responses of farmers of Panna district. Deviation in flowering time, flower intensity, shape, size and smell of flower, fruit bearing pattern, and shape, size, and taste of fruits have been observed. In crops, change in maturity time, quality of grain, sowing and harvesting time, and yield are the key indicators reflecting impact of unusual weather and climate. According to respondents the changes which have already occurred include increase in fruit drop in guava, decrease in size and taste of mango, jamun and other fruits, reduction in oil content and fragrance in mustard flower, early harvesting of wheat and chick pea, shrinkage and reduction in grain size of wheat etc. Decline productivity of all crops was unanimously felt by villagers. Our findings on phenological behavior of plants corroborates with findings of Moza and Bhatnagar (2005) who suggested changes in plant phenology (like advancement of flowering in *Rhododendron arboreum*) and movement of species (like *Tagetis minuta*, *Lantana camara* and *Eupatorium* spp.) to higher ridges may be the earliest responses to modest climate change in Himalayan region. Another study by Joshi and Joshi, (2011) reported that flowering in *Rhododendron* (*R. arboreum*) occured 1–2 months earlier (January–February instead of March–April) and the size of the flower reduced from about 7–8 inches to 4–5 inches. Early ripening of berries in the Kaphal tree (*Myrica sapinda*, *Myrica nagi*), from May–June to March–April also reflected the phenological changes in tree species of Himalayan region.

Perception about impact on Livestock: Distribution of respondents according to their perception regarding impact of climate change on livestock of the study area has been presented in Table 9. The perception data revealed that a steady shift in feeding habit of domestic animals is taking place. Majority perceived (44%) increase in stall feedings, 8% perceived decrease in grazing while 32% believed that both stall feeding and grazing have increased. The entire respondents perceived change in age of 1^{st} calving of cattle heifers. Majority of respondent perceived increase of age at 1^{st} calving while 12% perceived decrease. Majority of respondents perceived that calving pattern have changed due to climate change whereas 44% respondents perceived no impact. Increased demand of veterinary doctor due to complications at the time of calving is perceived by 32% of respondents. In absence of veterinary help, calves die hence increasing calf death rate is perceived by 24% respondents. The general perception (96%) of farmers is reduction in milk production. However, 4% respondents perceived increase in milk production due to climate change. Poultry was not domesticated in the region.

Farmers perceived that livestock production system is also at risk due to changing weather and climate. In comparison to earlier time now the cattle

Table 9. Perception of farmers' about impact of climate change on behavior of livestock / domestic animals

S. No.	Perceived impact by farmers	% of respondents	Remark
1.	Change in feeding habit of domestic animals		
	Normal / no change	16	
	Increase in stall feeding	44	
	Decrease in grazing	8	
	Both stall feeding and grazing have increased	32	
2.	Change in age of 1st calving of cattle		
	No change	0	Heifers of cross bred animal come early (2-3 years) in calving.Earlier *desi breed* heifers used to come at 1st calving in 3 years, but now more than 3 years (3-4 year)
	Age of 1st calving reduced	12	
	Age of 1st calving increased	88	
3.	Change in calving pattern of cattle		
	Normal / no change	44	Veterinary doctor to be consulted as complications at the time of calving are increasing
	Changed	32	
	Increase in calf death rate	24	
4.	Change in milk Production		
	No Change	0	
	Decreased	96	
	Increased	4	
5.	Unusual behavior of poultry		
	Not domesticated	100	Rearing of poultry is not in practice.

are to be more stall fed, which indicate that both grazing lands and the quality of fodder / browse have decreased. The poor quality fodder is manifested in poor health of animals which, consequently increases age of heifers to reach at 1st calving. Further, poor health also invites more complications in calving process resulting in more deaths of newly borne calves. The ultimate result is decrease in milk production. The changing trends in livestock rearing in the form of more stall feeding due to lack of grazing lands has also been reported by Maharjan et al (2011). They reported decrease in livestock number, outbreak of new disease and decrease in grazing land in Nepal. The reduction milk production as an impact of climatic alteration has also been observed by Joshi and Joshi (2011) in middle Himalaya and Sarkar and Padaria (2010) in coastal ecosystem of West Bengal.

CONCLUSION

The present study concludes that the local communities in the Panna district of Bundelkhand seem to have extensive knowledge and clear cut perception about climate change and its impacts on agriculture, animal husbandry and biodiversity. Their knowledge conforms to the findings generated by other studies in different parts of the country. Delayed onset and early withdrawal of monsoonal rains, decrease in number of rainy days, increase in dust storm and droughts, temperature and extreme weather events in summer as well as in winter have multitude of impacts on livelihood and bio diversity of the region. Deviation in flowering time, flower intensity, shape, size and smell of flower, fruit bearing pattern, and shape, size, and taste of fruits have been observed. In crops, change in maturity time, quality of grain, sowing and harvesting time, and yield are indicated. Decline in productivity of all crops was unanimously felt by villagers. The livestock production system appears to be at risk due to changing weather and climate. In comparison to earlier time, now there is increase in stall feeding, age of heifers to reach at 1st calving, complications in calving process resulting in more deaths of newly borne calves and decrease in milk production.

REFERENCES

Chaudhary P., Rai, S., Wangdi,S., Mao,A., Rehman, N., Chettri, S. and Bawa, K.S. 2011. Consistency of local perceptions of climate change in the Kangchenjunga Himalayas landscape. *Current Science*, 101 (3): 1-10.

Dhaka, B.L., Chayal, K. and Poonia, M.K. 2010. Analysis of Farmers' Perception and Adaptation Strategies to Climate Change. *Libyan Agric. Res. Cen. J. Intl., 1 (6):* 388-390.

Joshi, A.K. and Joshi, P.K. 2011. A rapid inventory of indicators of climate change in the middle Himalaya. *Current Science* 100(6): 831-833.

Maharjan S. K., Sigdel E. R. , Sthapit B. R. and Regmi, B. R 2011. Tharu community's perception on climate changes and their adaptive initiations to withstand its impacts in Western Terai of Nepal. *International NGO Journal* Vol. 6(2):35-42.

Moza, M. K. and Bhatnagar, A. K. 2005. *Current. Science* 89, 243–244.

Palsaniya, D.R., Dhyani, S.K., Singh, R. and Tewari, R.K. 2012. Changing agro-ecological scenario with climate change as perceived by farmers in Bundelkhand, India. Indian J. Forestry 35(1): 21-28.

Prasad, R., Ram Newaj and S.K. Dhyani 2011. Local Innovations for Supporting Climate Resilient Agriculture. *Agroforestry Newsletter* 23 (1):3-4.

Salick, J. and Byg, A., Indigenous peoples and climate change.Tyndall Center for Climate Change Research, Oxford.

Samra, J.S. 2008. Report on Drought mitigation strategy for Bundelkhand region of Uttar Pradesh and Madhya Pradesh. Inter - Ministerial Central Team, pp144.

Sarkar, S. and Padaria, R.N. 2010. Farmers' Awareness and Risk perception about Climate Change in Coastal Ecosystem of West Bengal. *Indian Res. J. Ext. Edu*. 10 (2):32-38.

Singh, G. 2008. Challenges of climate change and options to overcome them. *Intensive Agriculture*, pp.9-16.

Singh, Ramesh, Rizvi, R.H., Kareemulla, K., Dadhwal, K.S. and Solanki, K.R. 2002. Rainfall analysis for investigation of drought at Jhansi in Bundelkhand region. Indian J. Soil Cons. 30(2): 117-121.

Tiwari, A.K., Sharma, A.K., Bhatt, V.K. and Srivastav, M.M. 1998. Drought estimation through rainfall analysis of Bundelkhand region. Indian J. Soil Cons. 26(3): 280-283.

Journal of Soil and Water Conservation **11**(4): 365-371, October-December 2012
ISSN: 022-457X

Crop growth and methane emission dynamics of soil under different methods of transplanting of rice

PRIYANKA SURYAVANSHI[1], Y. V. SINGH[2], K.K. SINGH[3] and Y.S. SHIVAY[4]

Received: 28 June 2012; Accepted: 10 October 2012

ABSTRACT

A field experiment was conducted during the rainy (*kharif*) season of 2010 at the research farm of the IARI, New Delhi to study the influence of methods of rice transplanting and varieties on crop growth, methane emission pattern in soil and to determine the correlation between different genotypic and phenotypic characters and yield. The experiment was laid out in factorial randomized block design (FRBD) with nine treatments combinations comprising three methods of crop establishment viz., conventional transplanting (CT); system of rice intensification (SRI) and double transplanting (DT) and three rice varieties viz., 'Pusa Basmati 1401'; 'Pusa 44' and 'PRH 10'. In CT, SRI and DT seedlings of 21, 12 and 41 days, respectively were transplanted in puddled fields. Results showed that water management through alternate wetting and drying (AWD) in SRI led to one week early maturity compared to CT in all the three cultivars. Rice hybrid 'PRH 10' in SRI gave the highest grain yield (5.36 t/ha) and per day productivity (46.2 kg/day/ha). Rice grain yield had significant positive correlations with root volume (r = 0.816), effective tillers (r = 0.917), dry weight (r = 0.432) and filled grain (0.412). Crop growth rate (CGR) at 60-90 DAT was higher in 'Pusa Basmati 1401'compared to other varieties. Significant temporal variations in the individual methane ûuxes were observed during rice growing period. Flux of methane was higher in early stage of crop and peaked about 21 days after transplanting coinciding with tillering stage of crop. Methane flux was drastically increased when observation was taken after N fertilizer (urea) application. However, methane flux declined gradually from 75 days after transplanting and stabilized at the harvest stage of rice in all the 3 methods of transplanting.

Key words: correlation, methane emission pattern, per day productivity, phenology, rice yield, SRI

INTRODUCTION

Rice is not only a food commodity but also a source of foreign exchange earning of about Rs 11,000 crores annually in India. Based on the population growth (1.4%) and per capita consumption (215-230 g/day), the projected demand for rice in India by 2025 would be around 130 million tonnes(Mahendra, 2000). Irrigated rice production is the largest consumer of water in the agricultural sector, and its sustainability is threatened by increasing water shortages. Such water scarcity necessitates the development of alternative irrigated rice systems that require less water than traditional flooded rice (Bouman *et al.* 2005). Rice crop is known to have very low water use-efficiency and under irrigated conditions it consumes 3,000 to 5,000 litres of water to produce one kilogram of rice. The high water demand for lowland rice cultivation is due to high unproductive water losses (> 80% of water applied), evaporation (16-18%), surface run-off and percolation (50–72%) (Stroosnijder, 1982). Globally, about 90% of the fresh water is used for irrigated agriculture and of this >50% is used in rice cultivation. Water scarcity is becoming more and more a global concern and in India signs of water scarcity are already evident in agricultural areas. Global availability of water has declined from 3,500 m^3 $person^{-1}$ $year^{-1}$ in 1,950 to 1,250 m^3 $person^{-1}$ $year^{-1}$ in 2003 and is estimated to be 760 m^3 $person^{-1}$ $year^{-1}$ in 2050. So there is a need to grow rice with less water without compromising yield.

[1 & 4] Agronomy Division
[2] Centre for Conservation and Utilization of Blue Green Algae (E mail: yvsingh63@yahoo.co.in)
[3] Seed Production Unit, Indian Agricultural Research Institute, New Delhi, 110012, India

Paddy fields are considered as a significant source of methane (CH_4) and nitrous oxide (N_2O) emissions, which have attracted considerable attention due to their contribution to global warming (Hadi *et al.* 2010). Paddy cultivation occupies about 44 million ha in the Indian subcontinent, the largest in Asia, and is one of the major sources of methane emission. Indian rice fields are often blamed to be major contributors of atmospheric methane (Bhatia *et al.*, 2004). CH_4 emissions are controlled by various factors under ûeld conditions, including the water regime and soil characteristics (Yan *et al.* 2009). In permanent ûooded ûelds, methane emissions are much higher than those in mid-season drained ûelds (Cai *et al.* 2003; Mosier *et al.* 2004). The development of efficient irrigation water management minimizes the emission of these gases from paddy soil and intermittent drainage has been proposed as a recommended water management to reduce CH_4 emission from paddy soil (Hadi *et al.* 2010). System of Rice Intensification (SRI) has been proposed as a strategy which is more efficient, resource-saving, and productive way to practice rice farming. SRI, developed in Madagascar with the help of Malagasy farmers, involves reduced water application, including adoption of alternate wet and dry Irrigation (AWDI) as a part of a new strategy of rice intensification *i.e.* growing rice under mostly aerobic soil conditions(Uphoff *et al.* 2011). Double transplanting has been reported as promising method of transplanting, especially under contingent conditions (Routray, 2006; Akter *et al.* 2008) however, it has not been evaluated in terms of greenhouse gas emission potential. Considering these facts, the experiment was undertaken to study the effect of different transplanting methods on plant growth of rice and methane emission pattern from soil.

MATERIALS AND METHODS

The experiment was conducted during rainy (*kharif*) season (June-November) of 2010 at the research farm of Indian Agricultural Research Institute, New Delhi, situated at a latitude of 28°40' N and longitude of 77°12' E, altitude of 228.6 meters above the mean sea level (Arabian Sea). The mean annual rainfall of Delhi is 650 mm and more than 80% generally occurs during the south-west monsoon season (July-September) with mean annual evaporation 850 mm. However during the year 2010, more than normal rainfall was received. There was 929.8 mm rainfall during June to November and July, August and September months had 9, 11 and 15 number of rainy days, respectively. The soils of experimental field had 139.9 kg ha^{-1} alkaline permanganate oxidizable N, 15.64 kg ha^{-1} available P, 283.2 kg 1 *N* ammonium acetate exchangeable K and 0.56% organic carbon. The pH of soil was 7.8 (1: 2.5 soil and water ratio).

The experiment was laid out in factorial randomized block design with nine treatments combinations comprising of three methods of crop establishment viz., conventional transplanting (CT); system of rice intensification (SRI) and double transplanting (DT) and 3 rice varieties / hybrid viz., 'Pusa Basmati 1401; 'Pusa 44' and 'PRH 10' and these treatments were replicated four times. In CT, twenty-one days old seedlings of rice varieties were transplanted at 20 cm × 10 cm spacing keeping 2 seedlings $hill^{-1}$. For DT, uprooted seedlings were transplanted on another land in closer spacing (7.5 cm x 7.5 cm). When the total age of these seedlings became 41 days, they were uprooted again and transplanted on the main field. For SRI, 12 days old seedlings were transplanted in main field. In conventional and double transplanting method 5 cm cropping water was maintained from transplanting to grain filling stage of crop and later only moist soil conditions were maintained. However in SRI, alternate wetting and drying conditions were maintained throughout the cropping season. In the experiment equal dose of inorganic fertilizers (120:60:40) kg N, P_2O_5 and K_2O ha^{-1} was applied in all the treatments. Observations on plant growth, yield attributes and yield were recorded by standard methods. Crop growth rate (CGR) referred to the dry matter accumulation of the crop per unit land area in unit of time expressed as g m^{-2} d^{-1}. The mean CGR values for the crop during the sampling intervals were computed using the formula of Brown (1984).

$$CGR\ (g\ m^{-2}\ d^{-1}) = W_2 - W_1 \div SA\ (t_2 - t_1)$$

Where,

SA= Ground area occupied by the plant at each sampling. W_1 and W_2 are the total dry matter production in grams at the time t_1 and t_2, respectively.

Methane gas sample collection and analysis

Collection of gas samples for methane (CH_4) was carried out by the closed-chamber technique using the chambers of 50 cm x 30 cm x 100 cm (length x width x height) (Pathak *et al.* 2002). First sample was taken on 14 July (7 DAT) and it was followed by sampling at 14, 21, 30, 45, 60, 75, 90 and 105 DAT in CT and SRI. In DT first sampling was done with the third sampling (21DAT) in other two methods of stand establishment. This chamber was placed between the rows of the plants and one hill was kept inside the chamber. One fan was installed in this box for homogenization of gas in the chamber.One aluminium metal platform was inserted in soil to keep the box and water was filled in groves to prevent the leakage of gas. One hill of rice seedlings were covered in each sampling chamber. Gas samples were drawn with 50 ml syringe with the help of a hypodermic needle (24 gauge) at 0, 15 and 30 min for CH_4. The samples of gases were collected and brought to the laboratory where they were analyzed within 2 hours. Concentration of CH_4 in the gas samples was estimated by Gas Chromatograph ûtted with a ûame ionization detector (FID). Samples of three replications were taken from each method of stand establishment and the mean was taken as the representative value for that method.

A gas chromatograph meter fitted with a 6–1/8-ft stainless-steel column (Porapack N; length × inner diameter: 3 m × 2 mm) and a flame ionization detector (FID) was used for measuring CH_4. For determination of methane, N_2 (flow rate 330 ml min$^{”1}$), H_2 (flow rate 30 ml min$^{”1}$), and zero air (flow rate 400 ml min$^{”1}$) were used as the carrier, fuel and supporting gas, respectively. Column, injector and detector temperature were set at 55, 100 and 200°C, respectively.

The gas emission flux was calculated from the difference in gas concentration according to the equation of Zheng *et al.* (1998).

$$F = ph\left(\frac{dC}{dt}\right) 273(273+T)^{-1}$$

where F is the gas emission flux (mg m$^{”2}$ h$^{”1}$), ñ is the gas density at the standard state, *h* is the height of chamber above the soil (m), *C* is the gas mixing ratio concentration (mg m$^{”3}$), *t* is the time intervals of each time (h), and *T* is the mean air temperature inside the chamber during sampling.

RESULTS AND DISCUSSION

Effect on plant growth and yield

Tillering is an important morpho-physiological trait for grain yield in rice. Conventional transplanting (CT) recorded an increase in tillers from 387.3 (60 DAT) to 472.0 at 90 DAT which was significantly higher than SRI being 325.6 and 426 at 60 and 90 DAT, respectively (Table 1). Double transplanting (DT) registered lowest number of tillers at 30 and 60 DAT, but DT was *at par* with SRI in tiller count at 90DAT. Rice hybrid, 'PRH 10' produced significantly higher number of tillers compared to inbred varieties 'Pusa Basmati 1401' and 'Pusa 44'. Lu *et al*. (2004) also reported higher number of tillers in closer spacing that contributed to obtain higher yield. 'PRH 10' produced significantly higher number of tillers at all the observations as compared to inbred varieties 'Pusa Basmati 1401' and 'Pusa 44'. Yoshida (1972) reported that rice hybrid variety had more tillering capacity than inbred variety. Higher dry matter production is the ultimate goal of application of any inputs in crop because it is directly related to the yield. At 60 DAT, SRI recorded significantly higher dry matter accumulation (246.3 g m^{-2}) followed by CT (225.7 g m^{-2}) and DT (214.4 g m^{-2}). However, at 90 DAT, both SRI and DT were statistically *at par*. Among the varieties,' PRH 10'

Table 1. Effect of methods of crop establishment and varieties on plant growth parameters

Treatment	Total tillers (m^{-2})		Dry matter accumulation (g m^{-2})		CGR(g m^{-2}day $^{-1}$)
	60 DAT	90 DAT	60 DAT	90 DAT	60-90 DAT
Planting Method					
Conventional	387.2	472.0	225.7	744.4	17.7
SRI	327.8	426.8	246.3	775.9	17.7
Double transplanting	262.3	450.8	214.4	739.2	17.1
LSD (P=0.05)	36.10	27.34	17.19	26.84	NS
Variety					
'PRH 10'	328.2	438.6	240.9	773.4	17.8
'Pusa Basmati 1401'	309.8	430.6	218.8	771.5	18.2
'Pusa 44'	339.3	480.3	226.8	714.8	16.5
LSD (P=0.05)	NS	27.34	17.19	26.84	1.1

produced the highest dry matter (241.0 g m^{-2}) which was significantly higher than 'Pusa 44' (226.8 g m^{-2}) and 'Pusa Basmati 1401' (218.8 g m^{-2}) at 60 and 90 DAT. The rapid increase of dry matter was observed between 60 DAT and 90 DAT. It was due to the maximum growth and tillering of plant in this period. After 70 DAT although tillers mortality and senescence occurred but reproductive parts contributed a considerable amount of dry matter in plant. Crop growth rate (CGR) was significantly affected by genotypes between 60-90 DAT, the maximum being in 'Pusa Basmati 1401'. After maximum vegetative stage (90 DAT) the growth rate declined. However, CGR among the methods of cultivation was *at par*.

Rice hybrid 'PRH 10' performed better over the varieties 'Pusa 44' and 'PB 1401' under SRI compared to CT. All the three cultivars performed better in SRI than than CT and DT, but 'PRH 10' gave the highest yield in SRI (5.3 t/ha).(Table 2). Per day grain productivity was higher in SRI in all three varieties compared o CT and DT. Contrary to the perception that SRI method is genotype neutral, significant differences were observed between the varieties under SRI in terms of grain yield. Nissanka and Bandara (2004) reported that grain yield was 7.6 t ha^{-1} in the SRI and it was 9% greater than the conventional transplanting and they suggested that the higher grain yield production in the SRI farming system might be attributed to the vigorous and healthy growth, development of more productive tillers and leaves ensuring greater resource utilization in the SRI compared to conventional transplanting. Since seed requirement is quite low in SRI, this could be the best method for cultivating hybrids whose seed cost is relatively higher compared to inbreds.

In this experiment total duration of crop was reduced in SRI compared to CT and DT (Table 2). A mean reduction of 11 days to 50% flowering was recorded across the methods and varieties. Crop maturity was found 8 to 10 days earlier than CT and DT in all the cultivars. Thus SRI can help in water saving and timely sowing of succeeding crop. Paraye and Kandalkar(1994) reported a delay of 8 days in flowering due to the delay in transplanting by 20 days.Uphoff (2005) reported that SRI required reduced time for maturity. Due to reduction in duration and increase in yields, per day crop productivity was found to be the highest in 'PRH 10' grown under SRI method (46.2 kg/day/ha) and it was lowest in'Pusa Basmati 1401' under CT (27 kg/day/ha). Similar results were reported earlier (Ramesh, 2007; Subba Rao, 2007).

Yield formation in cereals is a complex coordinated process that involves the build-up and subsequent re-assimilation of yield components. These processes are under genetic control and strongly affected by environmental conditions. The correlation among the various plant growth, yield attributes and yield were estimated which indicated all the yield attributes were highly correlated with yield. The attributes like ear bearing tillers, filled grains per panicle, 1000-grain weight and panicle weight showed high positive correlations with grain yield (Table 3). The positive correlation between root volume and grain yield also was recorded (Fig 1).

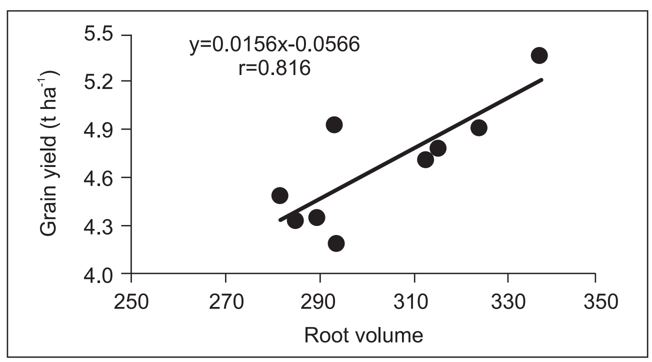


Fig 1: Relationship between grain yield and root volume (cc/0.3 m^2) in rice

Table 2. Effect of methods of crop establishment and varieties of rice on maturity period, grain yield and per day grain productivity

Parameter	Conventional transplanting			SRI			Double transplanting		
	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3
Days to 50% flowering	90	115	98	86	110	95	98	122	105
Days to maturity	121	144	128	116	134	121	128	156	136
Grain yield (t ha^{-1})	4.90	4.48	4.18	5.36	4.93	4.78	4.73	4.33	4.35
Per day grain productivity (kg ha^{-1})	40.4	31.1	32.6	46.2	36.8	39.5	36.9	27.7	31.9

V_1 = 'PRH 10', V_2 = 'Pusa Basmati 1401' and V_3 = 'Pusa 44'

Table 3. Correlation between plant growth, yield attributes and grain yield of rice

	Effective tillers	Dry weight	Total grain	Filled grain	Fertility index	Panicle weight	Test weight	Grain yield
Effective tillers	1.000	0.315	0.515	0.611*	0.634*	0.722**	0.571	0.910**
Dry weight		1.000	-0.508	-0.403	0.174	-0.123	-0.367	0.432
Total grain			1.000	0.977**	0.380	0.627	0.810**	0.306
Filled grain				1.000	0.568	0.614*	0.778	0.409
Fertility index					1.000	0.252	0.273	0.578
Panicle weight						1.000	0..860**	0.772**
Test weight							1.000	0.539
Grain yield								1.000

Similar findings were reported by Geetha (1993) and Meenakshi *et al.* (1999).

Methane emission pattern

The pattern of methane ûux from rice transplanted with three different methods was analysed by measuring methane at 7, 15, 21, 30, 45, 60, 75, 90 and 105 days after transplanting (Fig.2). The methane flux fluctuated between 79.7 to 482.0 under CT; 46.0 to 315.0 in SRI and 86.7 to 467.3 in DT. Considerable temporal variations in the individual methane ûuxes were observed. Methane ûuxes increased sharply to a very high level right after transplanting of rice and peaked within about 3 week in SRI and CT, then decreased gradually to a negligible amount towards harvest. In DT, flux peak was noticed in first observation itself. Results indicated that overall methane emission concentrations were higher at tillering stage of crop. The methane flux peaks were found when observations were taken at 21 and 60 DAT, after application of chemical fertilizer (urea). Methane flux came to mean levels, few days after application of fertilizer. The flux of methane was generally higher in early stage of crop and peaked about one month after transplanting at a late tillering stage. Methane flux declined gradually 75 days after transplanting and stabilized at the harvest stage of rice in all the 3 methods of transplanting. Cumulative methane flux was highest in conventional transplanting throughout followed by double transplanting and SRI. Lindau *et al.* (1991) also showed that urea fertilization increased CH_4 emissions by 86% with the application of 300 kg N ha^{-1} when compared with the control plot. Higher emission of methane due to urea application could also be due to the presence of blue green algae biofertilizer, which provided mediation of CH_4 transport from floodwater of rice soil into the atmosphere (Ying *et al.* 2000). In this field blue green algae was applied in previous years and this field is under rice-wheat cropping since last 10 years. A higher CH_4 emission at tillering stage is generally due to the lower rhizospheric CH_4 oxidation and more effective transport mediated by rice plants. Flux of methane was generally higher in early stage of crop and peaked about one month after transplanting coinciding with active tillering stage of the crop. Methane flux declined gradually from 75 days after transplanting and stabilized at the physiological maturity of rice in all the 3 methods of transplanting. Cumulative methane flux was the highest in conventional transplanting throughout followed by double transplanting and SRI. Total methane emission was highest in CT (32.33 kg ha^{-1}) followed by DT (29.30 kg ha^{-1}) and SRI (19.93 kg ha^{-1}). Global warming potential (GWP) of CT was the highest (807.4 kg CO_2 ha^{-1}) followed by DT (732.5 kg CO_2 ha^{-1}) in and SRI (498.25 kg CO_2 ha^{-1}). The higher methane emission under flooded rice has been reported (Bhatia *et al.* 2005). Hadi *et al.* (2010) suggested that intermittent irrigation and drainage

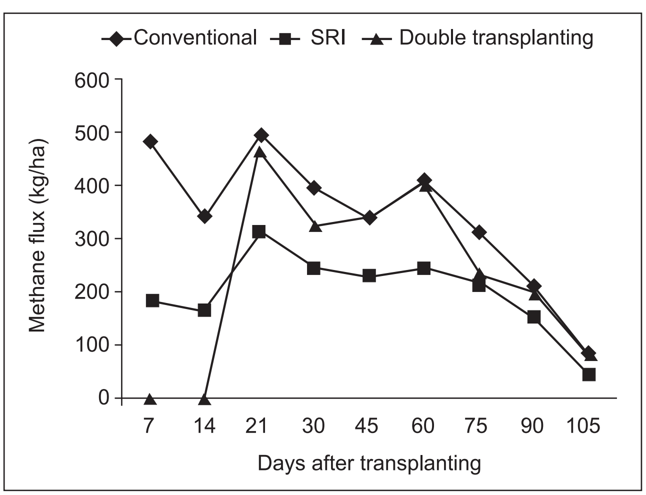


Fig. 2. Effect of methods of rice transplanting on methane flux

can be a suitable option to reduce greenhouse gas emission from paddy soil in Japan and Indonesia. In SRI, alternate drying and wetting conditions were maintained and these conditions reduced methane emission. CH_4 emission fluxes peak was recorded at 60 DAT also. It may be possibly due to the fact that rice was at the highest growing stage, the available organic carbon in the form of root exudates increased (Kumaraswamy *et al.* 2000), which led to an increase in methanogen population. But, at later growth stages of rice, CH_4 emission fluxes decline gradually (Yoshida, 1978) and CH_4 was at relatively low levels at physiological maturity of crop. This was due to drainage from the fields as a result there was increase in the activities of the oxidized phase and decreased activity of the reduced phase, leading to a gradual increase in the Eh of soil (Takai, 1970). Due to maintenance of aerobic conditions in SRI, the activity of methane producing bacteria was less and thus methane production was much lower under SRI. In double transplanting method, methane emission flux maintained the trend as found in CT, but due to late transplanting in DT by 20 days, total methane emission was low. The variations in methane emission from soils planted with different rice establishment methods are in agreement with the findings reported by other researchers (Kludze *et al.* 1996). The root exudates have been implicated to be the major source of methane in rice and a considerable variation in the root exudate pattern of different rice varieties exists (Ghosh *et al.* 1995).

System of rice intensification (SRI) was found very favourable in terms of better crop growth, yield attributes and yield of rice. Rice hybrid 'PRH 10' may be more suitable for SRI compared to inbred varieties. Reduced water application in SRI supplemented by reduced duration can considerably reduce water use without compromising yield. Methane emission also was considerably lower in SRI thus it was better for the environment.

REFERENCES

Akter, M.S., Islam, M.A., Amin, H.A. and Bakul, M.R.A. 2008.Comparative efficiency of separated tiller vs *bolon* practice in t-*aman* rice. *Bangladesh Res. Publ. J.* **1**: 255-263.

Bhatia, A., Pathak, H. and Aggarwal, P. K. 2005. Inventory of methane and nitrous oxide emissions from agricultural soils of India and their global warming potential. *Current Sci*. **87**(3): 317-324.

Bouman, B.A.M., Peng, S., Castaneda, A.R. and Visperas, R.M. 2005.Yield and water use of irrigated tropical aerobic rice systems. *Agricultural Water Management* **74**:87–105.

Cai, Z., Sawamoto, T., Li, C., Kang, G., Boonjawat, J., Mosier, A., Wassmann, R., and Tsuruta, H. 2003. Field validation of the DNDC model for greenhouse gas emissions in East Asian cropping systems, *Global Biogeochemical Cycles* **17**: 1104-1107.

Geetha, S. 1993. Relationship between straw and grain yield in rice. *Agril. Sci. Digest*. **13**(3): 145-146

Ghosh S, Jain MC, Sinha S(1995) Estimates of global methane production from rice paddies based on substrate requirement, *Current Sci.* **69**: 937–939.

Hadi, A., Inubushi, K. and Yagi, K. 2010. Effect of water management on greenhouse gas emissions and microbial properties of paddy soils in Japan and Indonesia. *Paddy Water Env*. **8**: 319–324.

Kludge HK, Kludze D.1996. Soil redox intensity effects on oxygen exchange and growth of cattail and sawgrass. *J Soil Sci Soc America*. **35**: 616–621.

Kumaraswamy S, Rath AK, Ramakrishnan B, Sethunathan N.2000. Wetland rice soils as sources and sinks of methane: a review and prospects for research. *Biol Fert Soils* **31** (6): 449-461.

Lindau CW, Bollich PK, Delaune RD, Patrick WH, Law VJ. 1991. Effects of urea fertilizer and environmental factors on CH_4 emissions from Louisiana, USA rice field. *Plant Soil.* **136**:195-203.

Lu W.F., Chen W., Duan B.W., Guo W.M., Lu Y. and Lantin R.S. 2000. Methane emissions and mitigation options in irrigated rice fields in southeast China. *Nutri. Cycl. Agroecosys.* **58**:65-73.

Mahendra K.R.2000. System of Rice Intensification (SRI)– Present Status and Future Prospects. Rice system management portal. Directorate of Rice Research, Rajendranagar, Hyderabad, p 2-5.

Meenakshi T, Amirathadevarativum and Backiyarni S.1999. Correlation and path analysis of yield and some physiological characters in rainfed rice. *Oryza* **36**: 154-156

Mosier A, King J, Palm C.2004.Methane and nitrous oxide fluxes in tropical agricultural soils: sources, sinks and mechanism. *Environ Devlop Sustain* **6**:11-49.

Nissanka, S.P. and Bandara, T. 2004.Comparison of productivity of system of rice intensification and conventional rice farming systems in the dry-zone region of Sri Lanka. New directions for a diverse planet: Proceedings of the 4th International Crop Science Congress. Brisbane, Australia, 26 Sep.-1 Oct. 2004, pp.100-114.

Paraye, P.M. and Kandalkar, V.S. 1994. Effect of seedling age on long duration, rainfed variety of rice (*Oryza sativa*) under delayed transplanting. *Indian J. Agric. Sci.,* **64**(3): 187-188.

Pathak, H., Bhatia, A., Shiv Prasad, Singh, S., Kumar, S., Jain, M.C. and Kumar, U. 2002: Emission of nitrous oxide from soil in rice-wheat systems of Indo-Gangetic plains of India, *Environmental Monitoring and Assessment* **77** (2):163–178.

Ramesh B.P. 2007. Response of Rice varieties to SRI method of cultivation. In extended Summaries of National System of Rice Intensification (SRI) held at Agartala, Tripura, p 58.

Rautray, S.K. 2006. Yield and economics of promising rice (*Oryza sativa*) hybrids under double transplanting in late spring summer (boro) situation. *Indian J. Agric. Sci.* **76**(8):469-471

Stroosnijder, L.1982. Soil evaporation: Test of a practical approach under semi-arid conditions. *Netherland J. Agi. Sci,*. **35**: 417-426.

Subba Rao, L.V., Mahender Kumar, R., Chaitanya, U., Padmavathi, Ch., Surekha, K., Latha, P.C., Prasad, M.S., Rupela, O.P., Vinod Goud., Shobha Rani, N and Viraktamath, B.C. 2007.Quality Seed Production through System of Rice Intensification (SRI) in extended Summaries of National System of Rice Intensification (SRI)' held at Agartala, Tripura, –p58.

Takai, Y. 1970. The mechanism of methane fermentation in flooded paddy soil. *Soil Sci. Plant Nutition*. **16**: 238-244.

Uphoff, N. 2005. Possible explanations for the productivity gains achieved with the System of Rice Intensification (SRI). *In*: *Transitions in Agriculture for enhancing Water Productivity*. Proceedings of an International Symposium held in Killikulam, Tamil Nadu, India during 23-25, September 2003.

Uphoff, N., Kassam, K. and Harwood, R. 2011. SRI as a methodology for raising crop and water productivity: productive adaptations in rice agronomy and irrigation water management. *Paddy Water Environment.* **9**:3-11

Ying Z, Boecky P, Chen GX, Van Cleemput O.2000. Influence of *Azolla* on methane emission from rice fields. *Nutr Cycling Agroecosyst* **58**: 321–326.

Yoshida, S. 1972. Physiological aspects of grain yield. *Annual Review Plant Physiology* **23:**437-464.

Yoshida T .1978. Microbial metabolism in rice soils. In: IRRI (ed) Soil and rice. IRRI, Los Banos, Philippines, pp. 445–436.

Zhang L, Yu D, Shi X, Weindorf D, Zhao L, Ding W, Wang H, Pan J, Li CS.1998. Quantifying methane emissions from rice fields in the Taihu Lake region, China by coupling a detailed soil database with biogeochemical model. *Biogeosciences* **6**: 739–749.

Journal of Soil and Water Conservation **11**(4): 372-379, October-December 2012
ISSN: 022-457X

Role of communication technologies for enhancing farmers' agricultural knowledge

V.K. BHARTI[1], HANS RAJ[2], SURAJ BHAN[3] and PANKAJ KUMAR

Received: 12 December 2011; Accepted: 18 June 2012

ABSTRACT

Development experiences of the last decades have shown that human resources development is essential for food security and market integration. New agricultural technologies are generated by research institutes, universities, private companies, and by the farmers themselves. Agricultural advisory services (including traditional extension, consultancy, business development and agricultural information services) are expected to disseminate new technologies amongst farming community. The role of research and advisory services is to give highly accurate, specific and unbiased technical and management information and advice in direct response to the needs of the farmers. Due to poor linkages between research and advisory services, the adoption of new agricultural technologies by farmers is often very slow and research is not focusing on the actual needs of farmers. In Agricultural Knowledge and Information Systems, people and institutions are linked together to promote and enable mutual learning and generate, share and use agriculture-related technology, knowledge, skills and information. The system integrates farmers, agricultural educators, researchers, extension workers and the private sector to harness knowledge and information from various sources for better farming and improved livelihoods. The areas like; soil fertility, soil health, climate change, environment, effective utilization of water for higher productivity, watershed management, natural resource management, post harvest technologies, are the burning issues which are to be addressed effectively to farming community in order to enhance their knowledge which will make us agriculturally sustainable in future.

Key words: community radio, traditional media, development communication, indigenous technology, mass media, village level workers

INTRODUCTION

India is an agricultural country, where 70 per cent population is dependent on agriculture. Agriculture is the backbone of Indian economy. Agriculture is the main source of earning livelihood of the people. The planners in developing countries realized that the development of agriculture could be hastened with the effective use of mass media. Mass media plays a crucial role in information distribution. Radio, Television has been acclaimed to be the most effective media for transforming knowledge to the farmers. The television and radio, which is a strong media of communication is of vital importance and significant, as they transfer modern agricultural technology to literate and illiterate farmers alike even in interior areas, within very short time. With the main stream of Indian population engaged actively in agriculture, television could serve as a suitable medium of dissemination of farm information and latest technical know – how. The farmers can easily understand the operations, technology and instruction through television. Community radio, social media and traditional medias are still playing important role in enhancing the knowledge of the farmers in India.

Today is the age of communication, and if one says that every sphere of life is booming only due to the communication revolution, it is not exaggeration

[1] Chief Production Officer, [2] Information System Officer, Directorate of Knowledge Management in Agriculture, ICAR, KAB-I, New Delhi-110012
[3] President, Soil Conservation Society of India, New Delhi-110012

of the facts. Farm sector is not an exception, as each and every aspect of modern agriculture is to be communicated to the final user of the technology in the shortest possible time i.e. without a time lag. Indian farmers are using all available media of communication to become up-to-date in the latest agriculture information. (Jangid 2003).

Community Radio: an effective tool for agricultural development

In India, where literacy remains a substantial barrier to development, radio especially community radio, can reach a large number of poor people because it is affordable and uses less electricity. In 2000, AIR programmes could be heard in two-third of all Indian households in 24 languages and 146 dialects, over some 120 million radio sets. Community Radio gives a voice to the community they serve with programmes in local languages, respecting local culture, traditions and interests. Community Radio provides a counterbalance to the increasing globalization and commercialization of media. Most TV and radio stations, including public stations, are concentrated in urban areas.

In the more remote, rural areas, Community Radio stations are often the only media available, where they are listened to by large parts of the population. Community Radio stations fill the gap left by national and commercial media, and reach local audiences the national media ignore. They fulfill the role of public broadcaster, informing the public at a local level, and representing their views. In this way, they give a voice to the voiceless, enabling people to speak and make their opinions, grievances and ideas known to those who have the power to make decisions.

Community radio and internet

The internet holds potential for development, especially in rural areas. For example, information about agriculture, environment, health can be downloaded from it, it can be used to connect health workers, agricultural extension workers or ordinary village, with technical experts to discuss some particular problem and it can be use to put communities in contact with each other for online discussions and debates about issues that effects them.

Community radio for agricultural development

Agriculture has always been a highly knowledge-intensive sector requiring continuous information flow. Farmers' quest for authentic, credible and usable information both from established systems and traditional practices is ever increasing in this fluctuating global environment, to operate efficiently and compete economically. The rapid changes happening around with WTO / globalization, uncontrolled urbanization, uncertainty in climate change, discerning consumer segment and continued farm crisis emphasize the importance of timely, appropriate and need based information and knowledge to meet myriad developmental challenges.Effective extension, education and communication services are probably some of the key strategies for sustaining agricultural growth, strengthening food security and combating hunger and malnutrition. However, diverse socio-cultural backgrounds, linguistic barriers, geographical remoteness and differential incentives make the task of information dissemination challenging.

Radio is a powerful communication tool. India's post-independence experiments with ICT use in agricultural development started with radio. A network of All India Radio (AIR) stations were established across the country that broadcast agricultural programmes in regional languages. AIR (now Prasar Bharati) has been playing a significant role since many years – bringing new technological information on agriculture and other allied subjects to the farmers. With the recent liberalization of the broadcasting licensing policy, Community Radio has received a new impetus in India. This form of participatory communication has proved to be very successful as a tool for social and economic development at grass root level. The local community needs which are often neglected by the mainstream media could be adequately addressed by community radio. Even farmer to farmer extension can be easily made possible through adequate capacity building as the HAM radio experience underway in Tamil Nadu and Andhra Pradesh shows.

Experience with rural radio has shown the potential for agricultural extension to benefit from both the reach and the relevance that local broadcasting can achieve through participatory communication approaches. Extension workers use radio for communicating information on new methods & techniques, giving timely information about the control of crop pests & diseases, weather, market news, etc. For this purpose, talks, group discussions, folksongs, dialogues & dramas are usually organised.

There is an interesting combination of approaches in the use of rural radio for agriculture extension. They are locally focussed, using indigenous knowledge to build on local cultural and agro-ecological diversity, blending with technology and scientific innovation. Also a two way communication of sharing farmers experience can be an interesting adaptation. Historically agriculture extension has often failed to communicate technical information to farmers in a way that has enabled it to be adopted locally. Thus the combinations of approaches strike an effective balance between indigenous and scientific approaches to agricultural development. However using radio for agriculture extension is just one dimension, as rural radio can serve multiple roles of extending socio-economic development in rural areas such as health, nutrition, sanitation etc.

Traditional media: an effective communication Tool to sustain rural agriculture

Communication plays an important role in the development of nation. It is a process through which message, ideas, feelings and facts are conveyed to have common understanding. The useful developmental messages need to convey to the target group through various communication approached and should be understood in the context of its social structure. To approach rural farmers to make efficient, productive and sustainable use of their land and other agricultural resources it is necessary to provide information, advice, education and training by using traditional media. In India majority of the population belong to rural area, where these traditional media is grass root culture of the rural population. They serve as a significant tool in the process of motivating people in desired direction. With this concept certain traditional media are identified for making people aware about the concept of organic farming system which includes farm visits, demonstration, and street play, motivational tours etc. as it help in making the task of nation building and socio economic development easier and acceptable to rural masses.

Communication through traditional media

Providing knowledge to the farmers for agriculture plays an important role in achieving food security of the nation. It will strengthen and reframe the agricultural system for healthy and better life style. This world consequently help them to protect their natural assets like land and water therefore organic farming practices help rural farmers for sustainable land and other natural resources.

Sustainable development can only take place through an integrated approach in which the present situation is accepted as starting point. While considering agriculture, an understanding of the present farming, and land use systems and natural resource management is necessary. This has to be combined with the limitation and possibilities of natural ecosystem as well as the study of the agricultural knowledge and experience of the farming communities. It is important to develop understanding of the present situation, assessment of the potentials for agriculture development within available physical, biological and human resources in a region.

In rural setting the things are often worse for farmers. Changes from traditional to conventional farming practices did not bring much expected improvement of the lifestyle and income earning capacity. It did not being the much needed neither food security nor it bring harmony between people, and harmony with nature. Organic farming system is directed towards enhancing natural life, protecting ecosystem and natural resources. The organic movement has a responsibility in empowering farmers to enable them to play an active role in their development and improving life style.

Traditional media can be the most effective in rural area, tribal area and among illiterates as they do not understand the language of modern communication. Therefore, traditional media is nothing but the tool of communication having special characteristics to express socio-cultural, religious, moral and emotional needs of the people of society to which they belong.

Traditional media used to sustain rural agriculture

To create awareness, traditional media plays an important role as it help farmers to make efficient, productive and sustainable use of their land and other agricultural resources through the providing information, training and education. In this reference, certain traditional media need to identify to assist farm people to improve farming methods and techniques, to increase production, efficiency and income which ultimately improve their level of living and lift the social and educational standards of rural life.

Farm Visit: Meeting individual farmers or group of farmers in their farm can make them comfortable to share their problems. When group of farmers are present, they can discuss their local problems and solution can be given to them immediately.

Training: To give training of new techniques and methods. Practical knowledge is more effective and removes all doubts and problems. Training can be organized in village farm itself.

Demonstration: Demonstration is useful tool for the transfer of knowledge and encourages farmers to try new ideas and technology which is suitable in their area.

Agriculture Fair: In case of organic farming system fairs are helpful to create awareness about improved technology among large number of people within a short period of time. It helps farmers to see new technology, methods displayed by other farmers and government and non government agencies. It provides some relevant literature and discuss in a lively and informal atmosphere.

Visit and Motivational Tour: Visit to other farm and research organization or people who are successful in this area give farmers an opportunity to interact directly with experts in this area. Their problems will be solved on the spot and they are motivated also as seen others successful in this field.

Puppet: This is most popular to educate people. It is a dramatic expression with the help of little creatures called puppets. This will add entertainment in the whole process. Thus, traditional media have capacity to change and adopt the socio political situation. Message is fully realised when it passes through the attitude and behavioural pattern of the people.

Traditional media has found an effective tool in rural setup. They are used for educational purpose and as a tool to reform society. It is accepted by rural mass because it convey educational message through entertainment, colour, costume and dance. As it constitutes an integral part of the culture, the audience is able to identify itself with the experience provided by traditional media.

Social media to empower farmers

Farming has, as always, been a sociable sort of business. Farmers chat with other farmers to pick up cultivation tips and news about the outside world. Till now, the chats were face to face under the village banyan tree. Now, farmers are spreading the word, whether personal or business, through email, SMS, Facebook, Twitter, YouTube and blogs. And it is no teenage fad. Social media has become Indian farm's latest survival tool. It is true that there are very few computers in India's six lakh villages. Less than 0.5% of families have internet facility at home, says the National Sample Survey Organisation report on expenditure in 2009-10. But that is no longer a barrier to internet access. With mobile phones in the pockets of four out of every 10 rural people, internet, Facebook and email are a push-button away. This has transformed the game.

The social media revolution is operating at several levels. It empowers farmers with knowledge. Farmers continuously need information about new seeds, pest attacks, weather and rainfall, machinery, plant protection and prices. This helps them choose the right crop, utilise resources efficiently, maximise yield and income.

A host of SMS-based services are replacing traditional sources of information such as TV, radio, newspaper, extension workers and the local dealers and brokers that were neither timely nor reliable. For instance, Reuters Market Light, and IffcoKisan Sanchar, launched in some states in 2007 and 2008, is now becoming popular. Farmers pay to get customized SMSes and voice mails, several times daily, in the local language, which provide a variety of information throughout the cultivation cycle of their chosen crops, right up to *mandi* prices.

Social media encourages smarter farming through opportunities to learn from agricultural experts, progressive farmers and the community's thought leaders. Agropedia, spearheaded by IIT-Kanpur, is trying to create a kind of Facebook for agriculture where experts from across India can easily communicate with each other. Social media is able to cross the hurdle of illiteracy that has left small and marginal farmers to the mercy of traders and middlemen. Services such as Digital Green, Spoken Web, ConspeakousVoiceGen and VoiKiosk are using audio and video uploads to convey crop and market information. A mobile-based service, called GappaGoshti, allows Maharashtra farmers to send audio and video messages without using the keypad. During a tour of Punjab, two users shared videos of paddy fields on the social network. The rest of the users in Maharashtra could see the fields without actually travelling to Punjab.

Social media is allowing farmers to take charge of their lives. With this 'invisible technology' under the hood, people with no access to newspapers, TV or radios that broadcast in their native language, are becoming citizen reporters by using audio and video to record events in and around their fields, their villages and their community.

Mobile news service CGnetSwara (Voice of Chhattisgarh), developed with the help of Microsoft Research India, is transforming how people in remote areas receive and share news. Word has spread that a quick cell phone call can lead to food deliveries for hungry children, government investigation of police brutality and medical help.

Literate farmers are using Facebook to create a pan-India community of people growing the same crop, which can mobilise opinion and rapidly transmit information. It's a potent tool. In February, Maharashtra farmers used Facebook to boycott Sangli, Asia's biggest turmeric mandi, because traders were fleecing them.

Social media is helping farmers close the urban-rural divide. Farmers in organic, dairy, horticulture and floriculture have understood that they can customise their products better by using websites and blogs to connect with customers. Small tea growers in West Bengal are on Facebook and Twitter to interact with foreign buyers. The spread of mobile phones proves rural folk are ready to invest and adopt any new technology that can dramatically improve their lives. Social media gives the phone extra potency by empowering farmers with knowledge, encouraging precision agriculture and bridging the producer-customer and urban-rural divide. The digital revolution is promising millions of Indian farmers escape from poverty.

Development communication in India

Over the years of development experience in India has clearly indicated that it is not just economic modeling, legislative action or administrative reform that propels development. The key is motivation and that too at the mass level-mobilisation of commitment, involvement, participation and dedication of masses in planning and developmental tasks. It is in this area that the Indian woman could be the most powerful channel for motivation and development. Her moral force in the house of parents, the husband, children and others is stronger than that in any other society in the world. She has the unmatched faculty of being able to inspire others to act as she wishes. The ethical force she exerts is enmeshed in our religious convictions. Her participation in customs and ritual is inseparable from our culture.

In India, of late, the planners have realized the value of communication as an input in the overall developmental-approach to the rural sector. The real problem is one of tailoring media to suit to the aspirations of the people, and mobilizing media for development keeping in mind that illiteracy is the major barrier to communication. Some popular media in India include the followings:

- The radio has a wide coverage of agriculture and rural change programmes in Indian languages and dialects.
- The television devotes only 5 per cent of the time to rural programmes, the rest goes for entertainment, films, news, etc.
- The Hindi films are solely a means of entertainment for the masses, reinforcing existing values, projecting fatalism, fantasy and mythology.
- The reach of the process is limited to urban and sub-urban areas as the rate of literacy is very low among the rural population.
- The government has a field publicity unit as well as a song and drama division that propagates development messages through the use of folk music of drama forms and film screening. But the staff is limited and is unable to cope with the vast demands of the population.
- The number of village level workers is also inadequate. Very often, the VLW's job is target-oriented rather than people-oriented.

Till now the approach to rural developmental has been specific with communication as a supporting unit. India has not yet fully exploited for developmental efforts the 'little media' such as tape cassettes, 8 mm films and slide shows. They can be made specific to the needs of the village population and are easily operable by VLWs.

It is hoped that in the years to come communication policies and planning in the country will be sufficiently localized in content, decentralized in set up, giving scope for upward articulation of feedback.

Mass media

An extension worker desirous of bringing change for the masses can reach them, teach them and create desirable behavioural changes through the mass media. The opportunities are there for all the media, old or new to participate in the grand endeavour of development. In India, the mass media have to be rural oriented, for about 76 percent of the population lives in rural areas. Despite the enormous expansion of communication facilities over the years, the reach of mass media is limited, especially in the rural areas and amongst the weaker sections of the society. This is mainly due to five mutually reinforcing factors like, low literacy rate, language barriers, low purchasing power, poor means of transportation for timely delivery of newspapers or maintenance of radio or TV sets and lack of relevant information if purposive communication is the aim of media policy. Radio and television technology offer great potential for the communication of anything man can hear or see more quickly and cheaply to a large audience at one time. Similarly, the print media can perform as a basic communication tool for the total population.

Village Level Workers (VLW)

Development of mass media as instrument for getting development messages across to the people has brought about a neglect of the human factor. Mere information via mass media cannot automatically bring about motivation, action and change. For this purpose, the Village level workers can be an effective link for communicating at the grass root level. Village level workers has that personal touch, knowledge of his environment and the ability to initiate a mutual permanent and direct discussion with the villagers. The Village level workers contribute greatly to the developmental process by:

1. Collecting information about new ideas, techniques and practices from the central agency and disseminating it to the villagers. At the same time he initiates feedback about problems, needs and wishes of the people and provides this information to his agency for future activities.
2. Persuading and motivating villagers to try new ideas.
3. Trying to understand the socio-cultural barriers to acceptance and how to overcome them.
4. Arranging financial or technical support from the central agency or instructing support from the central agency or instructing villagers on how to prepare the needed instruments themselves.
5. The VLW opens the gates of communication of his village to the outside world. He can control the communication channels going to the villages and vice-versa.

Communicating indigenous technology

In designing a communication system for sharing of indigenous technology, we should rely heavily on the traditional media, channels, particularly in rural areas, because despite modernisation and industrialization, the rural people continue to rely on human and oral communication. The spread and effect of mass media on the bulk of the population that lives in rural areas is small. What is required for development is not unregulated and so called free flow of information but optimal dose of communication, which might act as a support to and nourish the development process. There is an urgent need for considerable research and action-oriented studies to design optimal, low- cost human oriented systems. Efforts have to be made to reach the people through audiovisual and interpersonal means of communication with locally available and indigenous forms of communication like folklore, puppetry and little media. Suggestions for comprehensive development communication approach

- Identify the role of various communication media, like films TV, radio, print, advertising and marketing in the development process.
- Develop inventories of overall resources in the communication area
- Locate developmental areas where the impact of communication can lead to accelerated growth.
- Determine the investment policy required for meeting the priorities.
- Recommend the special linkages, which need to connect the areas of education, culture, and communication.
- Examine how communication software and hardware systems can be improved with special reference to social change, cultural values and appropriate technology.
- Develop appropriate computer software programmers for scholastic, scientific, and social science studies.

- Develop the role of communication in the management areas.
- Suggest organizational, administrative, physical and legal measures required for planning, implementing monitoring and evaluating programmers formulated for giving effect to the relevant components of a National Communication Policy.

Rural communication and development

Development experiences of the last decades have shown that human resources development is essential for food security and market integration. Achieving sustainable agricultural development is less based on material inputs (e.g., seeds and fertilizer) than on the people involved in their use. New agricultural technologies are generated by research institutes, universities, private companies, and by the farmers themselves. Agricultural advisory services (including traditional extension, consultancy, business development and agricultural information services) are expected to disseminate new technologies amongst their clients. The role of research and advisory services is to give highly accurate, specific and unbiased technical and management information and advice in direct response to the needs of their clients. Due to poor linkages between research and advisory services,the adoption of new agricultural technologies by farmers is often very slow and research is not focusing on the actual needs of farmers. In many countries low agricultural production has been attributed, among other factors, to poor linkages between Research-Advisory Service-Farmers and to ineffective technology delivery systems, including poor information packaging, inadequate communication systems and poor methodologies.

In the traditional research context, agricultural scientists tend to overlook situations at the farm level. Their research projects are often oriented at producing publications rather than solving concrete on-farm problems. Producers on the other hand expect immediate answers to local problems, and are not concerned with experimental details or the goals and objectives of the scientists. Many linkage problems between major institutional actors are caused by alack of coordinated planning, poor communication between linkage partners, and absence of follow through with actual linkage resource planning or implementation. In addition, there is typically little or no involvement at all of representative farmers or their organizations. A lack of appropriate communication structures, methodologies and tools results in poor identification of farmers' needs and priorities, in appropriate research programs, poor or irrelevant extension information and technologies and finally, low farmers' take-up of technology innovations.

Rural communication is an interactive process in which information, knowledge and skills, relevant for development are exchanged between farmers, extension / advisory services, information providers and research either personally or through media such as radio, print and more recently the new "Information and Communication Technologies" (ICTs). In this process allactors may be innovators, intermediaries and receivers of information andknowledge. The aim is to put rural people in a position to have the necessary information for informed decision-making and the relevant skills to improvetheir livelihoods. Communication in this context is therefore a non-linear process with the content of data or information.

In communication for development approaches, the rural people are at the centre of any given development initiative and view planners, development workers, local authorities, farmers and rural people as "communication equals", equally committed to mutual understanding and concerted action. Communication for development is used for: people's participation and community mobilization, decision-making and action, confidence building, for raising awareness, sharing knowledge and changing attitudes, behaviour and life styles; for improving learning and training and rapidly spreading information; to assist with programme planning and formulation; to foster the support of decision-makers.

CONCLUSION

Green revolution has developed food crisis and raise need of more agricultural product as population increases. To fulfil the forcing need of more food farmers started using pesticides and chemical fertilizers in agriculture system which exploits the nature. In rural areas, communication needs and available channels are facing tremendous changes through structural transformations: subsistence oriented farming remains the basis for food security especially in disadvantaged areas, while there is a general shift to move intermediate farmers into market-oriented production. Market-oriented farmers need tostay competitive in an increasingly global business environment. While agriculture remains the mainstay for rural people, information and skills for alternative livelihoods gain in importance, not only as an exit strategy, butalso for the increasing division of labour. Each of these groups of farmers has specific communication needs and capacities for innovation, management and finance. However, client / demand-oriented service provision for innovation, information, qualification and local organizational development remains the key driver. These reform processes and their opportunities and consequences need to be communicated properly to rural people. On the other side, efforts to close the information gap and, inparticular, the digital divide in rural areas, have been supported by the wider availability and accessibility of communication technologies and infrastructures, like internet, rural radio and mobile phones.

REFERENCES

Jangid, B.L. 2003. Utilization of mass media of communication for agricultural information by the farmers at International Conference on Communication for Development in the Information Age: Extending the Benefits of Technology for All

Kokate, K.D. and others 2011. Future Agricultural Extension

Indian Council of Agricultural Research 2011. Proceedings of fourth national conference on Krishi Vigyan Kendra on KVK as Resource and Knowledge Centre for Agricultural Technology

Sharma, Arpita, Community Radio as an effective tool for agricultural development by traditional media.

Srinivas, Nidhi Nath 2012. Bringing Farmville to life: How social media empowers farmers

SOIL CONSERVATION SOCIETY OF INDIA

G-4/A, NATIONAL SOCIETIES BLOCK, NASC COMPEX, DEV PRAKASH SHASTRI MARG, New Delhi-110012

INCOME AND EXPENDITURE STATEMENT FOR THE YEAR ENDING 31ST MARCH, 2012

Previous Yr. Rs. P.	EXPENDITURE	Current Year Rs. P.	Previous Yr. Rs. P.	INCOME	Current Year Rs. P.
6,293.00	Entertainment/Hospitality Expenses	7,677.00	1,475.00	Admission Fee	1,450.00
41,291.00	Stationary & Printings Expenses	61,371.50	8,210.00	Annual Membership Subscription	12,190.00
3,33,319.00	Publication of Journals of SCSI Expenses	2,34,724.00	43,500.00	Library Membership Subscription	34,500.00
1,05,841.00	Postage Expenses	72,659.00	2,82,770.54	Interest on Deposit/Bank Interest	5,02,001.50
60,300.00	Salary, Wages Remuneration etc. Paid	91,800.00	550.00	Student Annual Membership Subscription	1,790.00
5,994.00	Miscellaneous Expenses	1,320.00	488.00	Sale of Old Journals	470.00
85,740.00	Depreciation to Stock & Assets of SCSI	65,283.00	13,776.00	Miscellaneous Receipts	15,012.00
11,030.00	Audit Fee Paid	11,236.00	66,000.00	Overheads/Institutional Exp. Received for Trainings	1,51,600.00
19,995.00	Telephone Rent/Calls Charges	32,576.00	1,86,000.00	Sale of Society's Publications	2,29,340.00
5,750.00	Conveyance Hiring Expenses	6,780.00		**Financial Assistance for Prtg. of Journals by ICAR**	
65,000.00	Annual Rent Paid to ICAR	65,000.00	-	- For the year 2010-11 Rs. 75,000.00	
10,031.00	Web-Site of SCSI Renewal Charges	22,060.00	-	- For the year 2011-12 Rs.1,31,250.00	2,06,250.00
27,101.00	Publication of Newsletters of SCSI Expenses	13,597.00	20,250.00	Registration Fee of National Conference	-
6,150.00	Subscription for Newsletters, Journals etc. Expenses	1,000.00	900.00	Sale of Tree Guides	-
1,00,518.00	Travelling (Outstation) Expenses of National Conf.	14,136.00		**Financial Assistance for National Conference by**	
24,021.00	Printing of Bulletin of National Conference	-	1,50,000.00	- National Bio Diversity Authority	-
50.00	Bank Charges/Commission Paid	-	1,00,000.00	- M/s. Reliance Infrastructure Ltd.	-
1,650.00	Repairs/Annual Maintenance Contract Expenses	-	98,000.00	- M/s. Arcelor Mittal India Ltd.	-
1,46,180.00	Other Publication of SCSI	-	50,000.00	- M/s. M.J.M.EnviroNet (P) Ltd.	-
			50,000.00	- Directorate of Agri. Mizoram	-
15,665.54	**Excess of income over expenditure**	**4,53,384.00**			
10,71,919.54	**TOTAL**	**11,54,603.50**	**10,71,919.54**	**TOTAL**	**11,54,603.50**

Place : New Delhi
Dated : 03.08.2012

Verified and found correct

Sd/-
for Rajesh Kumar Sachdeva & Associates
Flat No. 1013, Naurang House
21, Kasturba Gandhi Marg, New Delhi – 110001

Sd/-
(SURAJ BHAN)
President

Sd/-
(B. RATH)
Secretary General

Sd/-
(B.S. NEGI)
Treasurer

SOIL CONSISERVATION SOCIETY OF INDIA
G-4/A, NATIONAL SOCIETIES BLOCK, NASC COMPLEX
DEV PRAKASH SHASTRI MARG, NEW DELHI – 110012

BALANCE SHEET AS ON 31ST MARCH, 2012

Previous Year 2010-11 Rs. P.	LIABILITIES			Current Year 2011-12 Rs. P.
37,47,619.27	**Funds & Liability**			
	(a) General Reserve Funds as on 31.03.2011	-	Rs. 37,47,619-27	6,02,003.27
	Less Transferred to Corpus Fund of Society	-	(-) Rs. 35,99,000-00	
	Added Excess of Expenditure over Income	-	(+) Rs. 4,53,384-00	
1,00,000.00	(b) Corpus Fund of Society (SCSI)	-	Rs. 1,01,000.00	
	Added Transferred from General Reserve	-	(+) Rs. 35,99,000-00	37,00,000.00
18,80,780.00	(c) Share Towards Life Membership as Liability	-	Rs.18,80,780-00	
	Added contribution towards liability since 01-04-11	-	(+) Rs. 56,128-00	19,36,908.00
1,582.00	(d) Suspense Account		…..	1,582.00
11,030.00	(e) Provision for Outstanding Audit Fee For 2001-11		…..	11,236.00
520.00	(f) Provision for Late (Dr.) K.G. Tejwani Charitable Trust Award		…..	520.00
50,000.00	(g) Provision for Prof. J.S. Bali's Gold Medal Award		…..	50,000.00
42,961.00	(h) Provision for Late Y.P. Bali Memorial Fund		…..	42,961.00
1,300.00	(i) Friends of Tree Memberships Subscription		…..	1,300.00
-	(j) Outstanding Transfer of Funds to RCS-SCSI		…..	-
4,881.00	(k) Outstanding Payment to Dr. S. Subramaniyan's Account		…..	4,881.00
58,40,673.27			**TOTAL**	**63,51,391.27**

Contd.....

Previous Year 2010-11 Rs. P.	ASSETS		Current Year 2011-12 Rs. P.
Property and Stocks			
26,419.00	(a) Almirahs (11 Nos.) of Steel Made	Rs. 26,419-00	
	Less Depreciation @ 15%	(-) Rs. 3,963 -00	22,456.00
15,976.00	(b) Personal Computer (2 Nos.) with other Accessories	Rs. 15,976-00	
	Less Depreciation @ 60%	(-) Rs. 9,586-00	6,390.00
8,913.00	(c) Fax Machine	Rs. 8,913-00	
	Less Depreciation @ 15%	(-) Rs. 1,337-00	7,576.00
3,090.00	(d) Printers (1 Nos.) of HP-6L Gold / HP-PSC-14100	Rs. 3,090-00	
	Added Printer Purchased	(+) Rs. 6,458-00	
	Less Depreciation @ 60%	(-) Rs. 5,889-00	3,659.00
1,243.00	(e) C.V.T. Voltage Regulator	Rs. 1,243-00	
	Less Depreciation @ 15%	(-) Rs. 186-00	1,057.00
2,94,831.00	(f) Furniture & Fixture For Office Premises of SCSI	Rs.2,94,831-00	
	Less Depreciation @ 10%	(-) Rs. 29,483-00	2,65,348.00
63,517.00	(g) Automatic Duplexing Unit	Rs. 63,517-00	
	Less Depreciation @ 15%	(-) Rs. 9,528-00	53,989.00
33,545.00	(h) Hitachi Split Air Conditioner (2 TON)	Rs. 33,545-00	
	Less Depreciation @ 15%	(-) Rs. 5,032-00	28,513.00
4,524.00	(i) Refrigerator (180 ltrs. - Kelvinator)	Rs. 4,524-00	
	Less Depreciation @ 15%	(-) Rs. 679-00	3,845.00
	Outstanding Advances from		
32,778.00	Advances to SCSI, KSC for National Conference on BIOWD, 2009	…..	32,778.00
	Investments		
41,35,420.97	Fixed Deposits of Society at Syndicate Bank at Pusa Campus, New Delhi	…..	51,53,058.15
	Current Assets		
12,09,640.30	(a) Balance in Syndicate Bank Branch at Pusa Campus, New Delhi	…..	7,66,490.12
8,974.00	(b) Cash-In-Hand	…..	4,184.00
1,802.00	(c) Balance Unused Postal Stamp-tickets	…..	2,048.00
58,40,673.27	**TOTAL**		**63,51,391.27**

Place : New Delhi
Dated : 03.08.2012

Verified and found correct

Sd/-
for Rajesh Kumar Sachdeva & Associates
Flat No. 1013, Naurang House
21, Kasturba Gandhi Marg, New Delhi – 110001

Sd/-	Sd/-	Sd/-
(SURAJ BHAN)	(B. RATH)	(B.S. NEGI)
President	Secretary General	Treasurer

SOIL CONSISERVATION SOCIETY OF INDIA
G-4/A, NATIONAL SOCIETIES BLOCK, NASC COMPLEX
DEV PRAKASH SHASTRI MARG, NEW DELHI – 110012

INCOME AND EXPENDITURE STATEMENT FOR THE YEAR ENDING 31ST MARCH, 2012

Previous Yr. Rs. P.	EXPENDITURE	Current Year Rs. P.	Previous Yr. Rs. P.	INCOME	Current Year Rs. P.
	IMPACT EVALUATION STUDIES-NWDPRA			IMPACT EVALUATION STUDIES-NWDPRA	
2,25,670.00	Travelling Outstation Expenses of IES-NWDPRA	52,150.00	4,88,766.00	Amount received for IES-NWDPRA of NRAA	-
1,31,560.00	Salary Paid to Supporting Staff of IES-NWDPRA	44,400.00			
2,595.00	Presentations Expenses of IES-NWDPRA	-			
45,299.00	Miscellaneous Expenses of IES-NWDPRA	12,374.00			
3,51,000.00	Payment For Consultancy Services of IES-NWDPR	-			
8,235.00	Stationary/Equipment Expenses of IES-NWDPRA	-			
2,62,840.00	Printing of Project Report Expen. of IES-NWDPRA	-			
10,068.00	TDS on the payment of NRAA	-			
41,134.00	Service Tax charged on IES-NWDPRA	-			
664.50	Bank Charges/Commission Paid Account	-			
	BIO-INDUSTRIAL WATERSHED DEV., UP			**BIO-INDUSTRIAL WATERSHED DEV., UP**	
6,358.00	Travelling Outstation Expenses of BIWD A/C.	1,47,060.00	-	Amount received for BIWD of Govt. of UP	2,70,000.00
-	Salary + Honoarium to Supporting Staff of BIWD	93,150.00			
2,115.00	Miscellaneous + Presentation Expen. of BIWD A/C.	23,823.00			
90,000.00	Payment For Consultancy Services of BIWD A/C.	1,18,000.00			
1,211.00	Stationary/Equipment Expenses of BIWD A/C.	9,255.00			
26,906.00	Printing of Project Report Expen. of BIWD A/C.	-			
-	Service Tax charged on BIWD A/C.	27,419.00			
	PERSPECTIVE PLAN–ARU. PRADESH			**PERSPECTIVE PLAN – ARU. PRADESH**	
1,10,000.00	Travelling Expenses of Perspective Plan of AP	66,466.00	-	Amount received for Studies from Govt. of AP	3,19,200.00
-	Salary to Supporting Staff of Perspective Plan of AP	27,296.00			
-	Presentations Expenses of IES-NWDPRA	740.00			
-	Miscellaneous Expenses of Perspective Plan of AP	1,328.00			
-	Payment For Consultancy Services of P/Plan of AP	1,50,000.00			
17,143.50	Printing of Project Report of Perspective Plan-AP	45,150.00			
-	Service Tax charged on Perspective Plan of AP	31,670.00			
3,600.00	Printing of Report of Mizoram Training	-			
	IMPACT EVALUATION STUDIES-NWDPRA			**IMPACT EVALUATION STUDIES-NWDPRA**	
-	Payment For Consultancy Services of IES-NWDPR	70,000.00	-	Amount received from IES-NWDPRA of NRAA	1,45,520.00
-	Stationary/Equipment Expenses of IES-NWDPRA	11,840.00			
-	Service Tax charged on IES-NWDPRA	14,398.00			
-	Bank Charges/Commission Paid Account	479.50			
	CAPACITY BUILDING PROGRAMME IN NER			**CAPACITY BUILDING PROGRAMME IN NER**	
-	Boarding & Lodging Expenses of CBP-Manipur	8,37,600.00	-	Amount received for IES-NWDPRA of NRAA	12,23,700.00
-	Training Materials Expenses of CBP-Manipur	1,23,000.00			
-	Honorarium to Resource Persons of CBP- Manipur	31,000.00			
-	Honorarium to Training Coord. of CBP- Manipur	8,500.00			
	C/o	**19,47,098.50**		**C/o**	**19,58,420.00**

Previous Yr. Rs. P.	EXPENDITURE	Current Year Rs. P.	Previous Yr. Rs. P.	INCOME	Current Year Rs. P.
-	Local Transport Expenses of CBP- Manipur	63,500.00			
-	Miscellaneous Expenses of CBP- Manipur	12,000.00			
-	T.A. to Resource Persons of CBP- Manipur	62,500.00			
-	Overhead / Institutional Expn. of CBP- Manipur	85,600.00			
	CAPACITY BUILDING PROGRAMME IN NER			**CAPACITY BUILDING PROGRAMME IN NER**	
4,89,185.00	Boarding & Lodging Expenses of CBP-Mizoram	4,90,000.00	6,97,000.00	Amount received for IES-NWDPRA of NRAA	6,30,000.00
60,000.00	Training Materials Expenses of CBP-Mizoram	37,500.00			
24,000.00	Honorarium to Resource Persons of CBP-Mizoram	12,000.00			
5,000.00	Honorarium to Training Coord. of CBP-Mizoram	2,500.00			
35,000.00	Local Transport Expenses of CBP-Mizoram	20,000.00			
7,102.00	Miscellaneous Expenses of CBP-Mizoram	5,000.00			
40.713.00	T.A. to Resource Persons of CBP-Mizoram	30,000.00			
36,000.00	Overhead / Institutional Expn. of CBP-Mizoram	33,000.00			
	CAPACITY BUILDING PROGRAMME IN NER			**CAPACITY BUILDING PROGRAMME IN NER**	
3,88,500.00	Boarding & Lodging Expenses of CBP-Sikkim	4,90,000.00	5,93,500.00	Amount received for IES-NWDPRA of NRAA	6,27,500.00
50,000.00	Training Materials Expenses of CBP-Sikkim	39,119.00			
24,000.00	Honorarium to Resource Persons of CBP-Sikkim	10,000.00			
5,000.00	Honorarium to Training Coord. of CBP-Sikkim	2,500.00			
35,000.00	Local Transport Expenses of CBP-Sikkim	20,000.00			
5,938.00	Miscellaneous Expenses of CBP-Sikkim	3,012.00			
55,062.00	T.A. to Resource Persons of CBP-Sikkim	29,869.00			
30,000.00	Overhead / Institutional Expn. of CBP-Sikkim	33,000.00			
		8,47,633.00		***Excess of Expdt. Transferred to respective Heads A/C***	
-	***Surplus transferred to respective Heads of A/C.***			**-Trf. to IES-NWDPRA of NRAA (-)Rs.1,08,924.00**	
	- Trf. to IES-NWDPRA – Gujarat, NRAA	**48,802.50**		**-Trf. to BIWD of Uttar Pradesh (-)Rs.1,48,707.00**	
				-Trf. to Perspective Plan of AP (-)Rs. 3,450.00	**2,61,081.00**
26,26,899.00	**TOTAL**	**34,77,001.00**	**26,26,899.00**	**TOTAL**	**34,77,001.00**

Place : New Delhi
Dated : 03.08.2012

Verified and found correct

Sd/-
for Rajesh Kumar Sachdeva & Associates
Flat No. 1013, Naurang House
21, Kasturba Gandhi Marg, New Delhi – 110001

Sd/-
(SURAJ BHAN)
Chairman (Core Committee)

Sd/-
(SHAMSHER SINGH)
Member Secretary General
(Core Committee)

Sd/-
(T.K. SARKAR)
Member (Core Committee)

RURAL CONSULTANCY SERVICES-SCSI
G-4/A, NATIONAL SOCIETIES BLOCK, NASC COMPEX
D.P.S. MARG, New Delhi – 110012

BALANCE-SHEET FOR THE YEAR ENDING 31ST MARCH, 2012

YEAR 2010-11	LIABILITIES			YEAR 2011-12
	Surplus Transferred to the respective Source			
1,08,941.00	(a) Balance Amount for IES-NWDPRA of NRAA A/C.	…	Rs.1,08,941.00	
	Less Excess of expdt. trf. from Income & Expdt. A/C.	…	(-)Rs.1,08,924.00	17.00
1,48,707.00	(b) Balance Amount for BIWD of Uttar Pradesh A/C.	…	Rs.1,48,707.00	
	Added Amount received for BIWD of U.P. A/C.	…	(+)Rs.2,70,000.00	
	Less Expenditure of the year From BIWD of U.P. A/C.	…	(-)Rs.2,70,000.00	
	Less Excess of expdt trf. From Income & Expdt. A/C.	…	(-)Rs.1,48,707.00	-
1,71,998.50	(c) Balance Amount for Perspective Plan of A.P. A/C.	…	Rs.1,71,998.50	
	Added Amount received for Persp/Plan of A.P. A/C.	…	(+)Rs.3,19,200.00	
	Less Expenditure of the year From Persp Plan of A.P.	…	(-)Rs.3,19,200.00	
	Less Excess of expdt trf. From Income & Expdt. A/C.	…	(-)Rs. 3,450.00	1,68,548.50
-	(d) Bal. Amount for IES-NWDPRA-Gujaratof NRAA A/C.	…	Rs.1,45,520.00	
	Less Expdt. of the year From IES-NWDPRA-Gujarat	…	(-)Rs. 96,717.50	48,802.50
	Outstanding Credit/Advances of Training A/C			
	(a) Advances for Training Programme of Arunachal Pradesh	…	Rs.6,10,500.00	
	(b) Advances for Training Programme of Tripura State	…	Rs.6,70,000.00	12,80,500.00
4,29,646.50			**TOTAL**	**14,97,868.00**

YEAR 2010-11	ASSETS			YEAR 2011-12
	Outstanding Debit/Advances during the year			
7,000.00-	(a) Advances Paid to Dr. T.K. Sarkar	…		
	(b) Advances Paid to Dr. Suraj Bhan for Trg. Prog.	…	Rs.10,50,000.00	10,50,000.00
	Current Assets/Balances at the end of the year			
4,21,424.50	(a) Balances in current account at Syndicate Bank, NASC	…	-	4,36,228.00
1,222.00	(b) Cash-in-Hand	…	-	11,640.00
4,29,646.50			**TOTAL**	**14,97,868.00**

Place : New Delhi
Dated : 03.08.2012

Verified and found correct

Sd/-
for Rajesh Kumar Sachdeva & Associates
Flat No. 1013, Naurang House
21, Kasturba Gandhi Marg, New Delhi – 110001

Sd/-
(SURAJ BHAN)
President

Sd/-
(SHAMSHER SINGH)
Secretary General
(Core Committee)

Sd/-
(T.K. SARKAR)
Member
(Core Committee)

ACKNOWLEDGEMENT

Our sincere thanks are placed on record to the
Indian Council of Agricultural Research, New Delhi *for the grant of financial support for the publication of journal of the Association.*