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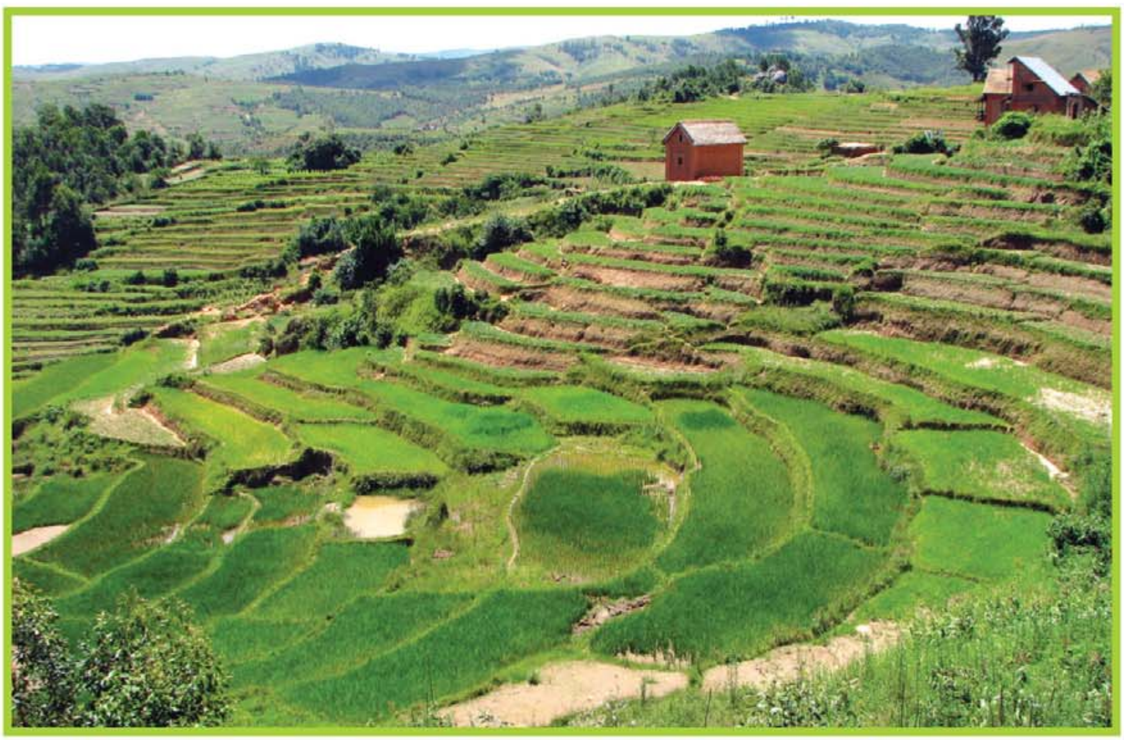

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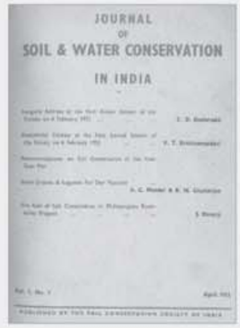

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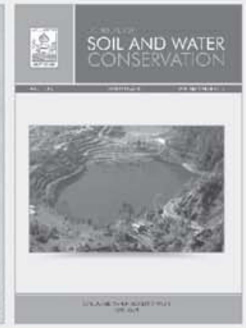

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Land degradation processes and factors affecting crop production in Foothills of Jammu Shivaliks

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ABSTRACT

Wide scale land degradation of catchments in terms of land, soil and vegetation has been observed in the foothill Himalayas of Jammu region. An attempt was made to identify and relate the factors involved in land degradation. It was found that there exists a continuous cycle of events, involving both natural and anthropogenic factors, promoting land degradation. The weak lithology of the lower Shivaliks consisting of rocks like sandstone, conglomerate, shale, silt stone and limestone are relatively easily weatherable and therefore prone to quick erosion. Sloping relief pattern results in accelerated erosion causing removal of surface material. Surface runoff is higher on sloping lands resulting in lesser percolation of water which is essential for profile development. The high intensity rainfall during monsoon disturbs the top soil, and in turn loosens it, resulting in sheet and rill erosion. Increased population coupled with poverty is putting pressure on land maintenance. Younger generations among the farming community has lesser interest in farming and, therefore, the maintenance of land takes a back seat. Lack of knowledge regarding soil and water conservation measures is another important factor contributing towards land degradation in the area. Only 43 per cent of the farmers in the lower Shivaliks of Jammu are aware about the severity of the problems related to runoff and soil loss. Increased population pressure and smaller land holdings have promoted deforestation leading to unabated soil loss and land degradation. All the above factors lead to continuous land degradation, thereby reducing the productivity of these lands, which in turn affects the economic condition of the farmers luring them to other sources of employment and the cycle continues. The challenge lies in protecting the limited land resource from further degradation, improving productivity of land and eroding poverty in Jammu region of the state.

Key words: Land degradation cycle, Himalayan foothills, Jammu and Kashmir, Soil erosion

INTRODUCTION

The predominantly hilly state of Jammu and Kashmir is divided into three political divisions *viz.* Jammu, Kashmir and Ladakh; each having its own set of agro-climatic zones. These agro-climatic zones suffer enormously from land degradation processes of different magnitude. The lower or the foothill Himalayas fall under the Jammu division of the state, extending from district Kathua in the southeast to Rajouri in the northwest, constituting about 12% of the total area of Jammu region. It is a dry semi-hilly belt, locally known as *kandi*. Land degradation is common in the catchments of lower Shivaliks of Jammu. The productivity of the soils of this region of Jammu is not only low but highly unstable. Soil erosion due to high runoff, results in sizeable loss of soil and nutrient and, is primarily responsible for low productivity and poor economic status of the farmers in these rainfed areas (Gupta *et al.*, 2010). The loss of top soil results in loss of nutrients necessary for plant growth, which influences the production and productivity of the crops. Soil erosion in the Shivalik or Southern Himalayas is due to massive deforestation and severe denudation of the hills and causes severe floods in the plains besides removal of more than 80 tonnes of soil ha^{-1} $year^{-1}$ (Sharma, 2004). Loss of plant nutrients, however, varies according to land use pattern. The top soils from forest and well managed cultivated land contained 0.83 and 0.58 per cent organic carbon, respectively, as compared to 0.40 and 0.30 per cent from the barren and unmanaged cultivated land (Gupta, 1994). Due to fragility, marginality, low accessibility and resource heterogeneity, there is little scope for enhancing crop productivity with the existing infrastructural facilities and the level of adoption of technologies. There is urgent need to identify the processes promoting land degradation and site specific technologies need to be developed for resource conservation.

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PHYSIOGRAPHY

The lower shivaliks of Jammu and Kashmir are classified under the physiographic unit Hills ranging from 320 to 720 meters above mean sea level (Rashid and Arora, 2007) (Fig. 1). The area is mostly dominated by Shivalik, Muree and Subathu group of sediments. The general lithology is sandstone, conglomerate, shale, silt stone and limestone. The lower Shivalik rainfed area of Jammu has unique land, soil and climatic features representing a semi-arid or sub-humid type of climate. However, the climate of the whole area is characterized by sub-tropical nature. The region is characterized by erratic rainfall (750-1200 mm annually), undulating terrain, frequent droughts, low soil organic matter and coarse textured soils. The soil surface is infested with sand stones and water retention capacity is extremely poor. The agriculture in the region is totally dependent on monsoonal rains. About 80 % of the rains occur in first two months of monsoon season (July-August), with high intensity rainstorms. The average temperature during summer, winter and rainy seasons varies between 18°C and 40°C, 4°C and 23°C and 14°C and 32°C, respectively. During the rainy season the soil erosion is heavy, resulting in loss of nutrients and removal of top fertile soil layer. Comparison of crop yields showed that average productivity of various crops is poor in *kandi* region compared to the state as a whole or country (Table 1). The yields are even lower than the same *kandi* belt (lower Shivaliks) extending into the state of Punjab, especially that of wheat where the yield is nearly two and a half times that of the *kandi* belt of Jammu. This shows that there is lot of potential to enhance the yields in this part of the state of Jammu and Kashmir provided degradation is checked and proper measures are taken. Economically, this is the most underdeveloped part of the state in which a substantial proportion of the population is living in poverty (Husain, 2000).

LAND DEGRADATION PROCESS

The entire lower shivaliks are drained by a number of major and minor rivers which include Chenab, Tawi, Basantar and Ujh. Apart from these, there are ephemeral streams (*khads*) like Devak, Bain, Bhagar and Sahar dotting the landscape. The

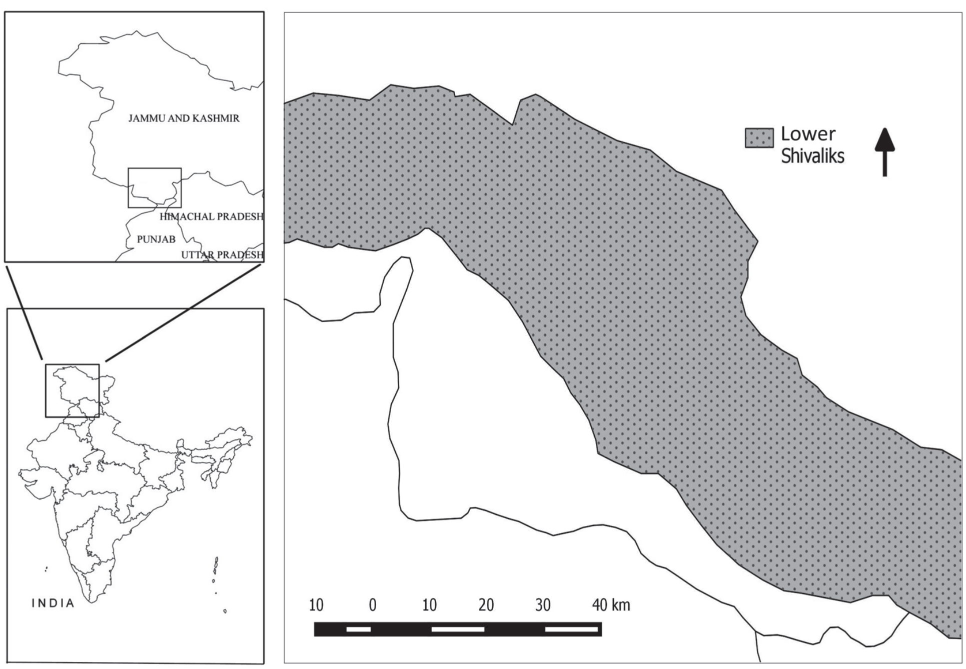

Fig. 1. Location map of the Lower Shivaliks (*kandi* belt) of Jammu division of J & K

Table 1. Comparison of major crop yields of *kandi* region of Jammu

Crop	Yield (kg ha^{-1})			
	Lower Shivaliks of Jammu (*Kandi* region)	J&K state	Punjab (*Kandi* region)	All India
Wheat	890	1530	2408	2583
Maize	1205	1710	1370	1755
Coarse cereals	1165	1617	1650	1065
Pulses	450	564	664	622

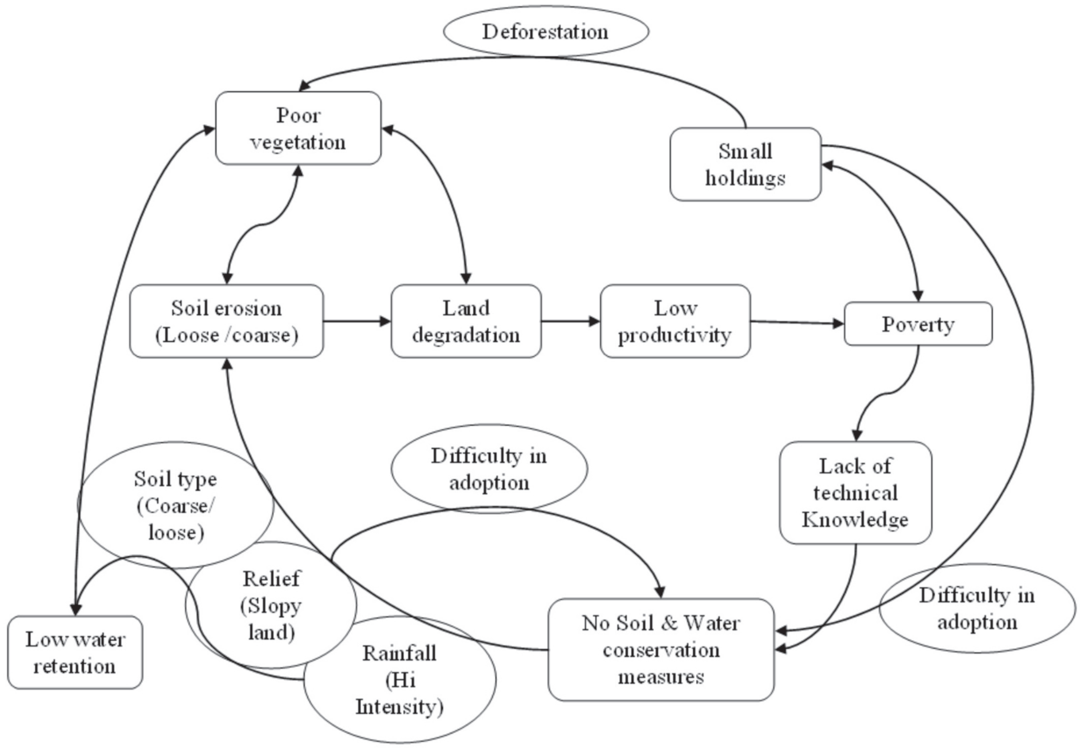

Fig. 2. Land Degradation cycle in lower Shivaliks of Jammu divsion

degradation of catchments in terms of land, soil and vegetation is enormous. It seems that there exists a continuous cycle of events, involving both natural and anthropogenic factors, promoting land degradation in the region (Fig. 2).

Natural Factors

The physiographic characteristic of the area is in itself a major factor contributing to the continuous degradation of these catchments. The weak lithology of the lower Shivaliks consisting of rocks like sandstone, conglomerate, shale, silt stone and limestone are relatively easily weatherable and therefore prone to quick erosion. The topography of the region ranging from gently sloping to moderately-steep sloping retards the vertical development of soils. Due to great variation in steepness of the slope in this region, erosion is the major problem of land husbandry (Gupta and Gupta, 2004). Sloping relief pattern results in accelerated erosion causing removal of surface material. Surface runoff is higher on sloping lands resulting in lesser percolation of water which is essential for profile development. Further, lesser water is available for the growth of plants and trees which are responsible for checking soil erosion.

Major share of the total rainfall received in the area is contributed by monsoons between July and September. The rainfall in monsoon is usually accompanied with thunderstorms due to lower pressure created because of warmer temperatures resulting in high intensity rainfall albeit for a shorter period. This high intensity rainfall is capable of disturbing the top soil, and in turn loosening it, resulting in sheet and rill erosion. The rills if not attended to may lead to the formation of small gullies. The problem is further aggravated as the soil in the area is coarse textured and prone to erosion (Sharma *et al.*, 2004). It is generally considered that as the silt (0.002-0.05 mm) or silt and very fine sand (0.05-0.10 mm) fraction increases, soil erodibility increases (Wischmeier amd Mannering, 1969). This is because of binding affect of clay, transportability of fine and non-aggregate particles and the detachability of sand and silt (Le-Bissonnais, 1996). The extent of rill soil erosion can be discerned in number of broad longitudinal valleys known as *Duns* like Udhampur, Jhajjar Kotli and Dansal in lower Shivaliks of Jammu region. These highly erodible soils are poor in nutrients and low in organic carbon (Sharma *et al.*, 2009) contributing to poor productivity. Among the different landuses, it has been established that the agricultural soils had the least amount of organic carbon content (Sharma *et al.*, 2014).

The seasonal high intensity rains also results in sudden and flash floods in rivers, *nallahs* and *khads* fed by their respective catchments. The water loaded with sediments from the catchments exerts enormous pressure on the banks resulting in stream bank erosion resulting in loss of size chunks of productive land over time.

Anthropogenic Factors

Increased human and cattle population pressure and decreased size of land holdings in the area have resulted in indiscriminate felling of trees, removal of bushes and grazing and browsing. The human population of the state increased at an annual compound growth rate of 2.64 % as against 1.08 % ACGR of food grains between 1961 and 2001 (Table 2; Sharma and Sharma, 2003). This indicated that while increase in the population was substantial, the food grain production did not cope with this increase. The situation is still worse in the *kandi* region where there has remained acute shortage of food grains.

Table 2. Population and food grain production in J&K state

Year	Population (million)	Food grain production (million tonnes)
1961	3.56	0.96
1971	4.61	1.00
1981	5.95	1.17
1991	7.72	1.32
2001	10.14	1.48
2011	12.54	1.50

Lack of knowledge regarding soil and water conservation measures is an important factor contributing towards land degradation in the area. It has been observed that only about 43 per cent of the farmers in the lower Shivaliks of Jammu are aware about the severity of the problems related to runoff and soil loss (Sharma *et al.*, 2004). Only 31 per cent of the farmers adopt any of the soil and moisture/water conservation measures in the area. More than 76 per cent of the farmers are cultivating land along the slope resulting in soil, nutrient and water loss as only 24 per cent of the respondents plough across the slope.

The community in these areas faces a lot of constraints in adoption of improved soil and water conservation measures. About 76.6 per cent of the farmers feel that they had lack of skill in handling the practices like contour bunding, staggered trenches etc. (Table 3; Sharma *et al.*, 2005). About 95 per cent of the inhabitants had problems due to undulating topography which causes problem in application of different practices. They had to rely more on human labour rather than machinery because they had sloping and fragmented fields. Small and fragmented land holdings of the farmers in the area is also one of the major constraint for adoption of improved practices. Further, poor economic condition of the farmers restricts them from employing any labour or using any machinery.

The land holdings in the *kandi* region are small and fragmented. A sample survey in the area showed that 92% of the families have cultivable holdings of less than 2 ha and 80 % have less than 1.5 ha (Arora *et al.*, 2006). The tenancy law of transferring the land to all children of the family has made the matter still complicated. At present, the land exists in different small to large categories of < 1.0 ha, 1 to 5 ha and > 5 ha holdings in the region (Table 4). Though the family size is bigger in the region, most of the members of the family go for job or labour work to earn their bread instead of performing agriculture practices on their small lands.

In order to meet the demand of food, fiber, fuel and fodder due to exponential increase in

Table 4. Land holding and family size in *kandi* region of Jammu

Category	Land holdings (%)	Family size category	Families (%)
< 1.0 ha	61.9	< 4	16
1.0 to 5.0 ha	36.9	8	41
> 5.0 ha	1.2	> 8	43

Source: Arora *et al.* (2006)

Table 3. Constraints in adoption of soil and rainwater management practices (n=120)

Sr. No.	Constraints for adoption of soil and rain water conservation practices	No. of Farmers	Per cent
1	Non-availability of design and implements used for rainwater harvesting	107	89.20
2	Lack of technical knowledge	92	76.60
3	Topographical problems	114	95.00
4	Ignorance of rainwater management practices	69	57.50
5	Small & fragmented land holdings	102	85.00
6	Poor socio-economic condition	105	87.50

Source: Sharma *et al.* (2005)

population pressure, there has been large scale deforestation. It has led to unabated soil loss and land degradation. Forest cover plays significant role not only in checking the soil erosion and run-off losses but also maintains the balance in physical landscape through the regeneration of degraded and eroded lands. It has also been found that natural fallows under grasses and shrubs or grasses alone have negligible run-off and soil loss than cultivated fallows which give maximum rate of run-off and soil loss (Gupta, 2005). Vegetative cover increases the water stable aggregates in soil, protects it against rain drop, reduces water velocity, increases infiltration capacity and fertility of the soil.

OPPORTUNITIES AND CHALLENGES

All the above factors lead to continuous land degradation, thereby reducing the productivity of theses lands, which in turn affects the economic condition of the farmers luring them to other sources of employment and the cycle continues so on. Increased human population resulting in smaller land holdings coupled with poverty is putting pressure on land maintenance. Younger generations among the farming community have started looking for other avenues for making their ends meet. This has led to lesser interest in farming and therefore the maintenance of land takes a back seat. The challenges and opportunities thus can be grouped in five major areas: overcoming constraints to technology adoption; managing conflict; balancing local economic and environmental services; and strengthening organizational and learning processes. Leach *et al.* (2002) indicated that public policy making and implementation in the United States are increasingly handled through local consensus seeking partnerships involving most affected stakeholders. The stake holders perceive that their partnerships have been most effective in addressing local problems. In short the stakeholder should be the central figure in any planning process for the rehabilitation of these degraded lands. Keeping in view the poor socio-economic status of the farmers and the inherent causes of soil erosion and land degradation prevalent in the area, the challenge lies in protecting the limited land resource from further degradation, improving productivity of land and eroding poverty in *kandi* region of the state. To rehabilitate the area, it is required to conserve soil against erosion, manage rainwater efficiently to produce more crops, to provide food, fodder and fuel. In fact poverty in itself is the number one constraint towards the rehabilitation of such areas. Land holdings being small possibility of subsidiary occupations like poultry, fisheries, animal husbandry, paper industry, etc. needs to be explored. Traditionally practiced agro-forestry needs to be developed on scientific lines to produce more biomass without degradation of resources. Horticulture has a good scope in the area. The possibility of combining horticulture and forestry with agricultural crops, grasses and fodders needs to be explored on scientific basis. This requires and integrated multidisciplinary approach for development in the area. Thus there is need to develop these areas for improving not only the productivity but also to check soil loss and conserve water.

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Transformation of physical, physicochemical and chemical properties of raised bed soil profiles under different elapsed time in a lowland ecosystem

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ABSTRACT

Representative soil profiles, one from prevailing lowland and three from different aged raised bed land were collected from the Dankuni basin of West Bengal with a view to assess the variations in physical, physicochemical and chemical properties of raised bed soils with respect to time as compared with the that of lowland soils. The results showed that in spite of severe disturbances while raised bed-pond structure construction, there was consistent improvement in the physical, physicochemical and chemical environment of raised bed soils with passage of time and the effect was more pronounced with advanced stages than the recent development in the existing lowland. The technology of raised bed-pond configuration, besides ensuring drainage in monsoon and providing assured irrigation in post monsoon, would likely to recover the soil health for stainable crop production.

Key words: Lowland, Raised bed soil, Soil properties, Dankuni basin, West Bengal

INTRODUCTION

The feasibility of raised bed-pond system in low-lying land of Dankuni basin of West Bengal for increasing crop productivity and resource sustainability has been well documented (Patra *et al.*, 2000). This alternate farming system has shown promise not only in increasing the yield and intensity of crops but also favours to switch cropping pattern from low to high value crops on naturally ill-drained land (Yadav *et al.*, 2003; Munda *et al.*, 2004). This new approach of crop cultivation in adverse land situation is cost-effective, eco-friendly and easily affordable to the resource poor farmers (Patra and Ray, 2002). However, there is every possibility of land degradation in respect of physical, chemical and biological environment of soils due to havoc soil inversion while construction of structure. In the present investigation, an attempt was being made to assess the physical, physicochemical and chemical properties of raised bed soil profiles as compared with the lowland soil profile with respect to time in the Dankuni Basin of West Bengal.

MATERIALS AND METHODS

Location and soil of the experimental site

The lowland ecosystem of Dankuni basin in West Bengal lying between 22°39'32'' to 23°01'20'' North latitude and 87°30'20'' to 88°30'15'' East longitude is most fertile and supports bumper crop production under favourable soil-climatic condition. The climate is subtropical-subhumid with high annual rainfall (1508 mm), the major portion (73%) of which is being received from June through September. The elevation of test sites is 3.2 to 3.5 m from mean sea level. The soils are Typic Fluvaqepts, clay loam in texture with low infiltration rate (0.002 m/day) and hydraulic conductivity (0.06 m/day). Long-duration water logging during monsoon and a significant part of post-monsoon season is adversely affecting the sowing and yield of crops. About 56.6 per cent of 4825 ha cultivable land is susceptible to prolonged water logging hazard.

In the raised bed-pond configuration, a part of the low-lying holding was excavated to construct a pond and the elevation of the remaining portion was raised using the excavated earth from the pond. The bed height was adjusted above the reach of local runoff accumulation. While earth excavation, the top soil (0-0.15 m) was scraped, kept aside and was subsequently used for uniform top-spreading over the extended raised bed areas. The pond slope was protected against soil erosion with grass plantation. The detailed design configurations of

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Table 1. Design configurations of raised bed-pond structures

Parameter	Age of raised bed-pond structure		
	1- year	3- year	7- year
Total land area (ha)	0.25	0.50	0.04
Raised bed area (ha)	0.17	0.40	0.03
Pond area (ha)	0.08	0.10	0.01
RB-pond ratio	2.1 : 1	3.8 : 1	2.3 : 1
Height from ground surface (m)	0.60	0.64	0.75
Pond slope	0.8 : 1	0.8 : 1	0.8 : 1

three raised bed-pond structures of different ages are given in Table 1.

Soil analysis

Composite soil samples were collected separately from original lowland (control) and 1, 3 and 7 year-old raised bed sites at a depth of 0-0.20, 0.20-0.40, 0.40-0.60, 0.60- 0.80 and 0.80-1.0 m. The samples were processed and were analyzed for pH (1:2), electrical conductivity (1:2), organic carbon, available N, P and K following the standard methods as described by Jackson (1973). Particle size analysis of soils was carried out by international pipette method (Piper, 1966), while particle density and bulk density by the methods of Black (1965). The data were further processed by two-way analysis of variance using Duncan multiple range test (DMRT) as outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Physical properties

Irrespective of soil depths, sand and silt contents in the prevalent lowland and different aged raised bed soils did not vary significantly (Table 2). However, clay content in lowland and 7 year-old raised bed soils were at par, but superior to 1- and 3-year old raised bed soils. The latter two treatments did not show any statistical variation. This reveals to the fact that while regeneration of raised bed soil profiles adjoining to the lowland, sand and silt particles were reoriented quicker than clay particle. The distribution of mechanical separates down the layers of the profiles in the undisturbed lowland and different raised beds in general did not exhibit any statistical deviation, in spite of exhaustive soil disturbances while excavation of earth. This was mainly due to the similar textural makeup of the soil profiles up to a depth of 13.6 m from the land surface in this alluvial tract (Patra and Ray, 2002).

The particle density of all the raised bed soil profiles showed the same value, but the magnitude was marginally lower than that of lowland soil profile (Table 2). The quantum along the three raised bed profiles did not follow definite trend of distribution, however, it was consistently increasing with the increase in depth in lowland soil profile. The bulk density of soils, on the contrary, increased progressively and significantly in all the raised bed profiles akin to lowland profile. Further, regardless of soil depth, the highest value of bulk density was observed in the undisturbed lowland soil profile and the lowest value in the 1-year old raised bed, which increased consistently and significantly with increasing age of the raised beds (Cotching and Dean, 2003; Peries *et al.*, 2010). These amply demonstrate that for restoring the particle and bulk density of soils parallel to inherent lowland soil, the developed raised beds need certain duration of time to regain the original status. The probable reason for variable bulk density in different raised beds were due to the fact that with passage of time after raised bed construction, the soils gradually got compacted and macro pore spaces decreased accordingly that led to the increase in the bulk density of soil (Biswas and Mukherjee, 1994).

Physicochemical properties

The pH and electrical conductivity of soils in the lowland profile consistently increased with increasing depth of soil (Table 3). Same observation was also recorded in all the three raised bed soil profiles with some exceptions for soil pH. Higher values were observed in the new raised bed, thereafter it was progressively decreased with the increasing age of raided beds tending towards the initial values of lowland profile. This might be due to the gradual losses of soluble salts from the soil profiles through leaching and crop removal. Similarly, organic carbon content in lowland profile was decreasing with increasing depth of soil (Khan and Kamalakar, 2012). It did not follow a definite

Table 2. Physical properties of raised bed soil profiles of different age

Depth (D), m	Age of raised bed soil profile (S)				
	Control*	1-year	3-year	7-year	Mean
			Sand (%)		
0.00–0.20	19.2	17.8	17.7	17.8	18.12_a
0.20–0.40	19.0	18.8	18.4	18.2	18.60_a
0.40–0.60	18.4	19.0	19.1	19.0	18.87_a
0.60–0.80	17.9	18.9	19.1	19.1	18.75_a
0.80–1.00	17.8	19.2	18.9	18.7	18.65_a
Mean	18.46_a	18.74_a	18.64_a	18.56_a	
		SEm (±) for D = 0.29	S = 0.26	D x S = NS	
			Silt (%)		
0.00–0.20	54.7	56.9	56.9	56.4	56.22_a
0.20–0.40	55.2	55.3	55.4	55.7	55.40_a
0.40–0.60	55.4	55.2	54.8	55.0	55.10_b
0.60–0.80	55.5	55.5	55.3	55.2	55.37_a
0.80–1.00	55.1	55.0	55.8	54.8	55.17_b
Mean	55.18_a	55.58_a	55.64_a	55.42_a	
		SEm (±) for D = 0.27	S = 0.24	D x S = NS	
			Clay (%)		
0.00–0.20	26.1	25.3	25.4	25.8	25.65_a
0.20–0.40	25.8	25.9	26.2	26.1	26.00_a
0.40–0.60	26.2	25.8	26.1	26.0	26.02_a
0.60–0.80	26.6	25.6	25.6	25.7	25.87_a
0.80–1.00	27.1	25.8	25.3	26.5	26.17_a
Mean	26.36_a	25.68_b	25.72_b	26.02_a	
		SEm (±) for D = 0.187	S = 0.167	D x S = NS	
			Particle density (Mg/m^3)		
0.00–0.20	2.64	2.63	2.62	2.63	2.63_d
0.20–0.40	2.65	2.65	2.65	2.65	2.65_b
0.40–0.60	2.66	2.63	2.65	2.65	2.64_c
0.60–0.80	2.66	2.65	2.63	2.63	2.64_c
0.80–1.00	2.67	2.66	2.66	2.67	2.66_a
Mean	2.65_a	2.64_b	2.64_b	2.64_b	
		SEm (±) for D = 0.002	S = 0.001	D x S = 0.003	
			Bulk density (Mg/m^3)		
0.00–0.20	1.56	1.44	1.46	1.55	1.50_e
0.20–0.40	1.57	1.47	1.47	1.56	1.51_d
0.40–0.60	1.59	1.47	1.55	1.58	1.54_c
0.60–0.80	1.60	1.55	1.57	1.57	1.57_b
0.80–1.00	1.61	1.58	1.58	1.58	1.58_a
Mean	1.58_a	1.50_d	1.52_c	1.56_b	
		SEm (±) for D = 0.002	S = 0.002	D x S = 0.004	

*Original lowland soil, Figures followed by common letter(s) in a column and a row do not differ significantly at 5% level by DMRT

trend in all the raised bed profiles; however, the higher magnitude was observed in topsoil. The value regardless of soil depth was found lowest in the lowland soil profile, but in raised beds it was consistently and significantly increasing with passage of time (Table 3). This might be due to the combined effects of regular addition of organic manures and decomposition of crop residues.

Table 3. Physicochemical properties of raised bed soil profiles of different age

Depth (D), m	Age of raised bed soil profile (S)				
	Control*	1-year	3-year	7-year	Mean
			pH		
0.00–0.20	7.33	7.50	7.50	7.30	7.40_e
0.20–0.40	7.50	7.70	7.66	7.65	7.62_d
0.40–0.60	7.63	7.83	7.70	7.60	7.69_c
0.60–0.80	7.78	7.80	7.90	7.58	7.76_b
0.80–1.00	7.89	7.93	7.96	7.93	7.92_a
Mean	7.62_c	7.75_a	7.74_b	7.61_d	
		SEm (±) D = 0.013	S = 0.012	D x S = 0.031	
			EC (dS/m)		
0.00–0.20	0.82	0.92	0.88	0.82	0.86_e
0.20–0.40	0.91	0.93	0.90	0.91	0.91_d
0.40–0.60	0.93	0.97	0.93	0.93	0.94_c
0.60–0.80	0.97	1.02	0.94	0.94	0.96_b
0.80–1.00	1.03	1.09	1.06	1.04	1.05_a
Mean	0.93_c	0.98_a	0.94_b	0.92_c	
		SEm (±) D = 0.004	S = 0.003	D x S = 0.007	
			Organic C (%)		
0.00–0.20	1.23	1.30	1.50	2.31	1.58_a
0.20–0.40	0.88	0.75	1.23	1.67	1.13_b
0.40–0.60	0.74	0.98	0.84	0.86	0.85_c
0.60–0.80	0.70	0.74	0.92	0.91	0.81_d
0.80–1.00	0.64	0.71	0.84	0.88	0.76_e
Mean	0.83_d	0.89_c	1.06_b	1.32_a	
		SEm (±) D = 0.004	S = 0.003	D x S = 0.007	

* Original lowland soil, Figures followed by common letter(s) in a column and a row do not differ significantly at 5% level by DMRT

Chemical properties

Available N and P content of soils gradually decreased with increasing depth in all the profiles of lowland and different aged raised beds (Table 4). Same trend was also observed for available K in the prevalent lowland. However, distribution of available K in different layers of raised beds was rather inconsistent. In all cases, the magnitudes of available N, P and K were observed to be maximum in the surface layer (0-0.20 m) and minimum in the bottom most layer (0.80-1.0 m). The amounts of available N, P and K, on an average, were lower in the lowland soil. These values were significantly lower in the new raised bed, which were consistently and significantly increased with the advanced stage of the raised bed. This implies that with continuous cropping coupled with judicious manure and fertilizer application, availability of N, P and K in soils of all raised beds was appreciably increased. In contrast, the availability of these plant nutrients in the existing lowland soil was relatively poor, although same agro-production technique was being followed. This may be due to the losses of nutrients from lowland soils due to excessive water logging hazards especially in the wet season, which was absolutely absent in raised bed soils.

CONCLUSIONS

Based on the above results, it may be inferred that in spite of exhaustive soil disturbances while raised bed-pond construction in the prevalent lowland ecosystem, this new approach of land configuration vis-à-vis farming system is capable to restore and improve the physical, physicochemical and chemical environment of soils with the passage of time, beside ensuring drainage alleviation in monsoon and providing assured irrigation facility in post-monsoon season for sustainable crop production throughout the year.

Table 4. Chemical properties of raised bed soil profiles of different age

Depth (D), m	Age of raised bed soil profile (S)				
	Control*	1-year	3-year	7-year	Mean
			Available N (kg/ha)		
0.00–0.20	276.7	282.2	337.5	517.5	353.5_a
0.20–0.40	198.0	168.7	276.7	375.7	254.8_b
0.40–0.60	87.7	169.2	182.2	216.0	163.8_c
0.60–0.80	85.5	118.9	209.2	249.7	165.8_c
0.80–1.00	81.0	99.7	189.0	200.2	142.5_d
Mean	145.8_d	167.8_c	238.9_b	311.85_a	
	SEm (±) for	D = 3.7	S = 3.3	D x S = 5.8	
			Available P (kg/ha)		
0.00–0.20	10.7	27.8	28.7	43.9	27.3_a
0.20–0.40	7.2	21.5	24.1	26.9	19.9_b
0.40–0.60	6.3	17.9	18.8	18.4	15.4_c
0.60–0.80	5.4	8.2	20.1	14.3	12.0_d
0.80–1.00	5.3	9.0	9.8	8.7	8.2_d
Mean	6.9_d	16.9_c	20.3_b	22.4_a	
	SEm (±) for	D = 0.26	S = 0.23	D x S = 0.42	
			Available K (kg/ha)		
0.00–0.20	295.3	312.8	299.0	327.4	308.6_a
0.20–0.40	278.4	274.3	228.1	234.6	253.8_b
0.40–0.60	216.9	288.4	258.2	251.1	253.7_b
0.60–0.80	157.9	164.0	296.1	259.5	219.4_c
0.80–1.00	94.1	151.3	132.8	149.0	131.8_d
Mean	208.5_d	238.2_c	242.8_b	244.3_a	
	SEm (±) for	D = 3.7	S = 3.3	D x S = 6.3	

* Original lowland soil, Figures followed by common letter(s) in a column and a row do not differ significantly at 5% level by DMRT

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Effect of in-situ moisture conservation practices on growth, yield and economics of pearl millet under dryland conditions

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ABSTRACT

Field experiments were conducted on a sandy loam soil at Research Farm, Agricultural Research Station, Bikaner during rainy (*kharif*) season of 2010-11, 2011-12 and 2012-13 to study the "effect of in-situ moisture conservation practices on growth, yield and economics of pearl millet under dryland conditions". Data reveals that among the in-situ moisture conservation practices, vegetative mulch at 30 DAS (T_5) gave significantly higher growth parameters (plant height, no. of green leaves/plant, total tillers/plant and effective tillers/plant) and yield attributes (ear head length and test weight) of pearlmillet. Similarly, highest grain (2044 kg/ha) and stover yield (3732 kg/ha) was obtained with vegetative much after 30 DAS followed by ridge and furrow at 30 DAS. Maximum gross return (Rs 35016), net return (Rs 27816), B:C ratio (4.86), production efficiency (26.90 kg/ha/day) and economic efficiency (381.04 Rs/ha/day) were also recorded in vegetative mulch at 30 DAS.

Key words: Soil moisture, Vegetative mulch, Yield, Pearlmillet, Dryland, Ridge and furrow

INTRODUCTION

Out of the estimated 143 m ha net cultivated land in India, 70% is dominated by rainfed farming where crop production is constrained by uncertainty of monsoon and low fertile soils with low organic matter and nutrient content. Pearl millet [*Pennisetum glaucum* (L.) R. Br. Emend. Stuntz] is fourth most important cereal after rice, wheat and maize in India. It is the most important staple food for millions of people in the semi-arid and arid tropics. Pearl millet survive in rainfed area because of its drought escaping mechanisms but still respond well to all inputs including fertilizers. The soils of the pearl millet growing regions mostly light in texture embody low moisture holding capacity. Soil moisture is the most important factor for successful crop production in dryland areas. Use of organic manures as well as mid-season correction through mulching, anti-transpirant and planting methods are effective in increasing the productivity and water use by the crop (Terarwal and Rana, 2006). Lal *et al*. (1992) reported beneficial effect of various mulches on the moisture conservation and yield under dryland conditions. As information on this aspect is meagre in the dryland conditions of Rajasthan, therefore, the present investigation was conducted to find out the suitable moisture conservation practices for higher productivity of pearl millet under dryland conditions.

MATERIALS AND METHODS

The field experiment was conducted on loamy sand soil at Research Farm of Agricultural Research Station, Swami Keshwanand Rajasthan Agricultural University, Beechwal, Bikaner in three consecutive rainy (*kharif*) seasons (2010-11, 2011-12 and 2012-13). This location was situated at 28.01^0 N latitude and 73.22^{0}E longitude at an altitude of 234.7 meters above mean sea level. According to National Planning Commission, Bikaner falls under Agro climatic zone XIV (Western Dry Region) of India. The soil was loamy sand in texture with pH 8.1, organic carbon 0.15%, low in available nitrogen (90.6 kg/ha), medium in available phosphorus (18.4 kg P_2O_5/ha) and available potassium (233.6 kg K_2O/ha). The rainfall received during growing period (June to October) was in 2010 365.8 mm, in 2011 276.1 mm and 196.2 in 2012. Treatments of the experiment were T_1- wider row spacing at 60 cm, T_2-compaction with rubber wheel, T_3-Ridge and furrow at 30 DAS, T-$_4$ soil mulch after every rain T_5-vegetative mulch at 30DAS, T_6-mixed cropping 2/3:1/3 guar and T_7-Control (sowing at 30 cm). The experiment was carried out in the same field for

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three years in the randomized block design with four replications. The crop fertilized with a uniform dose of 40 kg N/ha through urea and 32 kg P_2O_5/ha through single super phosphate. GHB-538 pearl millet and RGC-936 variety of guar were used as a test crop. Pearl millet seeds were sown @ 4 kg/ha by *kera* (dropping the seeds in furrow behind the plough). The optimum plant population was maintained by thinning and gap filling at 10-15 days after sowing. Various growth and yield attributes were observed at maturity following the standard procedure. Other cultural operations were carried out as per package of practices of the state. The data recorded were analysed as per analysis of variance technique for randomized black design. Production efficiency and economic efficiency was calculated by following given formula below (Kumawat *et al.*, 2012).

$$\text{Production efficiency (kg/ha/day)} = \frac{\text{Grain yield (kg/ha)}}{\text{Total duration taken crop (days)}}$$

$$\text{Economic efficiency ('/ha/day)} = \frac{\text{Net return ('/ha)}}{\text{Total duration taken crop (days)}}$$

RESULTS AND DISCUSSION

Effect of weather

In the present investigation, the meteorological data depicted in Figure 1 showed marked variation in weather condition. During the 3 years period of present study (June 2010-11 to October 2012-13), while average monthly temperature ranged from 26 ^{0}C to 35 ^{0}C and relative humidity (RH %) ranged from 39% to 68%. The rainfall ranged from 21.1 to 108 mm was received during monsoon period (June-October). This resulted in slightly better performance of the crop during 2010-11 than 2011-12 and 2012-13.

Effect of moisture conservation practices on growth and yield attributes

Pooled data of 3 years showed that various in-situ moisture conservation practices had significant effect on growth parameters and yield attributes of pearl millet (Table 1). The maximum plants height was recorded with vegetative much at 30 DAS (T_5) which was at par with ridge and furrow at 30 DAS (T_3), compaction with rubber wheel (T_2) and soil mulch after every rain (T_4) and these treatments proved significantly superior to rest of the in-situ moisture conservation practices. Similarly, higher number of leaves/plant was recorded under vegetative much after 30 DAS (T_5) which was statistically at par with ridge and furrow at 30 DAS (T_3) and significantly superior to rest of the treatments. Significantly higher total tillers/ plant was noted under vegetative much at 30 DAS (T_5) but it was at par with ridge and furrow at 30 DAS (T_3), compaction with rubber wheel (T_2) and soil mulch after every rain (T_4). Whereas, effective tillers/plant were also higher with vegetative much at 30 DAS (T_5) but it was statistically similar with ridge and furrow after 30 DAS (T_3) and soil mulch after every rain (T_4) only. Among, in-situ moisture conservation practices, vegetative much at 30 DAS (T_5) significantly gave higher ear head length and test weight. The magnitude of increased in ear head length and test weight were to the extent of 22.91 and 27.73 percent with the vegetative much at 30 DAS (T_5) over control plot, respectively. The lowest ear head length and test weight was recorded in control (sowing at 30 cm). This might be due to adequate availability of moisture to plants results

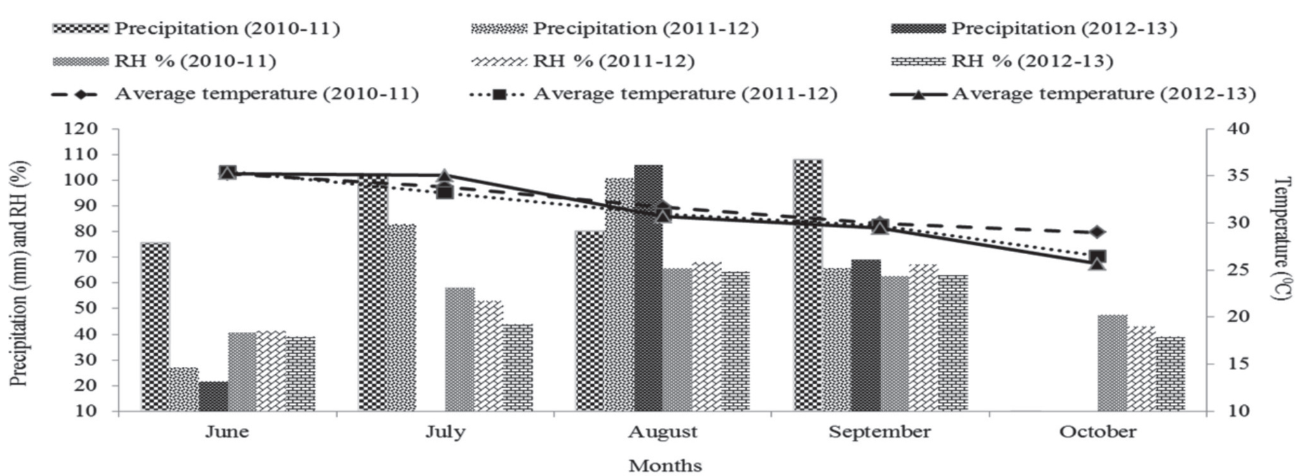

Fig. 1. Monthly rainfall, RH and average temperature during the three growing seasons of the study (2010-11, 2011-12 and 2012-13)

Table 1. Effect of in situ moisture conservation practices on growth characters and yield attributes of pearl millet (pooled data of 3 years)

Treatment	Plant height (cm)	No. of leaves/ plant	Total tillers/ plant	Effective tillers/ plant	Ear head length (cm)	Test weight (g)
T_1= Wide row spacing at 60 cm	155.00	6.33	2.77	1.53	19.90	5.93
T_2=Compaction with rubber wheel	164.67	6.77	3.33	1.47	22.85	7.13
T_3=Ridge and furrow at 30 DAS	174.33	7.93	3.67	2.73	23.22	7.17
T_4=Soil mulch after every rain	163.33	6.67	3.20	2.57	21.63	6.33
T_5=Vegetative mulch at 30DAS	177.07	8.37	3.73	3.00	23.50	7.37
T_6=Mixed cropping 2/3:1/3 guar	153.00	6.73	2.43	1.27	18.75	5.50
T_7=Control (sowing at 30 cm)	156.60	6.37	2.63	1.37	19.12	5.77
SEm±	6.21	0.51	0.23	0.18	1.14	0.30
CD (P=0.05)	19.14	1.58	0.71	0.55	3.52	0.94

Table 2. Effect situ moisture conservation practices on seed yield, stover yield and economics of pearl millet (pooled data of 3 years)

Treatment	Grain yield (kg/ha)	Stover yield (kg/ha)	Gross return (‘/ha)	Net return (‘/ha)	B:C ratio	Production efficiency (kg/ha/day)	Economics efficiency (‘/ha/day)
T_1=Wide row spacing at 60 cm	1486	3125	27514	21314	4.44	19.55	291.97
T_2=Compaction with rubber wheel	1712	3327	30333	23783	4.63	22.53	325.79
T_3=Ridge and furrow at 30 DAS	1969	3663	34069	25869	4.15	25.91	354.37
T_4=Soil mulch after every rain	1693	3274	29912	22712	4.15	22.27	311.12
T_5=Vegetative mulch at 30DAS	2044	3732	35016	27816	4.86	26.90	381.04
T_6=Mixed cropping 2/3:1/3 guar	1231	2807	30521	24021	4.70	25.35	329.05
T_7=Control (sowing at 30 cm)	1281	2994	25215	19015	4.07	16.85	260.47
SEm±	71	124	1049	1049	0.15	0.94	14.38
CD (P=0.05)	219	381	3234	3234	0.45	2.88	44.30

in cell turgidity and eventually higher meristematic activity, leading to more foliage development, greater photosynthetic rate and consequently better growth of the crop. These results confirm the findings of Gupta and Bhan (1993), Singh *et al*. (1997) and Shekhawat *et al*. (2013).

Effect of moisture conservation practices on yield

Grain and stover yield of pearl millet was significantly affected by different in-situ moisture conservation practices treatments (Table 2). The highest average grain and stover yield was recorded with vegetative much at 30 DAS (T_5) which was at par with ridge and furrow at 30 DAS (T_3) and significantly superior to rest of the practices. The magnitude of increase of grain and stover yield was to the extent of 59.56 and 24.65 percent with the vegetative much at 30 DAS (T_5) over control, respectively. This might be due to decrease in evaporation and availability of adequate soil moisture for longer period under limited water supply through the conservation of moisture and regulation of soil temperature which in turn increased the pearl millet yield (Ondal *et al*., 2008). The increased productivity of grain and stover with moisture conservation practices was owing to the use of vegetative much, which extend the period of storage of water in soil profile due to reduction in evaporation (Tetarwal and Rana, 2006). Similar results were also reported by Sharma *et al*. (2009) and Sharma *et al*. (2011).

Effect of moisture conservation practices on economics

Pooled data of 3 years showed that vegetative much at 30 DAS (T_5) gave remarkably higher gross return (Rs 35016), net return (Rs 27816) production efficiency (26.90 kg/ha/day) and economic efficiency (381.04 Rs/ha/day) as compared to other treatments, but it was statistically at par with ridge and furrow at 30 DAS (T_3) and significantly superior to rest of the treatments. Similarly, maximum B:C ratio was also recorded in vegetative much at 30 DAS (4.86) followed by mixed cropping 2/3 : 1/3 guar (T_6) and wider row spacing at 60 cm (T_1). These results are in agreement of Singh *et al*. (1997) and Sharma *et al*. (2011).

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Protocol for resilience of degraded Vertisol with field level validation

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ABSTRACT

A research investigation was carried out in the farmer's fields to study resilience capacity of degraded Vertisols of AESR 10.1. Field experiments were conducted on 10 farmer's fields which were selected based on soil quality index (SQI) values ranging from low to high. Each of the ten identified sites was amended with wood charcoal @ 0, 5.4, 10.8 and 16.2 t ha^{-1} at the time of land preparation before sowing of soybean crop. Thereafter, soybean followed by wheat crop was raised and yields were recorded. After the harvesting of wheat crop, soil samples were collected and analyzed for quantity values of the key soil quality indicators. Based on quantitative values of the key indicators, SQI were computed for all the interventions at ten sites. The resilience index (RI) of the soils of each site due to application of charcoal @ 5.4 t ha^{-1} (I_1), 10.8 t ha^{-1} (I_2) and 16.2 t ha^{-1} (I_3) was computed. The result showed that the loss of soil quality as compared to respective pristine soil are different in different sites and the values ranged between 0.114 unit to as high as 0.650 unit. After imposition of interventions, there was improvement in SQI values at each site, however, magnitude of improvement in SQI value varied from site to site. Under intervention I_1 (5.4 t ha^{-1}), I_2 (10.8 t ha^{-1}) and I_3 (16.2 t ha^{-1}) the improvement in SQI values ranged from 0.026 unit to 0.246 unit , 0.051 unit to 0.287 unit and 0.067 unit to 0.392 unit, respectively. It was further observed that out of the ten sites the value of resilience index ranged from 28.12 to 68.78% which resulted in gain in soybean yield from 264 to 442 kg ha^{-1} and gain in succeeding wheat yield from 103 to 815 kg ha^{-1}. The soil analysis carried out after the harvest of wheat crop showed that out of the eight key indicators identified for vertisol, only two indicators, namely, TOC and Alkaline Phosphatase activity showed significant improvement due to application of wood charcoal. Also, significant improvement in microbial biomass C content in the soil was observed due to charcoal application. Thus, the developed protocol for measuring soil resilience can be successfully used to measure the resilience capacity of degraded vertisols in response to management interventions.

Key words: Charcoal, Degraded Vertisols, Soil resilience, Soil quality

In India, soil degradation (~57% of the cultivated area) is a major threat to agricultural sustainability and environmental quality both in irrigated and rainfed agro-ecosystems. A perceived decline or stagnation in crop yield, partial factor productivity of inputs and also quality of the produce is the fall out of such degradation. In rainfed regions, the degradation is caused mainly by erosion resulting in loss of all important topsoil and ultimately crop productivity.

Decline in soil organic matter and its associated nutrients supply in soil is the major factor for yield decline (Dawe *et al*., 2000) under intensive cropping systems. In addition, stresses due to acidity, salinity, alkalinity, waterlogging etc. are also there for a considerable land area in different parts of the country. These degradative forces and processes impair soil's essential ecosystem functions and ultimately its health/quality. Therefore, for sustainable use of soil and its protection against degradation, soil quality assessment (fitness for use), its resilience capacity (ability to recover) and identification of diagnostic recovery modules are the only options available to address this critical issue.

The concept of soil quality and the methods for evaluating it with respect to various soil functions have been evolved to a considerable extent for identifying major soil quality indicator. Though the indicators are put in use for monitoring soil quality (Andrews *et al*., 2004), such indicators for resilience purpose are yet to be developed to assess the ease and degree of recovery of degraded soil system (Kuan *et al*., 2006). Theoretically, soil resilience has been defined as the capacity of soil to recover its functional and structural integrity after a disturbance (Lal, 1997). Agriculture is one of the important stresses and disturbances to the soil environment (Brussard, 1994). Although, there is a conceptual framework for evaluating soil resilience

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but there is limited field level validation. Soil resilience and resistance are affected by both inherent and dynamic soil characteristics and thus, will vary substantially from one area to the next and will change over time (MacEwan, 1997) and management practices (Lal, 1998).

Management practices that increase soil organic matter levels will improve most soil functions. Investigations by Glaser *et al*. (2000) and Glaser *et al*. (2001) also showed that carbonized materials from the incomplete combustion of organic material (i. e. black C, pyrogenic C, charcoal) are responsible for maintaining high levels of SOM and available nutrients in anthropogenic soils (Terra Preta) of the Brazilian Amazon basin (Zech *et al*., 1990) and Savannas of South Africa (Blackmore *et al*., 1990). Thus, an investigation was carried out to develop a protocol for evaluating soil resilience capacity of degraded soil with field level validation under different management interventions.

MATERIALS AND METHODS

Site selection for resilience study based on SQI value. Stratified multistage random sampling method was followed for selecting farmers' field in each identified district (Sehore and Vidisha), where Tehsil/block was considered as strata. From each district, 20 - 25 villages have been selected randomly. From each selected villages, six farmers' field have been selected based on high, medium and low resource use following participatory rural appraisal (PRA) technique. From each site (approx. 1000 m^2), composite soil sampling have been carried out using core sampler as per standard soil test method. Soil samples have been analyzed for various soil properties viz. MWD, bulk density, plant available moisture (physical properties), pH, EC, SOC, TOC, available N, P, K, Cu, Zn, Mn, Fe, S, B, total N, total organic P, total inorganic P, non exchangeable K, different carbon pools (chemical parameters), microbial biomass carbon, alkaline phosphatase, dehydrogenase enzyme (biological properties) following standard procedure.

Minimum data set formation (MDS) and soil quality index (SQI) computation: Significant variables were chosen for minimum data set (MDS) formation through principle component analysis (PCA) (Andrews *et al*., 2002a, 2002b; Shukla *et al*., 2004). After determining the MDS indicators, every observation of each MDS indicator was transformed using a linear scoring method (Andrews *et al*., 2002b). Once transformed, the MDS variables for each observation were weighted using the PCA results and then summed up the weighted MDS variables scores for each observation using the following equation:

$$SQI = \sum_{i=1}^{n} W_i S_i$$

where, S is the score for the subscripted variable and W is the weighing factor derived from the PCA. Here the assumption is that higher index scores meant better soil quality or greater performance of soil function. Based on these PCA derived SQI value, ten farmer's fields having varying SQI value (gradient of SQI value ranging from low to high) were selected for field experiment to validate the protocol developed for resilience study.

Treatment details, crop harvest and sampling of plant and soil samples: The charcoal used for experimental purpose was collected from the local vendor in bulk. Representative samples were sieved, grinded through rotar blade mill and analyzed for its physico-chemical properties (Table 1). Graded levels of wood charcoal were applied to the soil at selected sites having different SQI value in order to study the recovery of major indicators and the SQI values. Each of the ten identified sites was divided into four plots (minimum size 20 m x 20 m) and the soil was amended with wood charcoal @ 0, 5.4, 10.8 and 16.2 t ha^{-1} at the time of land preparation before the sowing of soybean crop. Thereafter, soybean followed by wheat crops was

Table 1. Chemical Composition of Charcoal

Properties	Range	Mean	± SD
Carbon (%)	60.11-72.42	65.95	4.48
N (g/kg)	7.9-12.9	10.4	2.08
K (g/k)	0.67-0.85	0.80	0.08
Ca (g/kg)	1.02-1.31	1.12	0.10
Mg (g/kg)	0.87-1.12	0.97	0.08
P (mg/kg)	573-639	609	23.68
S (mg/kg)	290-338	314.8	19.74
Fe (mg/kg)	65.6-81.8	73.75	6.33
Mn (mg/kg)	45.4-60.8	54.06	6.46
Zn (mg/kg)	21.8-33.4	27.71	4.56
Cu (mg/kg)	8.9-17.4	12.5	3.10
Ash (%)	5.43-6.08	5.76	0.26
pH	7.9-8.8	8.5	0.39
Co (mg/kg)	5.8-8.91	7.13	1.15
Cr (mg/kg)	13.26-23.40	18.72	4.18
Cd (mg/kg)	0.98-1.65	1.39	0.25
Ni (mg/kg)	9.50-15.71	11.46	2.49
Pb (mg/kg)	6.40-10.61	8.14	1.50

raised (with uniform recommended fertilizer management practice for soybean and wheat) and yields were recorded. From each plot, four sampling unit for biomass yield was done using 1 m x 1 m sampling grid method. Similarly for each treatment biomass sampling was done and dry matter yield was recorded separately for each crop. After the harvesting of wheat crop, soils samples were collected from all the sites and analyzed for quantity values of the key indicators indentified through PCA method (TOC, non-exch. K, total Zn, total Mn, BD, $CaCO_3$, available S and alkaline phosphatase activity). Again the soil data were used to derive SQI value to determine the effect of charcoal management interventions on resilience index of Vertisol.

Resilience index value computation. Based on quantitative value of the key indicators, SQI values were computed for all the interventions of the ten sites. The resilience index (RI) of the soils of each of the ten sites due to application of charcoal @ 5.4 t ha^{-1} (I_1), 10.8 t ha^{-1} (I_2) and 16.2 t ha^{-1} (I_3) was computed using the following expression

$$RI = \frac{SQI(I) - SQI(d)}{SQI(p) - SQI(d)} \times 100$$

where,

SQI (I): The computed SQI value of soil after management intervention (I)

SQI (d): The computed SQI value of soil before the management intervention (I)

SQI (p): The computed SQI value of pristine soil nearer to the corresponding site.

The numerator in the above expression indicates the recovery of SQI value due to management intervention where as the denominator indicates the loss of SQI value due to soil degradation processes.

Statistical analysis. Data obtained as treatment means were analyzed using two way analysis of variance (ANOVA) by the statistical package SPSS 9.0. Differences in mean values were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

Effect of charcoal on soybean and wheat yield. Addition of charcoal in all the sites showed a significant positive effect on yield (Table 2) and the corresponding mean soybean and wheat yield increased from 1630 kg ha^{-1} to 2159 kg ha^{-1} and 3214 kg ha^{-1} to 3816 kg ha^{-1}, respectively. Significant increase in soybean and wheat crop yield due to charcoal application might be due to increased physical, chemical and biological properties of soil. Several studies and field observations have also demonstrated that the addition of carbon rich material to soils often results in increased crop productivity. Steiner *et al*. (2007) also observed that application of charcoal increased crop growth and doubled the grain yield if fertilized with NPK in comparison to NPK fertilizer without charcoal. In all the ten sites with varying SQI values, soybean and wheat crop responded upto 16.2 t ha^{-1} of charcoal application. Increasing levels of charcoal increased the crop yield, but significant differences were observed when charcoal was applied at 10.8 and 16.2 t ha^{-1}, respectively over control (in the absence charcoal). Moreover, yield response to charcoal application was much greater in soybean

Table 2. Effect of charcoal on soybean and wheat yield grown on soil having different SQI value at Sehore and Vidisha (Grain yield kg/ha)

Site No.	SQI	Charcoal Application Rate (t/ha) — Soybean				CD (p=0.05)	Charcoal Application Rate (t/ha) — Wheat				CD (p=0.05)
		0	5.4	10.8	16.2		0	5.4	10.8	16.2	
1	0.959	845	904	1321	1580	106.95	1963	2012	2980	3342	236.83
2	0.991	1040	1323	1406	1628	120.08	2512	2580	2912	3446	251.90
3	1.097	1580	1735	2046	2286	183.53	2780	2830	3940	3940	313.64
4	1.117	1321	1453	1721	1872	144.84	3230	3310	3270	3420	NS
5	1.298	1768	1798	2105	2280	186.84	3030	3090	3230	3300	187.75
6	1.393	1908	2061	2120	2335	202.17	3250	3080	3480	3990	320.85
7	1.462	1991	2071	2363	2485	198.24	3380	3521	3700	3870	336.45
8	1.564	1983	2059	2372	2463	201.95	4000	4120	4340	4410	305.35
9	1.695	1893	2037	2171	2207	182.77	3970	4030	4080	4210	NS
10	1.745	1971	2177	2398	2452	215.95	4020	4080	4100	4230	NS

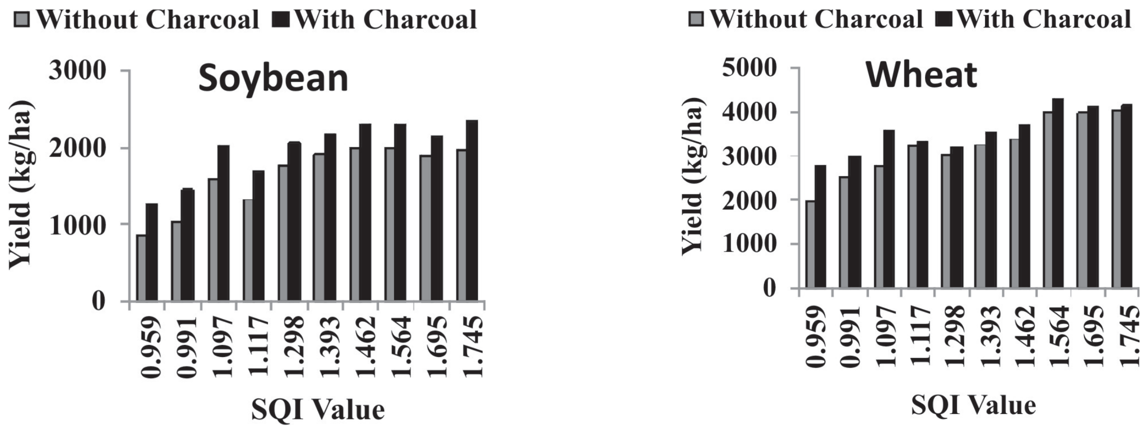

Fig. 1. Effect of charcoal on soybean and wheat yield at different sites of varying SQI values

as compared to wheat crop in all the sites (Fig. 1). It was clear from the result that the per cent increase in wheat yield as a result of charcoal application was highest (42%) at the site having lowest SQI value (0.959) whereas, the per cent increase in yield was lowest (3%) at the site having highest SQI value (1.745). Similar trend were also observed in soybean yield with highest per cent increase in yield (50%) was observed at the site having lowest SQI value (0.959). The per cent increase in soybean and wheat yield were in agreement with findings of Lehmann *et al*. (2003) who reported that the cowpea and rice yield were 39% to 45% higher yield in the charcoal amended plots over the un-amended plots. The result from our experiment was obvious that the soils which are relatively poorer in soil quality (sites having lower SQI value) responds better to the addition of carbon enriched material than the soil having relatively better SQI value.

Changes in soil quality indicators and SQI value as influenced by charcoal addition: Charcoal effect on crop yield and soil fertility status is well established and proven; similarly its impact is also likely on soil microbial activity. Apart from recalcitrant nature of carbon in charcoal, oxidizable carbon component in charcoal provides food source to microbes for multiplication. After the harvest of wheat crop, the soil analysis was carried out and it showed that out of the eight key indicators identified for Vertisol of Sehore and Vidisha district, only two indicators, namely, TOC and Alkaline Phosphatase activity had significant improvement due to application of charcoal. Also we observed significant improvement in microbial biomass C content in the soil due to charcoal application. The results also showed that the MBC, TOC and Alkaline phosphatase activity were increased with increasing level of charcoal application from 5.4 to 16.2 t ha^{-1}, respectively. Our experimental results were also in line with the findings of Kolb *et al*. (2009) and Wardle *et al*. (2008) who also reported that microbial biomass carbon and enzymatic activity was increased with increasing charcoal application.

Management interventions of charcoal addition on SQI value at different sites are presented in table 3. The result showed that the loss of soil quality as compared to their respective pristine soil are different in different sites and the values ranged between 0.114 unit (site no. 9) to as high as 0.650 unit (site no. 2). After imposition of interventions (different levels of charcoal addition), there was improvement in SQI values in each site, however, magnitude of improvement in SQI value varied from site to site. Under intervention I_1 (5.4 t ha^{-1}), I_2 (10.8 t ha^{-1}) and I_3 (16.2 t ha^{-1}) the improvement in SQI values ranged from 0.026 unit (site no. 10) to 0.246 unit (site no. 4), 0.051 unit (site no. 9) to 0.287 unit (site no. 2) and 0.067 unit (site no. 9) to 0.392 unit (site no. 2), respectively.

Soil resilience index value under different management interventions: Carbon–rich material of conventional charcoal or biochar addition to agricultural soils is receiving considerable interest due to its carbon sequestration potential, agronomic benefits and its potential to recover (resilience) soil functional properties of degraded soil (Quayle, 2010). Recent evidences also suggest that application of black carbon (biochar/charcoal) to soil substantially improves soil health, fertility and resilience. Resilience index after imposition of management interventions were computed for each of the ten sites and presented in Table 3. The resilience index under each intervention showed wide variation. Under intervention I_1, I_2 and I_3 the resilience index ranged from 10.97% (site no. 10 having SQI 1.745) to 58.01% (site no. 4 having SQI

Table 3. Effect of charcoal on soil quality index (SQI) value and resilience index (RI) on soil having different SQI Value at Sehore and Vidisha

Site No.	Soil Quality Index value (SQI) SQI(p)	SQI(d)	SQI(I_1)	SQI(I_2)	SQI(I_3)	CD (p=0.05)	Resilience Index (RI)(%) RI (I_1)	RI (I_2)	RI (I_3)
1	1.564	0.959	1.067	1.215	1.308	0.218	17.85	42.31	57.68
2	1.641	0.991	1.116	1.278	1.383	0.247	19.23	44.15	60.30
3	1.512	1.097	1.266	1.340	1.462	0.223	40.27	58.55	87.95
4	1.541	1.117	1.363	1.393	1.470	0.261	58.01	65.09	83.25
5	1.593	1.298	1.373	1.433	1.504	0.128	25.42	45.76	69.83
6	1.564	1.393	1.452	1.498	1.512	0.090	34.50	61.40	69.59
7	1.678	1.462	1.514	1.541	1.641	0.103	24.07	36.57	82.87
8	1.805	1.564	1.593	1.633	1.738	0.082	12.03	28.63	72.19
9	1.809	1.695	1.728	1.746	1.762	NS	28.94	44.73	58.77
10	1.982	1.745	1.771	1.812	1.852	NS	10.97	28.27	45.14

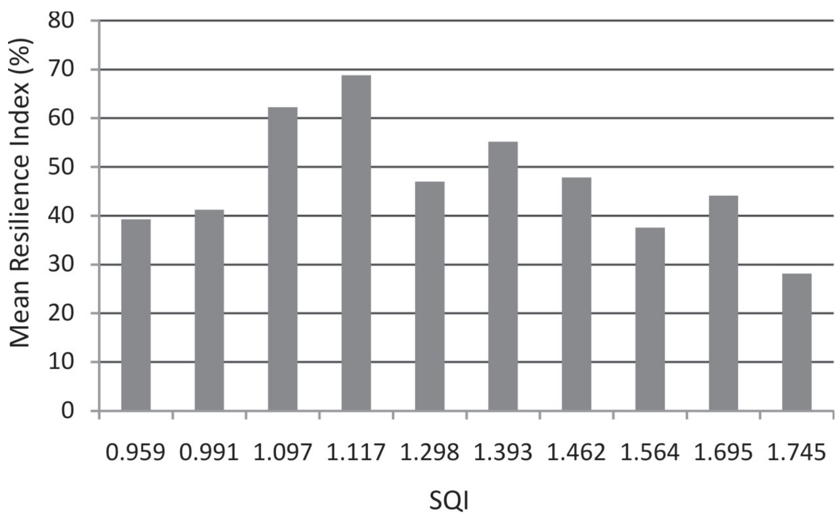

Fig. 2. Mean resilience index (%) of Vertisol at ten sites having different degree of degradation as measured by Soil Quality Index

1.117), 28.27% (site no. 10 having SQI 1.745) to 65.09% (site no. 4 having 1.117) and 45.14% (site no. 10 having 1.745) to 87.95% (site no. 3 having SQI 1.097), respectively (Table 3). Logically it was expected that the soils with low SQI value should show higher degree of resilience but the observed results are not in line with this expectation. The mean resilience index (summed over effect of I_1, I_2 and I_3) increased gradually from 28.12% (site no. 10, SQI (d) = 1.745) to 68.78% (site no. 4, SQI (d) = 1.117) and thereafter no definite trend was observed (Fig. 2). It was further observed that out of the ten sites the value of resilience index ranged from 28.12 to 68.78% which resulted in gain in soybean yield ranging from 264 kg ha^{-1} to 442 kg ha^{-1} and gain in succeeding wheat yield ranging from 103 kg ha^{-1} to 815 kg ha^{-1} (Fig. 3). The results indicate that resilience capacity of soil as a measure of soil function was increased significantly mainly due to increase in total carbon content as a result of charcoal application. The microbial activity as a measure alkaline phosphatase and microbial biomass carbon (MBC) were also increased and therefore these three parameters (TOC, MBC and alkaline phosphatase) were found to be responsible for increased resilience in Vertisol. Novotny *et al.* (2009) demonstrated that the presence of recalcitrant nature of carbon in Terra *Preta de Índios* soils ensures crop sustainability and resilience of soil fertility. In spite of intensive and degradative use of *Terra Preta de Indios* soil, high soil fertility maintenance and its resilience capacity is attributed to high levels of carbon as compared to adjacent soil (Sombroek *et al*., 1993; Glaser *et al*., 2001).

CONCLUSION

The conceptual framework for evaluating soil resilience has been designed with field level validation. The developed protocol for measuring soil resilience can successfully be used to measure

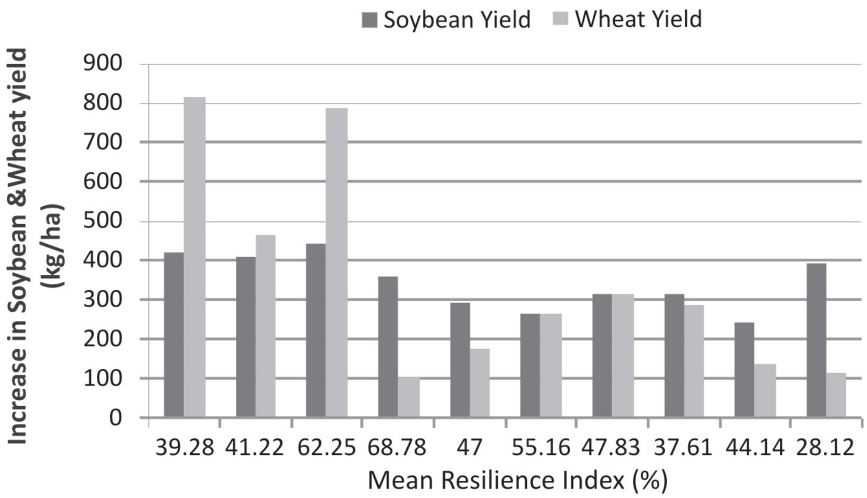

Fig. 3. Average gain in soybean and succeeding wheat yield at different values of measured resilience index in Vertisol

the resilience power of degraded soils in response to management interventions. Among the different management interventions, application of wood charcoal was found appropriate remedial options to improve soil resilience index. Further, it was observed that the farmers' field soils which had initially low soil quality index values showed maximum improvement in both resilience index as well as soil quality index values due to balance fertilization/charcoal addition.

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Estimation of Curve Number and runoff of a micro-watershed using Soil Conservation Service Curve Number method

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ABSTRACT

Since most of the Indian watersheds are ungauged, estimation of runoff depth is one of the key parameter not only for designing engineering structures in watershed but also for prioritization of sub watersheds within the watershed. Present study was undertaken to determine the runoff depth using the USDA Soil Conservation Service curve number (SCS-CN) method in Dadri Mafi micro-watershed, located between 25° 4′ 32.47′′ to 25° 6′ 27.47′′ N Latitude and 80° 28.11′′ to 80° 55′ 41.59′′ E Longitude which is situated at Manikpur block of Chitrakoot district, Uttar Pradesh. A total of 30 single storm events were selected between the years 2004 and 2012 for present study. Antecedent moisture condition (AMC) was calculated by taking preceding five days rainfall which gave three conditions AMC I, AMC II and AMC III. Weighted Curve Number for the entire selected micro-watershed was calculated based on site information of the watershed and found to be 82.40 for AMC II. The CN values corresponding to AMC I and AMC III were 66.28 and 91.50 respectively. The runoff for each storm events was estimated using Curve Number method and it was found that among the selected storm events maximum rainfall of 184 mm occurred on July 7, 2012 giving runoff value of 158.44 mm and minimum rainfall of 35 mm occurred on July 13, 2009 with runoff value of 0.61 mm. Runoff volume of the micro-watershed for each storm events were also calculated and maximum runoff was found be 918499.37 m^3. Strong correlation has been observed between rainfall and estimated runoff as well as observed and estimated runoff which indicate applicability of SCS-CN method in predicting runoff for the study area.

Key words: Surface runoff, Antecedent moisture condition (AMC), Curve number (CN), Micro-watershed

INTRODUCTION

Water is one of the most important continuing resources for sustaining life and development in our society. Surface runoff is the major hydrologic variable used in the water resources applications and management planning. Knowing the amount of runoff from a catchment is of vital importance particularly for planning the hydraulic structures and taking necessary erosion control measures. One of the most important objectives of engineering hydrology is to calculate the water yield of the catchments to determine the flood flows for planning the discharge facilities for water storage structures. In situation where there is no sufficient and reliable data, the calculation based on empirical methods lead to mistakes in determining the dimensions of water conservation structures. A good runoff model includes spatially variable parameters such as rainfall, soil types and land use/ land cover etc (Kumar; 1997). Identification of runoff is also of critical importance where the basic reservoirs support drinking water needs of the people.

United States Department of Agriculture Soil Conservation Service (USDA,1964), developed an empirical method for determining approximate amount of direct runoff from small agricultural catchments with different soil groups, vegetation covers and land uses by examining measured precipitation and runoff amounts, and named it as "Soil Conservation Service Curve Number (SCS-CN) Method". The SCS-CN method (SCS, 1972) also known as hydrologic soil group method is a versatile and popular approach for quick runoff estimation and is relatively easy to use with minimum data and to get adequate results. It is widely and efficiently used for planning the structures aimed at water storage and erosion and

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flood control. Generally, the model is well suited for small watersheds of less than 250 km^2 and it requires details of soil characteristics, land use and vegetation condition (Sharma *et al*., 2001). The method requires numeric catchments of interest that define the runoff potential. Hydrologic soil group number, land use type, vegetation cover, soil conservation measure, antecedent soil moisture conditions are the basic catchments characteristics used for curve number calculation. Hawkins (1973) has shown the existence of strong relationship between Curve Number and rainfall as well as Rao (1996) had studied the applicability of Curve Number method for estimation of runoff from daily rainfall data. A significant research on several issues related with the CN method have been worked in the recent past years by many authors (Hjelmefelt *et al.*, 1983; Chong and Teng, 1986; Hauser and Jones, 1991; Hawkins, 1993; Simantan *et al.*, 1996; Lewis *et al.*, 2000; Mishra *et al*., 2003; Bonta, 2005; Tejaswini, 2011; Tedela *et al*., 2012).

Dadri Mafi micro-watershed is under Bundelkhand region was in a grip of severe drought continuously from 2004 to 2007. The area is under treatment of Integrated Watershed Management Programme (IWMP-VII) starting in year 2010-2011. In the region, more than 85% of open wells were dried up due to deficit rainfall and severe ground water pumping. Over exploitation of existing vegetation, expansion of agricultural activities on degraded lands without due care of soil and water resources and faulty cultural practices on medium to shallow soils has aggravated the situation as resulted in wide spread erosion, land degradation and exposed parent rock. Ground water recharge is negligible on account of rocky sub strata causing slow growth of trees and low yields of crops. Due to reduction in vegetal cover and no provision for surface water storage, all the rainwater flows as runoff. This situation can certainly be corrected by *in-situ* water harvesting and planting of trees in agricultural fields, on bunds and wasteland. Because of all these reasons conservation of water generated as runoff in the region is very necessary for the development of region. Realizing the importance of the above mentioned views, the present study was undertaken to estimate the runoff in Dadri Mafi micro-watershed using Soil Conservation Service Curve Number method.

MATERIALS AND METHODS

Study area

Dadri Mafi micro-watershed which is situated in block Manikpur of Chitrakoot district, Uttar Pradesh has been selected. Geographically, it is located between 25°4′32.47″-25°6′27.47″ N Latitude and 80°28.11″-80° 55′41.59″ E Longitude. The total geographical area of the micro-watershed is 579.72 ha, out of which 300 ha is the treatable area. The entire watershed is rainfed and 40% area has life saving irrigation mainly through open shallow dug wells. Fig 1 shows the location of the catchment. Dadri Mafi micro-watershed falls in agro-climatic zone of Central Plateau Region representing a transitional zone of tropical sub-humid to semi-arid and comes under hot moist semi-arid ecological sub-region. The agro-climate of the watershed is characterized by dry and hot summer, warm and moist rainy season and cool winter with occasional rain showers. Mean annual temperature ranges from 24 to 25°C. The mean summer (April-May-June) temperature is 34°C which may rise to maximum 46 to 49°C during the month of May and June. The mean relative humidity varies between 40 and 60%.The annual rainfall of the Bundelkhand region part of Uttar Pradesh varies from 800 to 950 mm, about 90% of which is received during South-West monsoon (Singh *et al*., 2002). Soil of the micro-watershed is categorized into three groups viz. coarse grained soil, sandy loam soil and fine grained black soil. The land use of this watershed can be mainly divided into four categories viz. agriculture, forest, hills and habitation. Out of the total area 72% area is under rainfed cultivation. Fig 2 shows the classified land use map of the study watershed. The dominant slope category in the micro-watershed were 0-5% followed by 5-8%.

Data collection

The data related to the characteristics of Dadri Mafi micro watershed were collected from Department of Land Development and Water Resources, IWMP-VII, Manikpur, Chitrakoot, Uttar Pradesh. The daily rainfall data (2004 to 2012) were collected from Tulsi Krishi Vigyan Kendra, Ganivan (Banda), Chitrakoot, Uttar Pradesh to estimate the runoff.

SCS-CN method

To describe these curves mathematically, SCS assumed that the ratio of actual retention to potential maximum retention was equal to the ratio of actual runoff to potential maximum runoff, the latter being rainfall minus initial abstraction. In mathematical form, this empirical relationship is,

$$\frac{F}{S} = \frac{Q}{P - I_a} \qquad \ldots(1)$$

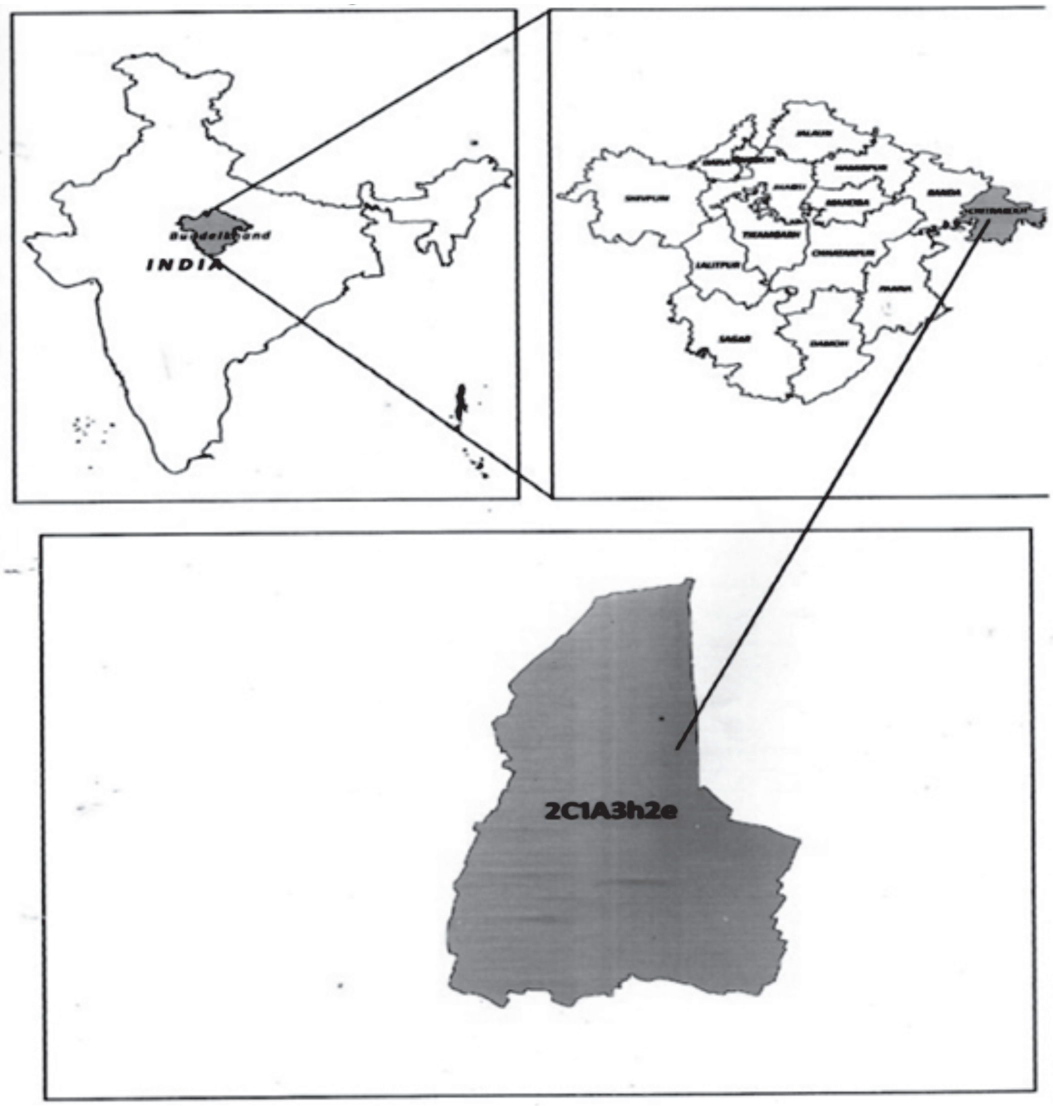

Fig. 1. Location map of Dadri Mafi micro-watershed

where,

F = actual retention (mm)
S = potential maximum retention (mm)
Q = accumulated runoff depth (mm)
P = accumulated rainfall depth (mm)
I_{-a} = initial abstraction (mm)

After runoff has started, all additional rainfall becomes either runoff or actual retention (i.e. the actual retention is the difference between rainfall minus initial abstraction and runoff).

$$F = P - I_a - Q \qquad \ldots(2)$$

Combining Equations (1) and (2) results,

$$Q = \frac{(P - Ia)^2}{P - Ia + S} \qquad \ldots(3)$$

To eliminate the need to estimate the two variables I_{-a} and S in Equation (3), a regression analysis was made on the basis of recorded rainfall and runoff data from small drainage basins. The data showed a large amount of scatter (Soil Conservation Service, 1972). The following average relationship was found

$$I_{a=0.2\,S} \qquad \ldots(4)$$

Combining Equations (3) and (4) yields,

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \quad \text{for } P > 0.2\text{S} \qquad \ldots(5)$$

Equation (5) is the rainfall-runoff relationship used in the CN method. It allows the runoff depth to be estimated from rainfall depth, given the value of the potential maximum retention S. This potential maximum retention mainly represents infiltration occurring after runoff has started. The S can be obtained from CN by using the relationship given

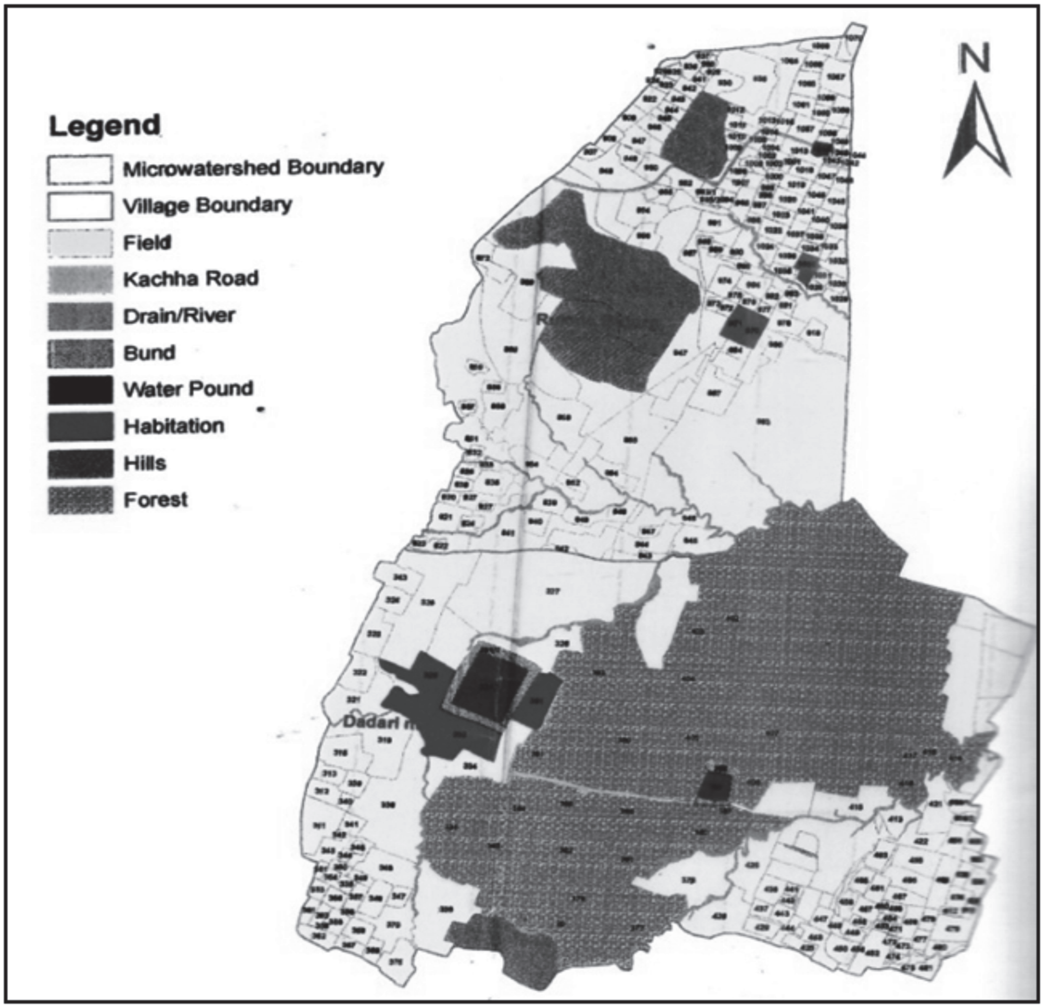

Fig. 2. Land use map of Dadri Mafi micro-watershed

in Equation (6). As the potential maximum retention (S) can theoretically vary between zero and infinity, Equation (6) shows that the CN which is a dimensionless number can range from one hundred to zero.

$$CN = \frac{25400}{254+S} \qquad \ldots(6)$$

AMC condition of Dadri Mafi micro-watershed can be calculated by taking five days preceding rainfall data of each storm event.

The CN values documented in the present case is AMC-II (as per the criteria of USDA, 1985). To adjust the CN values for the cases of AMC-I and AMC-III, equations (7) and (8) (Chow and Maidment, 1988) given below were used where, CN_I, CN_{II} and CN_{III} represents curve numbers for dry, normal and wet conditions respectively.

$$CN_I = \frac{4.2\,CN_{II}}{(10-0.058\,CN_{II})} \qquad \ldots(7)$$

$$CN_{III} = \frac{23\,CN_{II}}{(10+0.13\,CN_{II})} \qquad \ldots(8)$$

Runoff Computation

In the present study, thirty storm events were selected between 2004 and 2012 for calculation of runoff for Dadri Mafi micro-watershed. Weighted CN of the watershed was calculated from the hydrologic conditions of the watershed like characteristics of the soil, vegetation, including crops and land use. The hydrologic soil group of the micro-watershed was taken as 'C'. Once the CN value was calculated, potential maximum retention (S) was estimated from Equation (6). Thus, corresponding direct runoff depth of each storm event was estimated by using SCS-CN Equation (5). Runoff volume of each storm event was also computed.

Correlation between observed and estimated runoff

Number of factors relating to the catchment and climate influences the relationship between rainfall and the resulting runoff. The correlation between runoff and rainfall can be evaluated by obtaining a linear regression equation between two variables and ascertaining the value of the correlation coefficient. Subramanya (2006) provided the Equation (9) for straight line regression between runoff (R) and rainfall (P) as:

$$R = aP + b \qquad \text{...(9)}$$

$$a = \frac{N(\sum PR) - (\sum P)(\sum R)}{N(\sum P^2) - (\sum P)^2} \qquad \text{...(10)}$$

$$b = \frac{\sum R - a \sum P}{N} \qquad \text{...(11)}$$

where, a, b = coefficient P = rainfall (mm), R = runoff (mm), N = no. of sets of R and P.

In generally, observed runoff is calculated in the field by measuring the actual runoff following a rainfall event. Since conventional hydrological data are hardly available in watershed or micro-watershed level, in the present study, it is being estimated using the given regression Equation (9) (Kumar, 2004 and Tirkey *et al.*, 2013) in which runoff calculated using the SCS-CN method and rainfall is taken as input parameter.

Performance evaluation

Performance evaluation of method used is done to judge the goodness of fit between observed and predicted values. The visual evaluation is done based on the graphical comparison between observed and predicted values. Since visual observation may lead to personal bias, statistical indices such as root mean square error (RMSE), correlation coefficient (r) and coefficient of efficiency (CE) were also used to evaluate performance of the method.

Root mean square error (RMSE)

RMSE is determined to measure the prediction accuracy of a model. It always produces positive values by squaring the errors. The RMSE is zero for perfect fit and increased values indicate higher discrepancies between predicted and observed values. It is determined by following relationship as:

$$RMSE = \sqrt{\frac{\sum_{j=1}^{n}(O_j - P_j)^2}{n}} \qquad \text{...(12)}$$

where, O_j and P_j are observed and predicted values respectively and n is the number of observations.

Correlation coefficient (r)

Correlation coefficient (r) evaluates degree of closeness between observed and predicted values. It is computed by using the relationship as:

$$r = \frac{\sum_{j=1}^{n}\{(O_j - \bar{O})(P_j - \bar{P})\}}{\sqrt{\sum_{j=1}^{n}(O_j - \bar{O})^2 \sum_{j=1}^{n}(P_j - \bar{P})^2}} \times 100 \qquad \text{...(13)}$$

where, $\bar{O}$ and $\bar{P}$ are mean of observed and predicted values.

Coefficient of efficiency (CE)

For estimating goodness of fit between observed and predicted values, the CE was suggested by Nash and Sutcliffe (1970) and it is expressed as:

$$CE = \left(1 - \frac{residual\ variance}{initial\ variance}\right) \times 100 = \left(1 - \frac{\sum_{j=1}^{n}(O_j - P_j)^2}{\sum_{j=1}^{n}(O_j - \bar{O}_j)^2}\right) \times 100 \qquad \text{...(14)}$$

A perfect agreement between observed and estimated values yield coefficient of efficiency of 100%. For zero agreement, all the estimated values must be equal to the observed mean. The closer this ratio is to unity, the better is the regression relation.

RESULTS AND DISCUSSION

Curve number

Using information collected about the land use pattern, treatment adopted, cropping pattern, areal extent, AMC of Dadri Mafi micro-watershed, weighted CN for the entire micro-watershed was calculated and found to be 82.40. CN_{II} value was converted to CN_I and CN_{III} based on AMC of each storm event and found to be 91.50 and 66.29 respectively for CN_{III} and CN_I. Values are presented in (Table 1). From the table, it is revealed that higher the values of CN lesser is the potential maximum retention S and vice versa for different AMC's.

Potential maximum retention (S)

Potential maximum retention values (S) were estimated and results are depicted in Table 1. The table shows that the value of Potential maximum retention varies from 23.59 mm to 129.18 mm, which also indicates that S values are minimum for AMC III values. This basically shows that soil is fully saturated and value of runoff will be more. S value for AMC II was found to be 54.25 mm. For

Table 1. Rainfall, Curve number and computation of estimated runoff

Storm events	Rainfall (P), mm	AMC	Curve Number retention values (S), mm	Potential maximum (0.2 S), mm	Initial abstraction	Estimated runoff, mm	Runoff volume, m^3
June 16,2004	95.00	III	91.50	23.59	4.72	71.58	414974.07
July 3,2004	50.00	I	66.29	129.18	25.84	3.81	22076.12
September 21,2004	75.00	I	66.29	129.18	25.84	13.55	78573.07
June 28,2005	96.00	III	91.50	23.59	4.72	72.54	420524.70
July 28,2005	80.00	I	66.29	129.18	25.84	16.00	92766.51
August 17,2005	50.00	I	66.29	129.18	25.84	3.81	22076.12
September 10,2005	126.00	III	91.50	23.59	4.72	101.54	588626.53
July 21,2006	82.00	III	91.50	23.59	4.72	59.21	343260.73
August 29,2006	62.00	I	66.29	129.18	25.84	7.91	45857.18
October 22,2006	36.00	I	66.29	129.18	25.84	0.74	4298.62
February 11,2007	109.00	I	66.29	129.18	25.84	32.57	188826.21
May 19,2007	75.00	I	66.29	129.18	25.84	13.55	78573.07
August 3,2007	68.00	III	91.50	23.59	4.72	46.10	267252.81
September 19,2007	77.00	I	66.29	129.18	25.84	14.52	84152.01
June 27,2008	75.00	I	66.29	129.18	25.84	13.55	78573.07
July 25,2008	88.00	III	91.50	23.59	4.72	64.90	376248.84
July 3,2008	86.00	III	91.50	23.59	4.72	63.00	365229.98
July 13,2009	35.00	I	66.29	129.18	25.84	0.61	3519.69
August 14,2009	126.00	I	66.29	129.18	25.84	43.75	253609.65
September 8,2009	106.00	I	66.29	129.18	25.84	30.70	177963.17
February 12,2010	45.00	I	66.29	129.18	25.84	2.48	14353.61
July 19,2010	56.00	I	66.29	129.18	25.84	5.71	33104.63
September 14,2010	47.00	II	82.40	54.25	10.85	14.46	83800.28
June 21,2011	112.00	III	91.50	23.59	4.72	87.95	509847.28
August 12,2011	51.00	III	91.50	23.59	4.72	30.66	177733.65
September 4,2011	70.00	I	66.29	129.18	25.84	11.25	65233.01
July 7,2012	184.00	III	91.50	23.59	4.72	158.44	918499.37
July 24,2012	120.00	III	91.50	23.59	4.72	95.70	554805.20
August 5,2012	83.00	III	91.50	23.59	4.72	60.16	348744.07
September 15,2012	105.00	III	91.50	63.65	4.72	81.19	470659.54

the storm events which belongs to AMC I and AMC II, the S values are much higher than that of AMC III which shows that soil condition is dry thus absorbing maximum amount of rainfall falling on it will lead to generation of less amount of runoff.

Estimation of runoff depth and runoff volume

Direct runoff (Q) of each storm event was calculated using SCS-CN method and values are presented in Table 1 and the estimated runoff was depicted in the form of graph as shown in Fig 3. It was observed that among the selected storm events maximum rainfall of 184 mm occurred on July 7, 2012 giving highest runoff value of 158.44 mm and minimum rainfall of 35 mm occurred on July 13, 2009 with runoff value of 0.61 mm. Runoff volume of each storm event was also calculated considering the total area of watershed and shown in Table 1. It is found that maximum value of runoff volume is 918499.37 m^3 for storm event of July 7, 2012 and minimum value of 3519.69 m^3 for storm event of July 13, 2009.

Correlation between observed and estimated runoff

The correlation coefficient between rainfall and runoff (calculated using the SCS-CN method) was evaluated and it is found as 0.86, and the result is shown in Fig 4. It is clear from the fig that rainfall and estimated runoff are strongly correlated with coefficient of determination, R^2 = 0.74. The performance evaluation of SCS-CN method in estimating runoff for the study area was performed

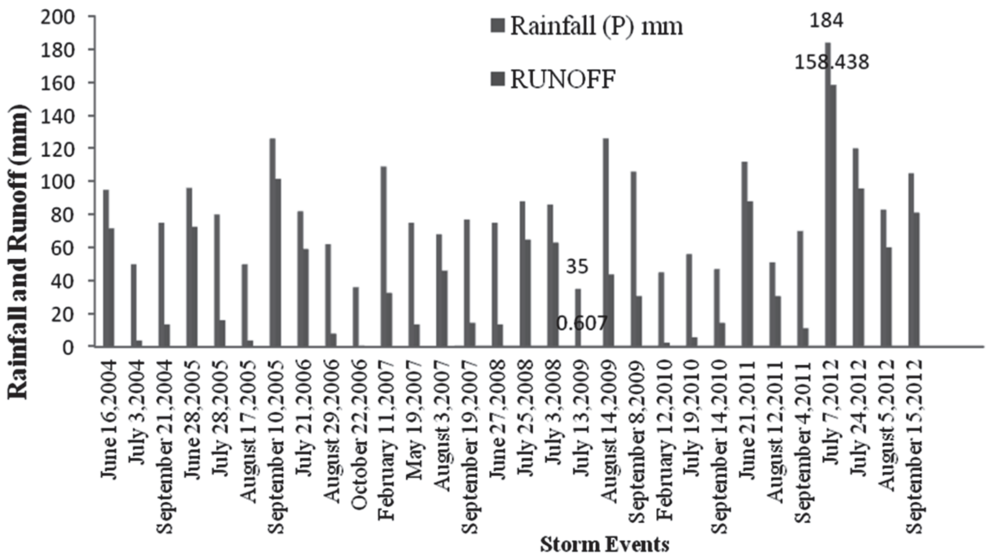

Fig. 3. Estimated runoff of Dadri Mafi micro-watershed using SCS-CN method

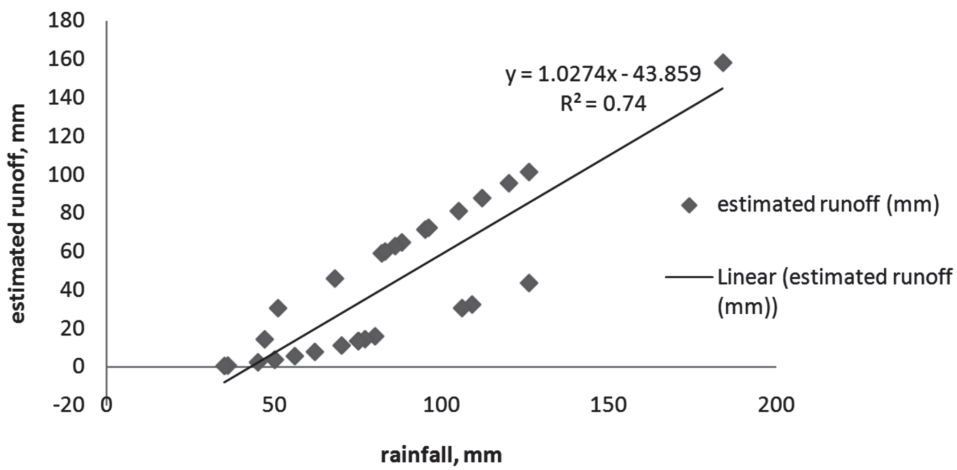

Fig. 4. Relation between rainfall and estimated runoff

qualitatively as well as quantitatively by visual observation and various statistical indices viz. RMSE, r and CE. The observed and estimated runoff is being compared in the form of graph and scatter plot which are shown in Figs. 5 and 6 respectively. It is observed that both observed and estimated runoff for the study area are approximately similar and are well correlated with R^2= 0.75. The values of RMSE, r and CE are found to be 19.22, 0.87 and 63.98%, respectively.

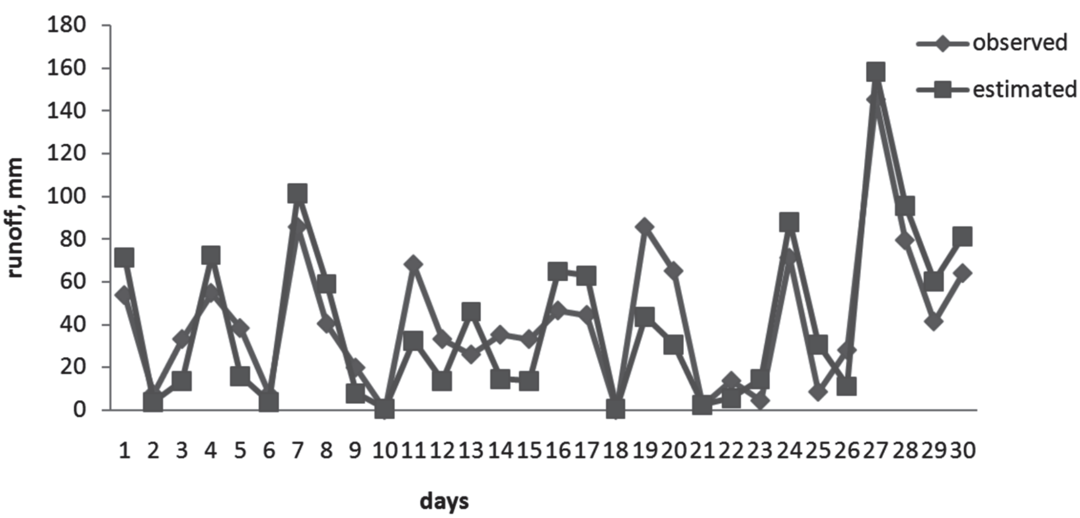

Fig. 5. Comparison between observed and estimated runoff using SCS-CN method

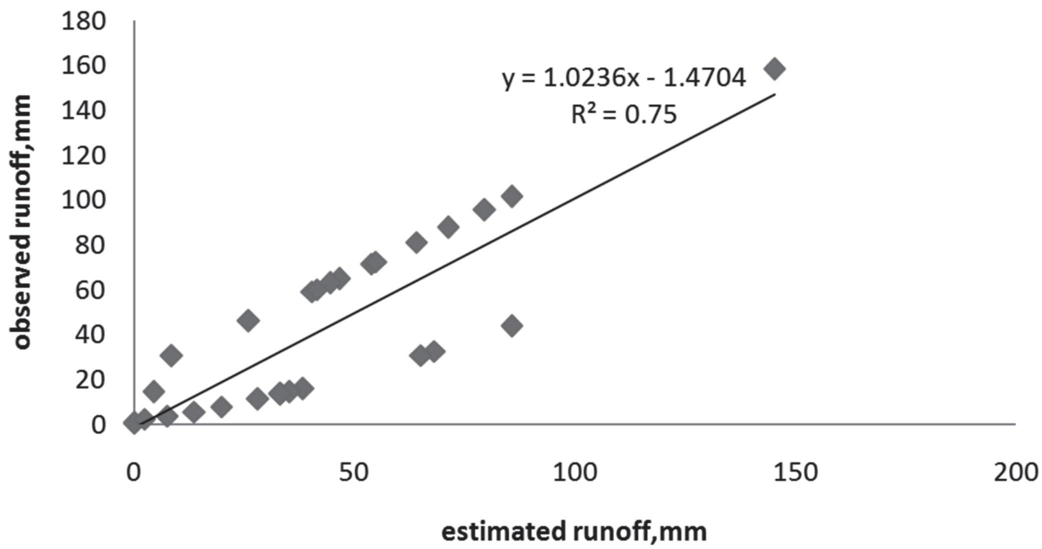

Fig. 6. Relation between observed and estimated runoff

SCS-CN method for estimating runoff was validated in several studies for its suitability in runoff prediction. Tejram *et al*. (2012) determined the run-off using SCS-CN method of the Uri River watershed in the lower Narmada basin of central India and compared the results with the actual runoff calculated from observed hydrograph and found a good correlation. Tirkey *et al*. (2013) validated the use of SCS-CN techniques for rainfall-induced runoff estimation using high-resolution satellite data for Daltonganj watershed, a small watershed of Palamu district, Jharkhand and found strong correlation between observed and estimated runoff. Sunu *et al.* (2013) compared calculated surface runoff using SCS-CN with the observed runoff in the Upstream Ciliwung Watershed, West Java and good results were observed. The present study also shows similar result, thereby exhibiting a good correlation between observed and estimated runoff.

CONCLUSIONS

The results of the study show that the SCS-CN method satisfactorily computes the runoff in Dadri Mafi micro-watershed for the selected rainfall events which substantiate various previous studies stating suitability of this method for runoff estimation from micro watersheds. The present study also shows that there is good runoff potential in the region which can be harvested to supplement the canal and ground water for productive agriculture and hence, it will be helpful for utilization during the lean season and can be stored in recharge structures increasing groundwater potential of the area. As the problem of water scarcity in Dadri Mafi micro-watershed even for domestic and drinking purposes is very severe for the recent past years, there arises a need for building recharge structures for harvesting and utilization of surface runoff which can be helpful in increasing the water availability in the area facilitating increased crop production, crop diversification and overall profitability. The study can also help in design and construction of various Soil and water conservation structures like drains, ponds, reservoirs etc. for assessing the water yield of the watershed and for determining potential for different uses like irrigation, domestic and power generation in the region.

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Land use pattern of selected sub-watersheds of the Siang river of Arunachal Pradesh using remote sensing and GIS techniques

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ABSTRACT

Geo-coded satellite images had been used for studying land use/land cover pattern of selected sub-watersheds of Siang river covering parts of Arunachal Pradesh and Assam. Among different land use/ land cover classes in the study area, evergreen/semi-evergreen dense forest occupies the largest area (46.15 per cent) predominantly in hill slopes followed by settled cultivation in alluvial and flood plain areas (21.73 per cent). Other land use classes are scrub land (6.13 per cent), scrub forest (5.81 per cent), grass land / grazing land (2.46 per cent), shifting cultivation (1.62 per cent), forest plantation (0.34 per cent), river sand (8.01 per cent) and river/stream/nalah (6.51 per cent).

Key words: Geo-coded, Satellite image, Land use, Land cover, Forest, Shifting cultivation, Plantation

INTRODUCTION

Land use refers to man's activities and the varied uses which are carried over land, and land cover refers to natural vegetation, water bodies, rock/soil, artificial cover and others noticed on the land (Anonymous 1989). The land use pattern study of an area is the prerequisite for any developmental planning of that area on a sustainable basis. The land use map can provide precise and accurate information on the existing land use/land cover and it shows the spatial distribution of various land use/ land cover features of the area. New technologies like satellite remote sensing and Geographical Information System (GIS) provide data to study and monitor the dynamics of natural resources for environmental management (Berlanga-Robles and Ruiz-Luna, 2002). Recent development in the use of satellite data is to take advantage of increasing amounts of geographical data available in conjunction with GIS to assist interpretation (Tziztiki *et al.*, 2012). These technologies are used for generating various land use/land cover features of an area, their distribution and also the temporal changes of these features.

Land use data of an area plays a crucial role and input for decision makers, planners and anyone involved in land resources management. Sustainable development of an area lies in the concept of developing and utilizing land and water resources of the area in order to meet the need of the people and maintain the sustenance of the productivity and environment for the future generation also (Chennaiah *et al.*, 1998). Remote sensing has proved to be a very effective means of developing an integrated information system that can meet the challenges of managing lands for meaningful and sustainable utilization (Gautam *et al.*, 1996). With the development of spectral, spatial and radiometric resolutions of the sensors on the satellite, now, land use/land cover features can be better mapped on different scales and their spatial extent can be precisely found out. Land use/land cover studies using remote sensing and GIS techniques has been carried out in Pondicherry (Nagamani and Ramachandran, 2003), Tamil Nadu (Prahasam, 2010), Andhra Pradesh (Appala Raju *et al.*, 2013, Sreenivasulu *et al.*, 2013), Tripura (Das and Sarkar, 2014), but such studies are very meager in North East India and particularly in Arunachal Pradesh. In this paper, an attempt has been made to present the mapping of land use/land cover of a watershed and analysis of land use pattern using satellite remote sensing and GIS technology. The main objectives of the study of land use pattern is to prepare land use/land cover map of the study area using satellite data and to find out the spatial

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arrangement and distribution of different land uses of the study area. It also aims at generating reliable information on land uses in the form of maps and statistics for their uses in planning and management of existing natural resources.

MATERIALS AND METHODS

The study area is basically a cluster of sub-watersheds of four tributaries *viz.*, Kemi, Sille, Leko and Sibo korong of the mighty Siang river. It covers a total geographical area of 788.60 sq. km. The major part of this watershed cluster comes under East Siang district of Arunachal Pradesh while a small part of it falls under Jonai subdivision of Dhemaji district of Assam. In Arunachal Pradesh, the area is located within Pasighat, Bilat, Seren and Oyan administrative circles under Pasighat Community Development Block and Pasighat sub-division. The area lies in between 27°50′ N and 28°30′ N latitudes and 94°30′ E and 95°30′ E longitudes. Fig. 1 shows the location of the study area and its geographical extent.

Data in-puts : Main data inputs of the study are remotely sensed satellite data, topographical maps on 1:50,000 scale and Ground truth information.

Satellite	Sensor/Bands	Month of pass	Spatial resolution
RESOURCESAT (IRS-P6)	LISS (Linear Imaging Self Scanner) - III / Band 2,3,4,5 (Green, Red, Near Infrared and SW Infrared) False Colour Composite (FCC)	February, 2009	23.5 metre

Geo-referencing of data: The toposheets on 1:50000 scale were scanned and geo-referenced using image processing software ERDAS Imagine. Satellite data were then geo-rectified, taking GCPs (Ground Control Points) with reference to the geo-referenced toposheets.

Satellite data interpretation: On-screen interpretation technique was used for mapping various land use/land cover features of the study area using ArcGIS software. The features of remotely sensed data were deciphered from the satellite images through on-screen interpretation technique based on various image interpretation keys or elements such as shape, size, tone, pattern, texture, shadow and association.

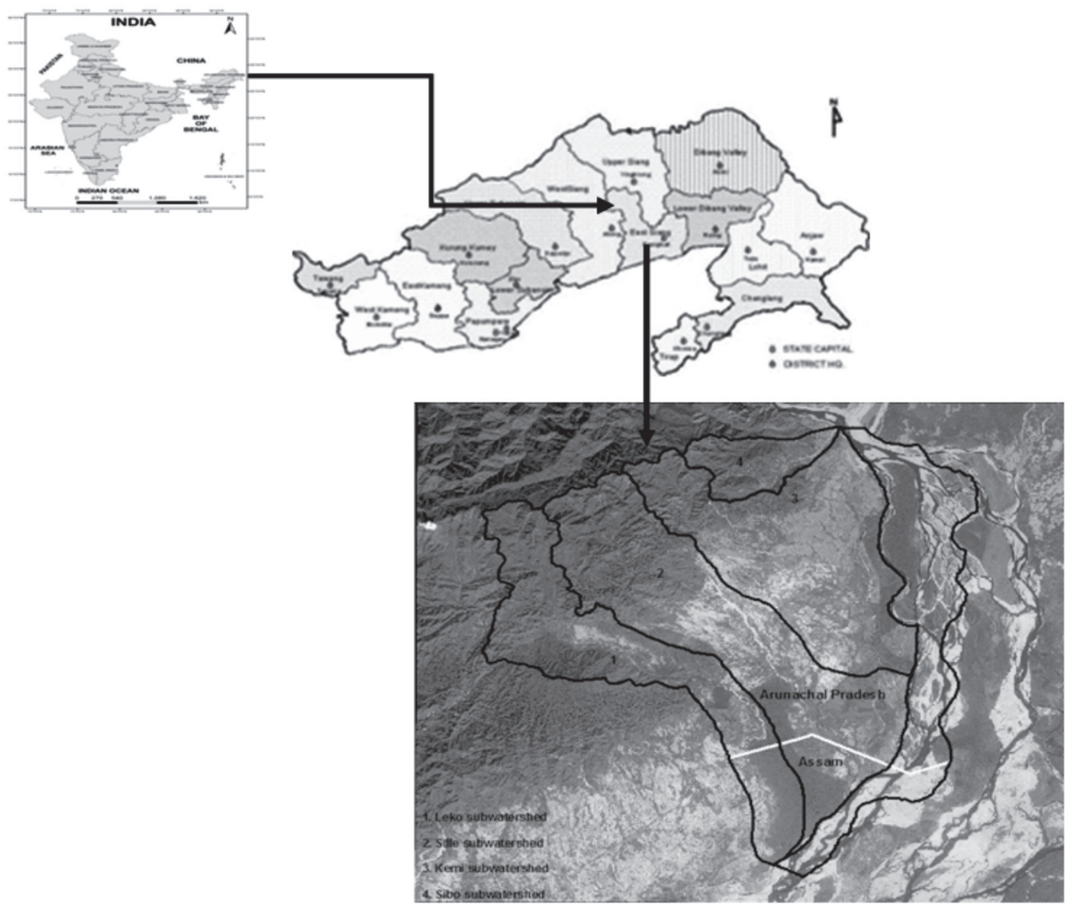

Fig. 1. Location map and image of the study area

Ground truth verification : The interpretation was followed by ground truth verification of those doubtful areas already marked during the process of pre-field interpretation. Doubtful areas were visited and interpretation were checked and rectified.

Finalization of maps: The information collected through ground survey was incorporated on the maps with necessary modifications and area statistics under different land use/land cover classes were generated. The Flow chart of land use/land cover mapping is presented in Fig. 2.

RESULTS AND DISCUSSION

The land use / land cover map prepared on 1:50,000 scale is presented in Fig. 3. The area of extent of different land uses is presented in Table 1, Fig. 4 and Fig. 5. The land use / land cover features found in the study area are built-up land or settlement, agricultural land both *kharif* and *rabi*, area under plantation crop, scrub land, dense forest, open forest, scrub forest, reserved forest, bamboo forest, rivers, river sand etc. The hilly parts of the study area are mostly covered under semi-evergreen forest. They are classified as dense, open and scrub forests. In the plain area, settled agriculture is the pre-dominant practice with paddy as the major crop. The flood plains along the river Siang, specially Kemimukh and Jampani areas are under *rabi* vegetables, potatoes etc. with their bumper production. But lack of adequate communication facility in the area to the markets hinders marketing of these vegetables.

Built-up land : These are the areas under human habitation. The built-up land in the satellite image have dark bluish green tone, small to big sizes, irregular shape, coarse texture, clustered or scattered pattern and are found surrounded by agricultural land, forest, wastelands etc.

The area under built-up land is 9.80 sq. km. constituting 1.25 per cent of the study area. Built-up lands are classified as urban and rural. The urban area covers 15 sq. km. and rural built-up area covers 2.65 sq. km, which constitute 0.91 and 0.34 per cent of total geographical area respectively. Pasighat town, the district headquarter of East

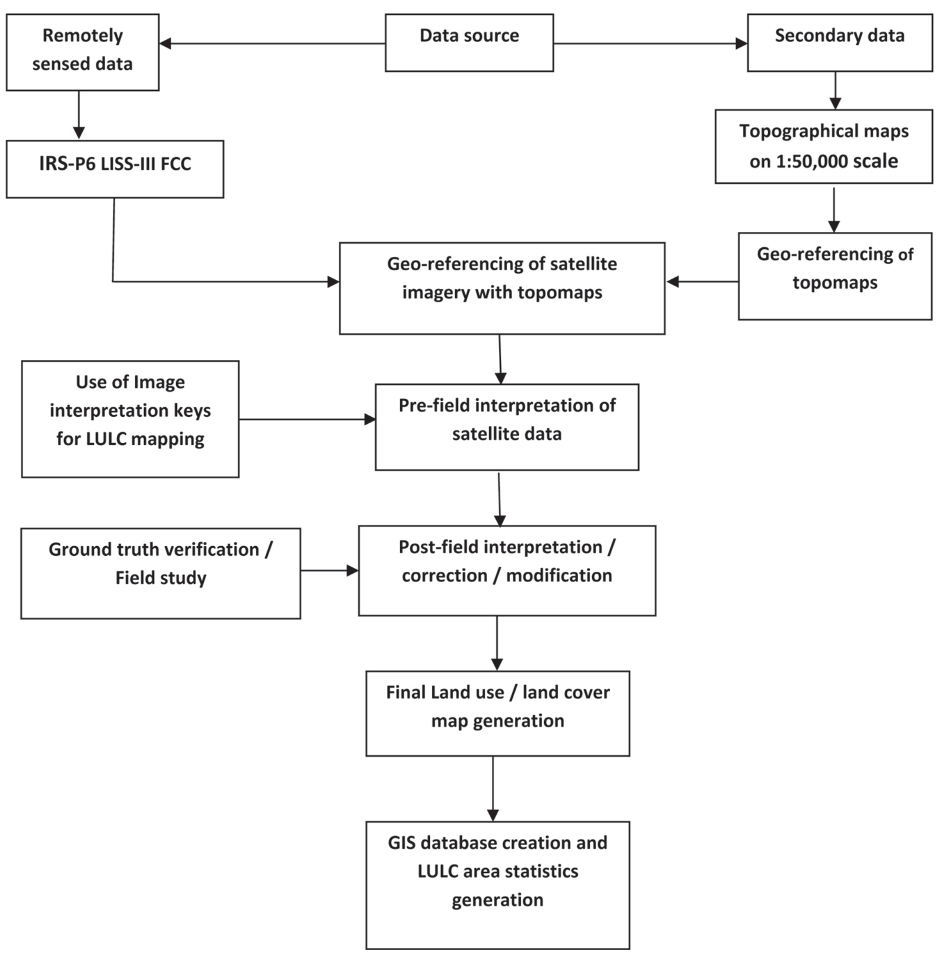

Fig. 2. Flow chart of land use / land cover mapping

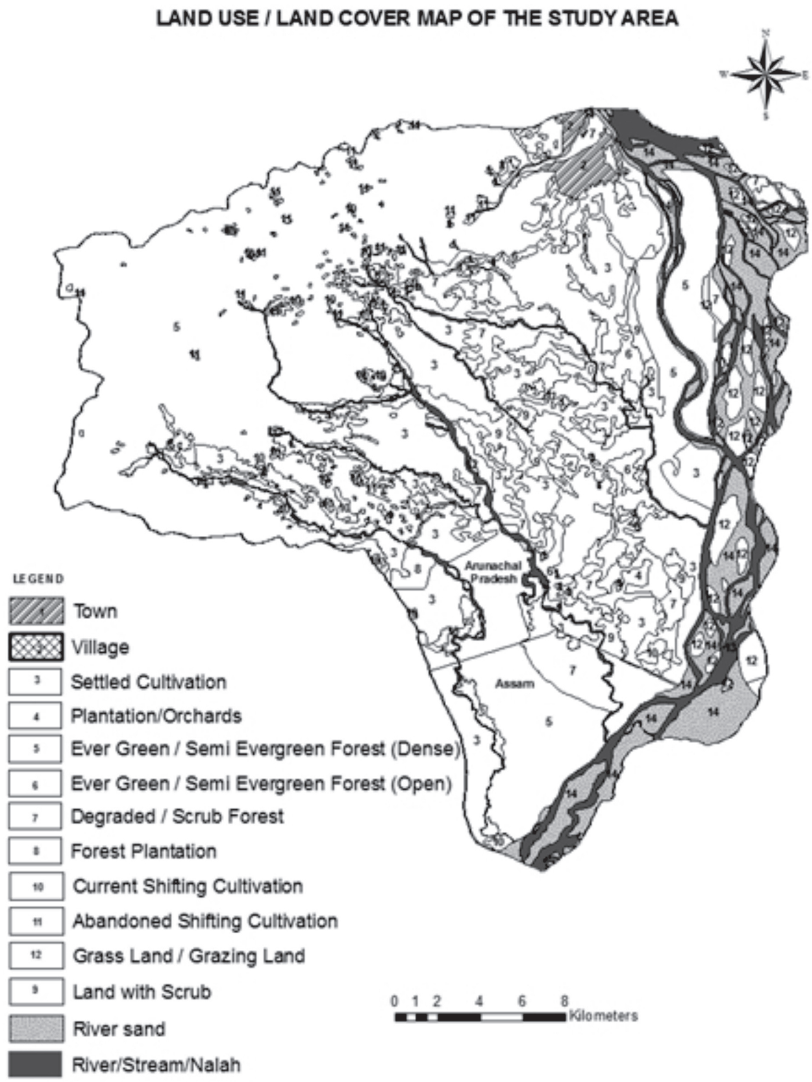

Fig. 3. Land use / land cover map of the study area

Table 1. Land use / land cover classes of the study area

Land use / land cover classes		Area (Sq. km.)	Percentage of total study area
Built-up areas	Village	2.65	0.34
	Town	7.15	0.91
	Total	**9.8**	**1.25**
Agricultural land	Settled Cultivation	169.04	21.44
	Plantation/Orchards	2.32	0.29
	Total	**171.36**	**21.73**
Forest	Ever Green / Semi Evergreen Forest (Dense)	347.31	44.04
	Ever Green / Semi Evergreen Forest (Open)	16.64	2.11
	Degraded / Scrub Forest	45.79	5.81
	Forest Plantation	2.68	0.34
	Total	**412.42**	**52.3**
Shifting cultivation / Jhum land	Current Shifting Cultivation	9.72	1.23
	Abandoned Shifting Cultivation	3.10	0.39
	Total	**12.82**	**1.62**
Grass Land / Grazing Land		19.41	2.46
Scrub lands		48.33	6.13
River sand		63.14	8.01
River/Stream/Nalah		51.33	6.51
Total study area		**788.60**	**100.00**

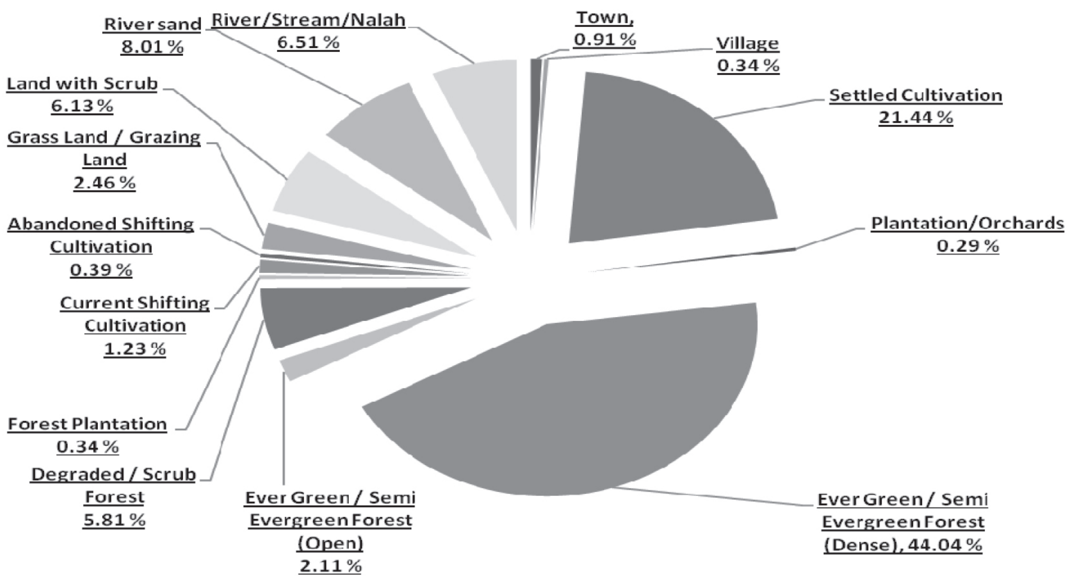

Fig. 4. Diagrammatic representation of land use / land cover classes (Percentage of Total Area)

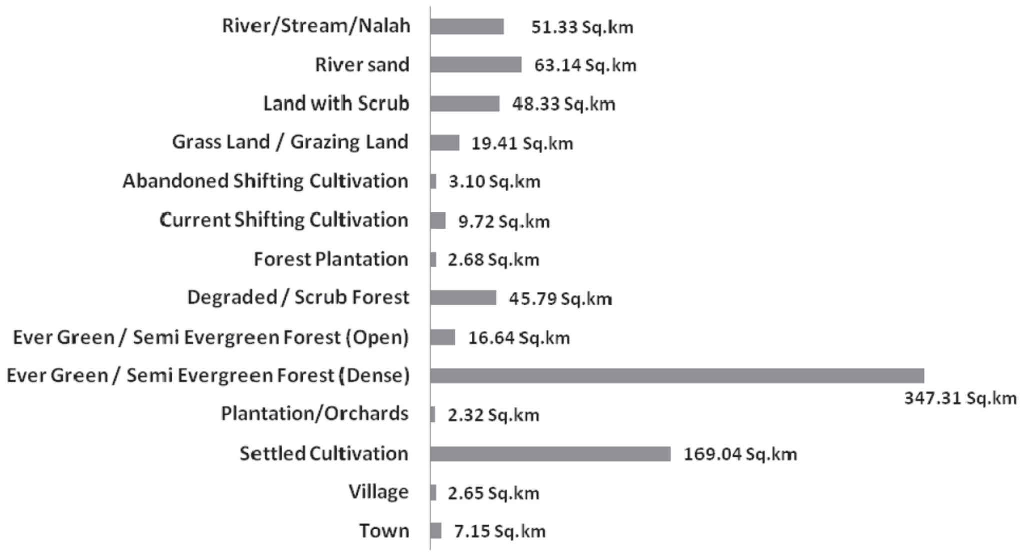

Fig. 5. Areal extent of Land use /land cover classes in the study area

Siang district is located in the study area. The town has been increasing and expanding in population and areas. There are other important places like Bilat, Ruksin, Oyan, Ngorlung, Nizluk classified as rural areas.

Agricultural land : The agricultural land includes crop land, fallow land and agricultural plantations. This class of land use/land cover in the satellite image has light to bright red, yellow to greenish blue tone, varying in sizes, regular to irregular shape, medium texture, contiguous to non-contiguous pattern, found in proximity to river and in alluvial plain, flood plain and valleys.

The agricultural land covers 171.36 sq. km. constituting 21.73 per cent of the geographical area. These are the agricultural lands under permanent or settled cultivation and plantation crops or orchards which cover 169.04 and 2.32 sq. km. respectively constituting 21.44 and 0.29 per cent respectively. The main crop is rice along with different summer and winter crops and vegetables grown in the vast stretch of alluvial plains and flood plains. This area can be utilized for crop intensification/diversification based on soil-site suitability assessment. One tea garden is also located in the study area near Oyan village.

Forest : The evergreen/semi-evergreen dense forest in the satellite image has dark red to bright red colour, open forest has red tone and these two classes are varying in size, discontinuous, smooth to medium texture and found in plains and hill slopes. Degraded forest has light red to dark brown tone and is varying in size, irregular and discontinuous, coarse to mottled texture and found in plains and hill slopes and in different forest types. Forest plantations appear in satellite image in dark red colour and are varying in sizes, regular to irregular shape, smooth to medium texture, found in proximity to river and in alluvial plain and flood plain of the study area.

The forest is the largest land use/land cover class extending over 412.42 sq. km. and constituting 52.3 per cent in the study area. The forests are generally evergreen and dominantly semi-evergreen forests. The forests are classified as dense, open and scrub forest based on their crown density. There are also considerable areas under mixed bamboo forest and forest plantation. There are two reserved forests located in the study area. One is Pasighat Reserve Forest in the eastern side of the study area along the Siang river and the other is Pobha Reserve Forest in the South-western side. Pobha forest covers area under Arunachal Pradesh and Assam. The extent of distribution of dense forest, open forest and degraded forest are 347.3, 16.64 and 45.79 sq. km respectively and constitute 44.04, 2.11 and 5.81 per cent of the study area respectively.

Scrub land: Scrub lands of the area are basically cultivable wasteland, mostly remaining unutilized for years. This land use class includes both land with scrubs and land without scrubs. The scrub land in the satellite image has light yellow to brown tone and is varying in size, irregular shape, coarse to mottled texture and dispersed in patches, found in foot hill and surrounded by agricultural lands. The area under scrub land is 48.33 sq. km., which is 6.13 percent of total geographical area. These lands have good potential for agricultural and horticultural uses.

Grass land/Grazing land: Grass lands are seen along the rivers and grazing lands are natural grasses mixed with other vegetation. This land use/land cover class in the satellite image has light red to light brown tones and are varying in size, irregular in shape, coarse to mottled texture, contiguous to non contiguous and found in proximity of river, in sand bars, alluvial and flood plain areas. The area covered is 19.41 sq. km., which is 2.46 percent of the study area.

Shifting cultivation: The shifting type of agriculture is practiced in hills of the study area. The shifting cultivation is classified as current and abandoned shifting cultivation. The crops grown in shifting cultivation are local rice varieties, marwa, maize, sorghum etc. The shifting cultivation areas in the satellite image are identified by light red to bright red or yellow to greenish blue tones based on existing cultivation or abandoned nature, small in size, irregular shape, coarse to mottled texture based on vegetation and found in hill slopes amidst forest.

The area under current shifting cultivation is 9.72 sq. km and the area under abandoned shifting cultivation is 3.10 sq. km., which is 1.23 percent and 0.39 percent of total geographical area respectively. Over the years, jhum cycle has been considerably reduced which has resulted in soil erosion, river siltation and occurrence of flood in the plain.

River/stream/nallah: These land uses/land cover classes in satellite image have light blue to dark blue tone; long, narrow to wide size, irregular sinuous, smooth to medium, contiguous, dendritic drainage pattern. The river/stream/nalah and river sand cover an area of 51.33 sq. km.

River sand: These land uses/land cover classes in satellite image have bright white with light bluish green tinge tone based on moisture content; small to medium size, smooth to medium, contiguous and are found in river bed developed by fluvial deposition process. This land use/land cover class covers an area of 63.14 sq. km.

From the land use/land cover mapping, it has been found that settled/permanent agriculture has been practiced in the vast alluvial land and long stretch of flood plains along Siang river, Remi and other rivers. These areas have nearly level to level and gentle slope and naturally possessing good suitability for growing various cereal and pulse crops. The long stretch of flood plain has been used for growing different summer and winter vegetables. Rice cultivation is found to be dominant crop grown in the alluvial plains with good harvest every year. Rice cultivation is also found in the lower piedmont plains of the study areas. The cropping pattern is predominantly single cropping. There are some areas cultivated exclusively for kharif crops and there are some areas where rabi crops are grown. In some areas double cropping with rice-maize, rice-mustard sequences are also seen. The tea cultivation is also found in the area. There is a tea garden (Oyan Tea Estate owned by Siang Tea and Industries Ltd.) near Oyan. The main crops during kharif season are rice and maize. Potato, mustard are grown during rabi season along with other rabi vegetables like cabbage, cauliflower, knolkhol etc. in the flood plains along the river Siang.

CONCLUSIONS

In the study area, a considerable area is under settled cultivation and mainly utilized for cultivation of rice and other summer and winter crops in alluvial and flood plain areas. Largest extent of land is under evergreen / semi-evergreen forest covers. In the hill slopes, shifting cultivation is practiced by local people inhabiting in the hills and nearby areas. Till date, there has been no appropriate or judicious utilization of the available resources in the study area. It is in this context, there is need for developing the hill slopes and the entire watershed area using appropriate land management practices like alternate land uses based on land suitability assessment and adopting soil conservation practices like terracing, contour bunding, contour cultivation etc. so that the environment and ecology of the watershed area is maintained on sustainable manner. These land use/ land cover information in conjunction with thematic data on soil, slope and other maps can be used for managing various problems and sustainable development of the area.

The state departments and organisations will be benefitted from the accurate and reliable information on land use/land cover in the form of maps, records and statistics, which are prerequisites for any developmental planning and management of land and water resources on sustainable manner and better uses of land for agriculture, horticulture, forestry, urban and rural area development etc.

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Leaf litter dynamics in Agroforestry system affecting microbial activity in Saline Soils

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ABSTRACT

The Litter fall is a very valuable resource. It has important role to play in soil nutrient dynamics, soil properties and energy transfer. Litter fall and decomposition are the two main processes accounting for soil enrichment in agroforestry system. Litter fall in soil has strong bearings in maintenance of hydrological cycles apart from influencing soil properties and ecology. The extent of enrichment in soil properties depends on the tree species, management practices and the quantity and quality of litter. Decomposition of various litter components results in conversion of nutrients and their release depends on litter composition, microbial activity, C:N ratio, temperature, moisture and other factors. It has been reported that 63, 50, 48, 67 and 57% of nutrient uptake returned to soil annually in *Dalbergia sisso* while 39, 9, 23, 14 and 13 % in *Eucalyptus* with respect to N, P, K, Ca and Mg, respectively. Litter fall significantly increased the soil microbial populations and the enzymes activities in the normal soil while in the saline or the alkali soils, salt concentration affect activity of microbial population and enzyme activity.

Key words: Agroforestry, Leaf Litter, Decomposition, saline soil,

INTRODUCTION

Plant Litter, Leaf Litter or Tree Litter is dead plant material, such as leaves, bark, needles, and twigs that has fallen to the ground. Litter provides habitat for small animals, microorganisms and plants. As litter decomposes, nutrients are released in to the environment. The portion of the litter that is not readily decomposable is known as humus. Leaf litter is an intrinsic component of the ecological integrity of a forested ecosystem.

Studies on leaf litter evaluated the leaf litter quantity and nutrients content to determine energy fluxes and productivity. Leaf litter and its subsequent decomposition, strongly influences primary production and regulates energy flow and nutrient cycling in soil. Thus, leaf litter is a major participant in the transfer of energy and nutrients in a soil. Plant residues with different chemical composition show variable mineralization potential and decomposition behaviour (Mtambanengwe and Kirchman, 1995). Decomposition is catalyzed by micro-organisms, which constitute part of the soil biomass. Heterotrophic micro-organisms act on organic materials and degrade them in soil and consequently nutrients are made available in soil.

Various types of organisms like non symbiotic N_2 fixing bacteria, phosphate, solubilizing bacteria and thiosulphate oxidizing bacteria population were observed during litter fall decomposition. If soil and leaf litter organisms are not present some break down of organic materials will occur through non-biological process but it will happen very slowly and nutrients will remain trapped in the unprocessed leaf litter.

Leaf Litter Fall

The litter fall is a complex eco-physiological process affected by a number of external and internal factors. Changes in temperature and photoperiod as well as within-plant properties such as leaf age or possible endogenous rhythams are also important triggers of leaf fall (Wright and Cornejo, 1990). *Leucaena leucocephala* and *Acacia nilotica* had leaf litterfall peak in autumn; while other group of *Azadirachta indica* and *Prosopis juliflora* shed maximum leaves during the summer season (Jha and Mohapatra, 2010). There were significant differences in leaf litterfall across months and species. Leaf litterfall of *Leucaena leucocephala* and *Acacia nilotica* ranged from 6.5 (June) – 126.7 (October) and 12.8 (June) – 116.7 (October) g m^{-2}, respectively. Mean monthly leaf litterfall of *Azadirachta indica* and *Prosopis juliflora* ranged from 4.5 (July) – 179.9 (March) and 25.8 (July) – 118.8

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Table 1. Annual leaf litterfall, nutrient composition and input under different tree species

Tress species	Litterfall ($Mg\ ha^{-1}\ y^{-1}$)	Nutrient decomposition (Percent)			Nutrient input ($Kg\ ha^{-1}\ y^{-1}$)		
		N	P	K	N	P	K
Leucaena leucocephala	3.3	2.31	0.07	0.65	76.2	2.3	21.5
Acacia nilotica	6.0	1.94	0.08	0.42	116.4	4.8	25.2
Azadirachta indica	5.4	1.23	0.08	0.59	66.4	4.3	31.9
Prosopis juliflora	8.1	2.46	0.11	0.54	199.3	8.9	43.7

(April) g m^{-2}, respectively. The leaf litterfall varied significantly across the forest species. Total leaf litterfall weight ($Mg\ ha^{-1}\ y^{-1}$) ranged from as high as 8.13 in *Prosopis juliflora* to 5.98, 5.38 and 3.31 under *Acacia nilotica, Azadirachta indica,* and *Leucaena leucocephala,* respectively (Table 1).

The litter fall of 4 main forest species followed the order *Shorea robusta*, *Eucalyptus* spp., *Tectona grandis* and *Pinus roxburghii* contributing 8.3, 5.9, 5.0 and 4.8 t $ha^{-1}\ yr^{-1}$with peak period from March to April in *Shorea robusta*. April to May in *Pinus roxburghii* and *Tectona grandis*, and two peaks in case of *Eucalyptus* first during October to November and second during April to May (Pande and Sharma, 1986) with annual litter production of 11.3, 9.7,7.7 and 6.5 t ha^{-1}, respectively. The total litterfall ranged between 3312.6 to 8061.5 kg $ha^{-1}\ yr^{-1}$ in *Eucalyptus* and 22 yr old *Pinus* plantation, respectively (Joshi *et al*., 1997).

Leaf litter and Soil Properties

Addition of Leaf litters increased the soil reaction significantly (Table 2) (Lal *et al.*, 2000). This may be due to release of basic cations. It has been reported that there was rise in soil pH when amended with organic materials (Datta, 1996). Increase in soil pH was recorded up to 60 days of incubation beyond which it decreased significantly. It confirmed that initially basic cations were responsible for rise in pH and after that release of organic acids played a major role in influencing soil reaction.

Table 2. Change in soil reaction (pH) during decomposition of organic matter in soil

Treatments	Incubation Period (days)			
	30	60	90	Mean
Control	5.50	5.65	4.90	5.35
Lantana tops	6.45	6.85	5.05	6.12
Ipomea tops	6.85	6.45	5.05	6.02
Water Hyacinth	6.00	6.15	5.25	5.80
Karanj leaves	6.05	6.25	5.25	5.85
Subabul leaves	6.75	6.65	5.30	6.23
Lentil straw	6.82	7.08	5.55	6.48
Maize stover	6.65	6.48	5.65	6.28
Rice straw	6.83	6.90	5.40	6.38
Mean	6.43	6.47	5.27	

CD (p = 0.05) Treatment = 0.10

Incubation period = 0.06; Interaction = 0.18

Source: Lal *et al.* (2000)

It was reported that significantly larger amounts of organic carbon, available N, P & K were found below the canopy of Multiple Tree Species (MPTs); having a crown diameter of 8m in the agrisilviculture system compared to the tree less control (Yadav *et al.*, 2008; Table 3). Soil properties significantly correlated with total litter production. Soil pH was significantly lower in MPTs based agrisilviculture system. Among MPTs, soils under *Prosopis cineraria* had a higher concentration of organic carbon (OC), available N, P and K and lower pH followed by *Dalbergia sisso, Acacia leucophloea, Acacia nilotica* compared to control (except for P concentration, where soils below *Acacia nilotica* were more enriched than those below *Acacia leucophloea*).

The annual input of nutrients ranged between 26.8 to 122.4 kg N ha^{-1} and 14.6 to 34.9 kg K ha^{-1} in *Eucalyptus* and *Leucaena*, respectively (Joshi *et al*., 1997). The tree plantation not only adds substantial amounts of nutrients to soil through litter fall but also enhances soil moisture storage and reduces surface runoff, nutrient losses and erosion on sloping lands (Joshi, 2004).

Soil Microbial activity

Soil carbon and energy flow mainly driven by microbial activity. The diversity of soil microorganisms is assumed to be extra ordinarily high but is largely unidentified (Prosser, 2002). The number of bacterial species is on the order of hundreds to thousands in 1g of soil; total species number is estimated at " to 3 million (Torsvik *et al.*, 1994; Dejonghe *et al.*, 2001) species diversity of soil fungi is probably only slightly less than that of

Table 3. Soil pH, OC (g kg^{-1}) and available NPK (μg g^{-1} soil) under four MPTs in an agrisilvicuture system

Multi purpose tree species	pH	OC	N	P	K
Prosopis cineraria	7.67	4.91	138.3	15.93	180.1
Dalbergia sisso	7.71	4.43	114.5	14.20	162.4
Acacia leucophloea	7.84	4.21	106.4	11.56	150.8
Acacia nilotica	7.87	3.82	99.67	13.09	151.2
Control	8.29	2.51	69.98	7.72	106.5

bacteria (Bridge and Spooner, 2001, Hawksworth, 2001). One likely reason for the enormous diversity of soil micro organisms is their high frequency combined with very short generation time and rapid growth. There factor promote a part speciation in response to relatively small environmental changes. Loreau (2001) suggested that microbial diversity has a positive effect on nutrient cycling efficiency and ecosystem process through their greater intensity of microbial exploitation of organic matter or functional niche complementarily (Hattenschwiler *et al.,* 2005).

Total count including bacteria and actinomycetes ranged from 25.0 ×10^5 to 65.7×10^5 with an average of 40×10^5 /g soil with more population in normal cultivated soil and less one in salt-affected soil (Table 4). At higher values of salt concentration and pH, the per cent population of actinomycetes was higher than at lower salt and lower pH values of the cultivated soils (Gupta and Bajpai, 1974), possibly due to lack of readily decomposable organic substance. Data revealed that spores increased at higher salt content which might be due to sporulation of bacteria in adverse condition created by higher salinity. Moderated salinization equivalent to ECe 5.0 did not appear to be injurious to bacteria except fungi, indicating the latter being more sensitive to salinity. Contrary to other microflora, actinomycetes appeared to be stimulated slightly at ECe 5.0 and were observed to be least affected by salinity (Gupta and Bajpai, 1974) (Table 4). Rao *et al.* (1972) showed a considerable increase in fungal population with the decrease in pH due to acidophilic in nature.

Addition of organic matter, in general, significantly increased non symbiotic nitrogen fixing bacteria. Non-symbiotic nitrogen fixing bacterial population was highest at 30 days of incubation and the lowest value was observed at 90 days which may be due to reduction in pH (Alexander, 1977). Subba Rao (1977) reported that cellulolytic micro organisms which degrade plant residues in soil are known to encourage the proliferation of *Azotobacter* in soil. The number of phosphate solubilising microorganisms initially increased and attained maximum value up to 60 days of incubation which was at par declined significantly. This was due to the degraded products of added organic water which stimulated the growth and proliferation of phosphate solubilising microorganisms during the course of decomposition (Debnath *et al.*, 1994, Saha *et al.*, 1995). The additional organic material, which, in the short term, provides additional substrates for

Table 4. Salinity, alkalinity and microflora (Per g soil)

Soil type	ECe	pH	Total count ×10^5			Nitrifires ×10^3			Fungi	Azoto-bacter	Bact. spores× 10^4
			Bac.	Actinomy-cetes	Total	Nitrite Former	Nitrate Former	Total			
CN	1.2	6.0	48.0	6.5	54.5	6.3	5.4	11.7	3000	5.7	17.0
CN	1.0	7.0	49.2	3.2	52.4	6.7	4.8	11.5	1500	6.2	24.0
CN	1.0	7.3	61.2	4.5	65.7	11.5	10.8	22.3	1000	12.0	5.0
HSA	28.0	7.8	94.0	9.0	58.0	1.7	2.1	9.8	1000	10.7	40.0
MSA	2.5	8.4	28.0	3.5	31.5	5.7	4.2	9.9	750	7.5	4.5
MSA	2.4	8.7	22.0	7.5	29.5	6.1	5.3	11.4	750	3.0	2.0
HSA	33.0	9.4	18.5	4.7	23.2	5.6	3.6	9.2	500	2.2	37.5
HSA	48.0	9.7	19.0	6.0	25.0	4.7	2.1	6.8	500	4.5	42.0
HSA	50.0	9.9	17.7	9.0	26.7	4.2	2.6	6.8	250	0.0	61.0
AV.	18.6	8.3	34.7	6.0	40.7	6.5	4.5	11.0	1039	5.8	25.8

CN= Cultivated normal; MSA= Moderately salt-affected; HSA= Highly salt-affected; Gupta and Bajpai (1974) the microbial population, may also relieve osmotic and pH stress on the microorganisms (Pathak and Rao, 1998). The presence of soil organic matter can provide a buffer to the soil solution and to soil microbiological properties, particularly where salinity or sodicity levels are high (Wong *et al.*, 2005).

Generally, fluctuation in the size and turnover of the soil microbial biomass can be related directly to environmental changes, particularly to a variation of soil moisture and temperature (Kramer and Green, 2000).

Leaf litter decomposition and Soil enzyme activity

Soil enzymes increase the reaction rate at which plant residues decompose and release plant available nutrients. The substance acted upon by a soil enzyme is called the substrate. For example, glucosidase (soil enzyme) cleaves glucose from glucoside (substrate), a compound common in plants. Enzymes are specific to a substrate and have active sites that bind with the substrate to form a temporary complex. The enzymatic reaction releases a product, which can be a nutrient contained in the substrate. Sources of soil enzymes include living and dead microbes, plant roots and residues, and soil animals. Enzymes stabilized in the soil matrix accumulate or form complexes with organic matter (humus), clay, and humus-clay complexes, but are no longer associated with viable cells. It is thought that 40 to 60% of enzyme activity can come from stabilized enzymes, so activity does not necessarily correlate highly with microbial biomass or respiration. Therefore, enzyme activity is the cumulative effect of long term microbial activity and activity of the viable population at sampling. However, an example of an enzyme that only reflects activity of viable cells is dehydrogenase, which in theory can only occur in viable cells and not in stabilized soil complexes.

Enzymes respond to soil management changes long before other soil quality indicator changes are detectable. Soil enzymes play an important role in organic matter decomposition and nutrient cycling (Table 5). Some enzymes only facilitate the breakdown of organic matter (e.g., hydrolase, glucosidase), while others are involved in nutrient mineralization (e.g., amidase, urease, phosphatase, sulfates).

Soil C and N mineralization

Carbon and Nitrogen ratio (C:N) is used as an indicator of which step in the nitrogen cycle occurs next. Ratio less than 20 mean the excess N is present and nitrification proceeds (with net gain of N). With ratio between 20 and 30, nitrification and immobilization rates are in equilibrium and there is no net gain or loss of N. Residues that have C:N ratio greater than 30, equivalent to N contents of about 1.5% or less, result in lowering mineral N reserves because of net immobilization (Makumba and Akinnifesi, 2008). This stimulates the process of Biological Nitrogen Fixation, where nitrogen is added to an N-deficient situation. Residues with C:N ratio below 20, N contents greater than 2.5% lead to an increase in mineral levels through net mineralization. Excess nitrogen (as NH_4^+) stimulates the process of Nitrification.

During the process of decomposition, the micro organisms grow on organic debris, than carbon is utilized for building up of the cellular materials and release CO_2, methane and other volatile substances. The rate of CO_2 evolution as a result of carbon decomposition is measured at regular interval.

Table 5. Role of soil enzyme

Enzyme	Organic Matter Substances Acted on	End Product	Significance	Predictor of soil function
β glucosidase	Carbon compounds	Glucose (sugar)	Energy for microorganism	Organic matter decomposition
FDA hydrolysis	Organic matter	Carbon and various nutrients	Energy and nutrients for microorganisms, measure microbial biomass	Organic matter decomposition nutrient cycling
Amidase	Carbon and nitrogen compounds	Ammonium (NH_4)	Plant availableNH_4	nutrient cycling
Urease	Nitrogen (urea)	Ammonia (NH_3) & carbon dioxide(CO_2)	Plant availableNH_4	nutrient cycling
Phosphatase	Phosphorus	Phosphate (PO_4)	Plant availableP	nutrient cycling
Sulfatase	Sulphur	Sulphate (SO_4)	Plant available S	nutrient cycling

Table 6. Change in available nutrients during decomposition of organic matter in soil

Incubation time (days)	Control	Lantana Tops	Ipomea Tops	Water Hyacinth	Karanj Leaves	Subabul Leaves
30	152.96	160.22	178.79	175.12	188.08	225.12
60	146.71	150.06	159.22	169.16	160.00	216.12
90	131.83	141.99	136.76	140.05	138.12	144.34
Mean	143.83	150.76	156.60	161.44	160.02	199.19

Source: Lal *et al.* (2000)

Sarode *et al.* (2009) studied the four species were FYM (Farm Yard Manure), wheat straw (WS), glyricidia (GM) and subabul (SB). In that there was highest CO_2 evolution at 30 days after incubation in all treatments. Carbon dioxide evolution was found the highest in subabul treatment, which showed 824.27 mg 100 g^{-1} at 30 days of incubation followed by glyricidia, wheat straw and FYM. After 30 days of incubation, the CO_2 evolution declined up to 80 days and again with all treatments except control. Jothimani *et al.* (1997) observed high CO_2 evolution in *Glyricidia* which might be due to high contents of nitrogen and narrow C:N ratio. Initial & quick decomposition of subabul lopping indicated its suitability for direct used in field, where as uniform & steady decomposition of FYM during the incubation period was produce to be base material for building up soil organic matter (Sarode *et al*., 2009).

Another study done by Maharudrappa *et al.* (1999) using *Teak, Acacia, Eucalyptus and Casuarina species* showed that the cumulative CO_2 release increased with the incubation period. The rate of decomposition, as indicated by the CO_2 released on day to day basis, were higher with larger quantity of litter addition (10 t ha^{-1}). Among the litters, teak showed rapid decomposition, *Aelile Casurina* recorded slow decomposition, the rate of decomposition of leaf litter was of the order: *Teak* > *Acacia* > *Eucalyptus* > *Casuarina*. The increase in the CO_2 release at higher levels of litter can be attributed to the faster decomposition of litter. Biological activities *viz*. decomposition, mineralization etc. increase with increase in substrate decomposable material, and concentration.

Carbon mineralization also affected by the salinity treatments. It has been reported that total mineralization and CO_2 evolution decreased with increased concentration of salt mixture from 0.1 to 1.5 %. The low rate of carbon mineralization in salt affected soils might be due to less population of heterotrophic microorganisms. Bajpai *et al.* (1980) made a comprehensive study of decomposition pattern of plant materials in salt affected soil vis-a-vis normal soil and reported low rate of CO_2 evolution in saline sodic soil as compared to normal soil probably because of low carbon mineralizing power of saline-sodic soil (Gupta, 1974).

Highest mean soil available nitrogen was recorded at 30 days of incubation as a result of decomposition of organic materials in soil as reported by Lal *et al.* (2000) (Table 6). This decreased significantly which may be due to utilization of nitrogen by increasing microbial population and loss through denitrification (Saha *et al.*, 1995). At later stages, the rate of denitrification loss exceeds the rate of mineralization of organic nitrogen and thus results in its lower value (Smith and Douglas, 1976).

Saline sodic soil behaved differently to that of normal soil in terms of NO_2-N formation with the former showing accumulation of nitrite nitrogen more while in normal, no nitrogen content was detected. Nitrite accumulation in saline sodic soil has been reported because of higher pH and higher *Nitromonas* than *Nitrobacter* number in salts – affected soil (Gupta and Bajpai, 1974). In contrast to NO_3-N, NH_4-N contents were higher at low salinity (ECe 5.3) than normal salinity. However medium and high salinity levels decreased NH_4-N.

Carbon sequestration

There is a much concern that the increasing concentration of green house gases (GHGS) in general, and carbon contributes to global warming by trapping long-wave radiation reflected from the earth's surface. Carbon sequestration, i.e. capturing and securing carbon that would otherwise be emitted and remain in the atmosphere might be a suitable alternative to control atmospheric emission of carbon, plants, capture CO_2 during photosynthesis and transform it to sugar and subsequently to dead organic matter. As the trees grow, they sequester carbon in their tissues and as the amount of tree biomass increases, the increase in atmospheric CO_2 is mitigated (Dyson, 1977).

Agro forestry would be one of the interesting areas of research in land-use related to carbon dioxide is currently accumulating in the atmosphere at the rate of about 3.4 Pg/yr (1Pg=1 billon tonnes) as a result of fossil fuel combustion and land-use change (IPCC, 1995). The Intergovernmental Panel on Climate Change (IPCC) estimated that it may be possible, over the course of the next 50-100 years, to remove between 40 and 80 Pg of the carbon by sequestrating it through agro forestry.

The carbon pool for Indian forests is estimated to be 2026.72 Mt. Estimates of annual carbon uptake increment suggest that Indian forests and plantation have been able to remove at least 0.125 Gt of CO_2. From the atmosphere and are also the major source of global carbon sink (Lal and Singh, 2000). Approximately, more than 75,000 tonnes of carbon has been sequestered and stored in the form of living biomass through Plant Organic Carbon (POC) by two agro forestry species viz. willow and poplar. Carbon loss from litter decomposition is largely determined by the amount of decomposing litter (Craswell *et al.*, 1997; Phani Kumar *et al*., 2009).

In addition to surface protection, leaf litter compost treatments can restore disturbed soil and facilitate revegetation increasing levels of organic matter. Increasing or restoring soil organic matter increases soils water holding capacity, cation exchange capacity, and nutrient levels while decreasing soil bulk density.

CONCLUSION

Organic matter inputs to soil come primarily from plants, for example via rhizo-decomposition and litter fall. In addition, plants take up a range of soil resources, such as water, nitrogen (N), and phosphorus, and as a result plants strongly influence physical, chemical and biological properties of soil. However, since plants exhibit broad variation in their natural history and physiology it is likely that differences in plant species traits will create distinctive soil environments and biotic communities. For instance, plant species differ in the quality and quantity of their inputs to soil, root architecture, and nutrient requirements. The studies demonstrated that the nutrient mineralization rate of various nutrient are highest in early days of incubation time an start declined after up to 90 days of incubation in Carbon, Nitrogen while it is highest at 60 days of incubation time in Ca, Mg, P, and S. The rate of decomposition and availability of K is highest up to 120 days of incubation. The studies demonstrated that the decomposition of Carbon and Nitrogen mainly depend on the C:N ratio of the litter species. So the rate of decomposition of litter depends on the species type as governed by its compositions. Thus, the rate of nutrient release is also determined by litter quality. Salinity of the soil affects the microbial activity and enzyme activity which ultimately decrease in the decomposition rate of litter. Another problem related with litter management and its burning will create environment problem will be managed by the use of litter directly as soil amendment or production of compost as rich source of nutrient.

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Water saving under a developed microcontroller based automated drip irrigation system in Kinnow crop

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ABSTRACT

Efficient utilization of available water resources is crucial for a country like, India, which shares 17% of the global population with only 2.4% of land and 4% of the water resources. More than 50% of water wastes in the conventional irrigation systems consequently resulting in to low irrigation efficiency at field level. Drip irrigation is though one of the best options for enhancing irrigation efficiency and crop yields per unit of water applied, it can be automated further using low cost sensors for irrigation automation. A microcontroller based sensor circuit to measure leaf-air temperature differential was developed in laboratory and was integrated with the drip head works for irrigation automation. Developed system was techno-economic evaluated in Kinnow and water saving as compared to other conventional irrigation systems was estimated. Soil moisture content, leaf-air temperature differential, crop canopy diameter, leaf area index were monitored during the study period. The system maintained soil moisture content nearer to the field capacity (30.02%) based on temperature differential values. The developed system uses 8.6% and 49.6% less water than to the manual operated drip irrigation system and check basin irrigation system, respectively.

Key words: Micro controller, Drip irrigation, Sensor circuit, Water saving

INTRODUCTION

Water, a scarce natural resource, is fundamental to life, livelihood, food security and sustainable development. India has more than 18% of the world's population, but has only 4% of world's renewable water resources and 2.4% of world's land area (Anonymous, 2014). Agriculture is the major consumer of water which presently consumes around 80% of our country's available water resources. Because of the increased competition for fresh water among industry, domestic and agriculture, a proper planning and management of available water resources particularly in agricultural sector is the need of the hour. As demand of other sectors is increasing, lesser water is likely to be available for irrigation. It is predicted that water availability for irrigation in India is likely to be come down by 10% by 2050 (Anonymous, 2013). Awareness among farmers also needs to be created about the need of efficient water use in agriculture to ensure future food security of the country. It is estimated that by 2050, about 22% of the geographical area of India will be under absolute water scarcity. Due to the limited availability of fresh water resource, saving of irrigation water is of paramount importance. The advent of precision irrigation methods such as micro irrigation system which includes drip irrigation (surface and sub-surface), bubbler irrigation, mini sprinkler, micro sprinkler and jets has played a major role in reducing the water required in agricultural and horticultural crops. Effective operation of these systems require a sensing system that determines irrigation need in real time or at least at frequent intervals , which in turn indicates a need for automated monitoring systems.

It has been found that plant canopy temperature is a good indicator of plant water stress (Jacson *et al*., 1981). Temperature differential of plant leaf and surrounding ambient gives a better indication of water status of a plant (Bhosale *et al*., 1996). The leaf-air temperature differential based irrigation scheduling aims at irrigating the crop whenever a predetermined leaf-air temperature differential reaches a given value. Thermocouple was used as a leaf temperature sensing device (Ahmed *et al*., 1990). Thermistor based sensors was

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also used by some researchers with the aim at determining plant canopy temperature (Fisher *et al*., 2010). Infrared sensor is another option to measure plant canopy temperature (Abraham *et al*., 2000). Microcontroller can be used for automatic irrigation scheduling (Swamy *et al*., 2013). But, commercially available sensors for leaf-air temperature measurements are costly and also require calibrations before their use in the field. A low cost, LM35 IC based sensor circuits was designed and developed at Water Technology Centre Indian Agricultural Research Institute, New Delhi using low cost locally available components and integrated with drip irrigation headwork to irrigate the crop automatically during the year 2013-2014. The present study was aimed to check out the water saving under developed automated system in kinnow.

MATERIALS AND METHODS

The experiment was conducted at the Precision Farming Development Centre, Water Technology Centre, Indian Agricultural Research Institute (IARI), Pusa, New Delhi, India, which is located within 28°37′22′′ N and 28°39′00′′ N latitude and 77°8′45′′ E and 77°10′24′′ E. The soil of the experimental area was deep, well-drained sandy loam soil comprising with 63.66% sand, 21.16% silt and 15.16% clay. The bulk density, field capacity and saturated hydraulic conductivity of the experimental soil was 1.58 g cm^{-3}, 30.02% and 1.19 cm h^{-1}, respectively. The pH and EC of soil was 9.17 and 0.138 dS m^{-1}, respectively.

A leaf-air temperature differential based low cost sensor circuit was developed and was integrated with drip irrigation head works. The system was operated by electrical powered pump. A field plot of 30m × 70 m containing 4 rows of plants was used for testing the developed system. Each row was having 12 plants at a plant to plant and row to row spacing of 5m × 5m. Plants with average canopy diameter of 3.20 m were identified for the study. Two rows of plants, 24 in numbers were given controlled irrigation meeting 100% crop water requirement and two rows of plants were irrigated through the developed automated system working on leaf-air temperature differential basis to meet the 100% crop water requirement. Surface drip irrigation system having non pressure compensating drippers of 8 lph^{-1} discharge was used for irrigating the plants. Each plant was provided 4 drippers. The Sensor circuit was installed in the shaded side of the plant (during the noon time). One LM35 sensor was attached to the lower side of the leaf by means of a plastic clip and another sensor was hanged freely in the air nearer to the leaf. Circular basin of 160 cm diameter was prepared in 4 knnnow trees to apply water through flood irrigation**.** Two access tubes per plant at a distance of 80 cm and 160 cm from the plant stem were installed up to 100 cm soil depth to measure the soil moisture using Frequency Domain Reflectometer (FDR). Daily measurements of soil moisture were taken in the root zone of plants during the experimental period. Plant Leaf Area Index was measured using instrument LAI-2000 Plant Canopy Analyzer during the testing period of the developed automated system.

Water requirement of Kinnow crop was calculated on the basis of reference crop evapo-transpiration (ET_0) on daily basis and a weekly irrigation was scheduled in conventional drip system and in the basin irrigation. The crop-evapotranspiration (ET_c) was estimated by multiplying reference evapo-transpiration (ET_0) with crop coefficient (K_c) for different months i.e. $ET_c = ET_0 \times K_C$.

The water requirement of the Kinnow crop was then calculated as

$$WR = (ETc \times Ac)/E, \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

WR = Water Requirement of crop, m^3 /day/plant

ET_c = Crop evapo-transpiration, m/day

A_C = Plant canopy area, m^2

E = Efficiency of the irrigation system (0.90 for drip and 0.60 for basin)

Microcontroller of the developed automated system was programmed with different leaf-air temperature differential conditions to irrigate the crop automatically.

RESULTS AND DISCUSSIONS

Soil moisture content variation for scheduling using developed automated system

Soil moisture status for a continuous 10 days period under automation based on leaf-air temperature differential was recorded (Fig. 1) . The system was able to irrigate crop as per leaf-air temperature differential conditions. The system irrigated the crop on every fourth day i.e., after every three days interval from the previous irrigation. For continuous 10 days period the system irrigated the field on day 1, 5 and 9 (shown by the red bars in the Figure 1). After 24 hours of irrigation

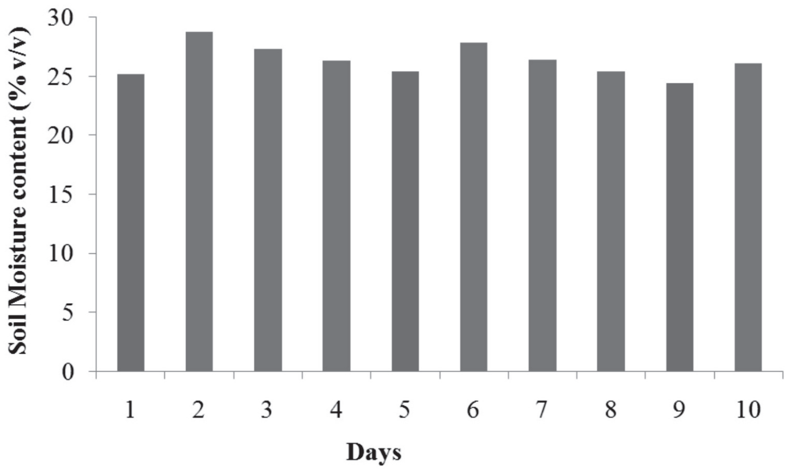

Fig. 1. Soil moisture status under automation based on leaf-air temperature differential

Table 1. Average crop canopy diameter, Leaf Area Index and water applied under the conventional drip system and the developed automated system

Parameters	Irrigation systems used for meeting the crop water demand of kinnow		
	Automated drip system	Conventional drip system	Basin irrigation
LAI	1.55	1.57	1.52
Canopy diameter (cm)	320	324	300

Table 2. Water applied under developed automated irrigation system, manual drip and check basin irrigation system

Parameters	Developed automated system	Manually operated drip system	Basin irrigation
Water applied (m^3/plant/month)	0.128	0.139	0.148
Water applied at pump outlet (m^3/ha/month)	56.8	61.7	85

Table 3. Percentage water saving under developed automated system

Parameters	Water savings under developed leaf temperature based automatic irrigation system in comparison to	
	Manually operated drip irrigation system	Basin irrigation system
Percentage water saving under developed system	8.6	49.6

the soil moisture content reaches to the field capacity, then decreased down in next two days. There was no rainfall received during the experimental period. The system maintained the soil moisture content nearer to the field capacity throughout the experimental period.

Plant physiology under the developed automated system and the conventional drip irrigation system

The reference evapo-transpiration (ET_0) and the average crop coefficient (Kc) during the experimental period were taken as 8.87 mm/day and 0.65, respectively. Table 1 shows the values of average crop canopy diameter and Leaf Area Index for crops irrigated under the developed automated system and manual drip irrigation system. The average crop canopy diameter and leaf area index values for the plants irrigated under the developed automated system were found to be nearly equal to that of plants irrigated under conventional irrigation condition. It was observed that without affecting the plant growth, amount of irrigation water can be saved in sensor based automatic drip system.

Water saving under developed system

Water applied by developed automated system as compared to manually operated drip irrigation system and the basin irrigation is shown below in the Table 2. Percentage water saving under developed system in comparison to manually operated drip system and check basin method of irrigation is shown in the Table 3.

CONCLUSIONS

A developed microcontroller based sensor circuit capable of measuring leaf-air temperature differential integrated with drip irrigation head works was tested for water saving in kinnow crop. The developed system saved 8.6% and 49.6% water respectively per month per hectare as compared to manually operated drip irrigation and basin irrigation. Developed system can be used for irrigating other horticultural crops too.

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Low Energy Water Application (LEWA) device: Concept and applications

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ABSTRACT

Currently available options in terms of efficient irrigation technologies to the growers in India lacks in technical and economic viability restricting their wide adaptability. Some of the major addressed constraints in this regard have been the majority of the cropping area under field crops, small and fragmented land holdings and limitations of users for high initial investments. This led adoption of these efficient irrigation technologies mostly by large farm holders for crops considered as high valued crop. At the other hand majority of the growers who comes under small and marginal categories still forced to practice surface methods of irrigation which incurs not only huge wastage of water but also the fuel and electric energy used for pumping. Keeping this in view and conditions of small farm holders, an attempt has been made to develop a low cost water and energy efficient device (above canopy). The major focus of the study was to develop a device which can operate at an operating pressure less than 1.0 kg/cm^2 at its nozzle head. Reviews indicated that a LEPA nozzle developed by A&M Texas is one of such attempt which operates between 0.07 to 0.35 kg/cm^2 operating pressure at nozzle head. Some of the concepts and lessons drawn from LEPA development have been taken into consideration along with the priorities of small holders during this development. This paper discusses the experiences of authors at preliminary stages of development of Low Energy Water Application device (LEWA).

Key words: Land holdings, Efficient irrigation technologies, Sprinkler, LEPA, LEWA

INTRODUCTION

Ideally, an irrigation system should apply water in completely 'uniform manner' so that each part of the irrigated area receives 'desired quantity' of water. Thus, the application efficiency and the distribution efficiency of water application are the two important factors affecting the spatial and lumped storage of water in the root zone of a cropped field, and needs to be given due consideration in the planning, design and selection of an irrigation system. The application efficiency, which accounts for deep percolation losses, is predominantly affected by the management; while the uniformity of water application is predominantly affected by the system design. The losses associated with the surface method of irrigation are: the conveyance losses due to seepage from water distribution networks, runoff, deep percolation, and direct evaporation from wet soil surface. In case of pressurized irrigation systems water is conveyed through networks of pipes therefore minimal or no conveyance losses occurs leading to higher efficiencies as well as uniformity as controlled volume of water is applied through a especially designed emitting devices. It is generally stated that, by adopting pressurized irrigation methods one can not only enhance crop productivity but also saves other critical inputs. Different types of pressurized irrigation nozzles commonly used are: sprinkler, micro sprinkler, and drip. Sprinkler and micro sprinkler irrigation system applies water in a rain like pattern through a rotating sprinkler nozzle and have efficiency in the range of 65-80% depending upon the spacing, operating pressure, wind conditions etc. Drip irrigation system, which applies water drop by drop on or near the plant root zone, is having efficiency in the range of 85-95%. The drip irrigation system is mostly suited to high valued horticultural and plantation crops and have limitation in use for close growing crops due to higher cost component. The sprinkler system is considered to be suitable for wider range of crops and does provide greater control over application rate than do furrow or

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other surface method of irrigation. However, its efficiency is greatly affected by high wind speed due to excessive spray evaporation losses. Besides this, most of the irrigation systems falling under pressurized irrigation systems need higher source of energy compared to surface irrigation systems. This not only increases operational cost but also the initial investment which makes pressurized irrigation system unaffordable to small and marginal farmers. Keeping this in view, an attempt has been made to develop a low cost energy efficient irrigation technology. In this endeavor before arriving at working model various concept and devices were tried. This paper discusses the experiences and lessons learnt at the initial stage of development of a low cost energy efficient irrigation technology.

Different low cost/energy efficient irrigation systems

Several attempts have been made to develop low cost / energy efficient irrigation technologies for different uses. This section discusses briefly their concept and purpose of its development. Keller and Bliesner (1990) reported the development of a "Perforated pipe sprinkler irrigation systems" and "Hose fed sprinkler system". The "Perforated pipe sprinkler irrigation systems" sprays water from smaller diameter holes (1.6 mm or less) drilled at uniform spacing along the top and sides of a lateral pipe. The water coming out from the holes produces a rain like pattern over a rectangular strip. The size and spacing of the holes are chosen in such a way that water is uniformly distributed between adjacent lines of perforated pipe. The water spread (area of coverage) from this type of system increases as the pressure increases and operates effectively at an operating pressure between 0.35 kg/cm^2 to 2.10 kg/cm^2. As the minimum application rate from perforated pipe is 13 mm/hr, they can be used only on coarse textured soils. The "Hose fed sprinkler system" employs hoses to supply water to individual small sprinklers, which are operated at a pressure as low as 0.35 kg/cm^2 to 0.70 kg/cm^2. This system also produces relatively uniform water application when sprinklers are moved in a systematic grid pattern with sufficient overlap. These systems are generally used in home gardens and turf irrigation, and are not in use for agricultural irrigation as these are labour intensive. The two types of aforesaid sprinklers are mainly used in home gardens and lawns but not for agricultural irrigation.

In order to reduce energy requirement, an attempt has been made at Texas Agricultural Experiment Station, Lubbock, USA (Lyle and Bordovsky, 1981, 1983) to modify the design of existing sprinkler nozzle and develop management strategies for efficient utilization of available water popularly known as Low Energy Precision Application (LEPA) system. The LEPA nozzles were developed in context of reducing the energy requirement in irrigation practices with a greater degree of precision by replacing the sprinklers' nozzles through "drop tubes" making it suitable to operate at low pressure (in the range of about 0.3 to 1.2 kg/cm^2 (Bordovsky *et al*., 1992). The LEPA concept was further modified by Sasketchewan and named LESA (Low Elevation Spray Application) and by others MESA (Medium Elevation Spray Application) by incorporating changes in LEPA nozzles and its mode of applying water. Moreover the major concept was same as it was developed by A&M Texas. The LEPA equipment discharges water through drop tubes very near to (50 mm to 75 mm above the soil surface) or at the soil surface into either every furrow or alternate furrows at a very low pressure (0.07 kg/cm^2 to 0.35 kg/cm^2). By discharging water near the field surface the spray evaporation losses, which are very common to the overhead sprinkler irrigation system, is reduced. Because of the low application pressure of LEPA nozzle, water is applied over a relatively small area causing high application rates of short duration. Since the high application rates quickly exceeds infiltration rates, successful irrigation with the LEPA system depends on storing some amount of water on the soil surface until it infiltrates into the soil. Vishalakshi *et al*. (2002), reported the development of a "LEPA type micro sprinkler" attempted by AICRP on water management at Agronomic Research Station, Chalakudy of Kerala Agricultural University, India, to provide irrigation in vegetable, horticultural, ornamental plants and lawns. The rotating sprinkler head is made of a small piece of 12mm/8mm diameter good quality LDPE (Low Density Polyethylene) pipe, plugged at both ends by end caps. The length of the unit is 8 cm for 12 mm and 5 cm for 8 mm pipe. Holes of 1 mm diameter were drilled on opposite sides of the pipe and pivoted at the centre to stand on a stake. The discharge rate is reported to be 30 lph to 45 lph at an operating pressure ranging from 0.3 kg/cm^2-1.0 kg/cm^2 for different pipe diameter. The wetted diameter ranges from 210-230 cm when nozzle rotates at a height of 30-90 cm above the ground. This system does not have any sophisticated components, almost free from clogging, provides better sub-surface uniformity, avoids losses due to percolation or runoff, facilitate the use of fertilizers and herbicides and most importantly it has considerably low initial investment and operational cost. However, systems have limitations in its use for small farm conditions growing closely spaced crops viz. rice, wheat, oil seeds etc. (Sonit *et al*., 2015) reported demonstrated use of drip irrigation system to irrigate rice to achieve better water use efficiency to tune of 2.7 to 2.9 kg/ha mm with respect to flood irrigation. Taking lessons from these and through series of experimentation, a new nozzle/system developed, named LEWA (Singh *et al*., 2009, 2010 and 2014) and field evaluated. The experiences gained over the development are presented in this paper that could be useful for researchers in the development of similar type of nozzles.

Experiences and Lessons while developing low cost energy efficient irrigation technology

Some of the major factors considered in development were the farming conditions and economic viability of the irrigation system at small and fragmented farm lands possessed by the majority of the farmers and growing field crops *viz*. cereals, pulses, oilseeds etc, followed by vegetables and orchards. These farmers generally practice surface method of irrigation as the cost of existing pressurized irrigation systems hardly matches with their socio-economic status. It is also been realized that average width of the these farms varies between 6 m to 8 m whereas the length is invariably equals to 2 to 4 times of the width. In case of small holders two third of their area is under field crops to support their livelihood. For these types of fields sprinklers can be one option which can be effectively used for field crops. As the rate of application from the sprinklers is less than or equal to the infiltration capacity of the soil, no land management is required to store water over the surface. Hence, it is realized that low pressure nozzles can be effectively used to fulfill the irrigation objectives of different field crops if it is cost effective. In this endevour prior to arriving at a working prototype, three prototypes using low pressure rating flexible plastic pipes to reduce overall cost, were developed based on irrigation systems/nozzles described in earlier section. The various attempts during developmental stages are described hereunder.

LEPA manifold: Similar to the concept of LEPA system developed by A&M Texas, a manifold (Fig.1) was designed and fabricated with following dimensions of its components;

Diameter of the manifold = 2.5 cm

Length of the manifold = 6 m

Number of drop tubes per manifold = 4 nos.

Diameter of the drop tube = 12.5 mm

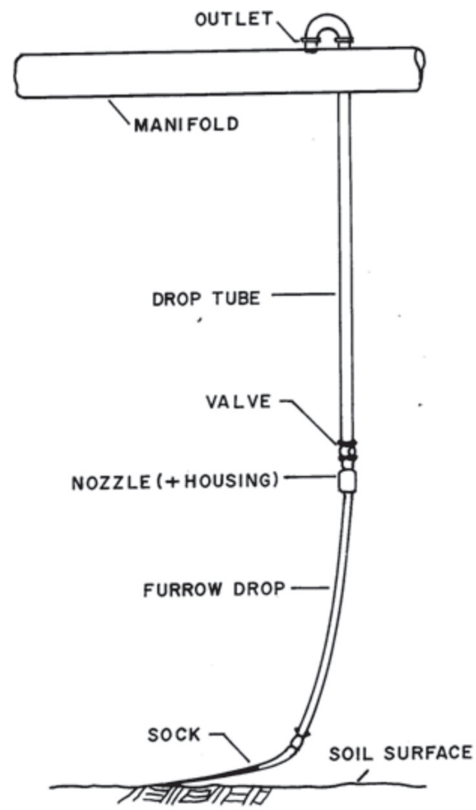

Fig. 1. LEPA Manifold

This prototype was tested by operating two manifolds together. The average discharge of each drop tube were recorded as 0.48 lps and 0.60lps at the lateral inlet pressures of 0.5 kg/cm^{2}and 0.75 kg/cm^2 respectively (Fig. 2 and Fig. 3).

The reason of variation in discharge among different drop tubes in each manifold was visualized due to manufacturing variation. Besides variation in discharge some of the major limitations observed was weight of the manifold which results in sagging of manifold. This was thought to nullify it by using manifold without riser pipe (i.e., coupling the manifold directly with the lateral). The testing (at different angle) revealed that at an angle of 45^0 from horizontal provided a maximum throw distance of water jet, but it caused erosion. Secondly, if it has to be replaced in place of impact sprinklers in hand move sprinkler systems, the additional weight of LEPA manifold would be a parameter of serious concern.

Water Distributing Devices: The objective here was to use the existing sprinkler system for irrigating

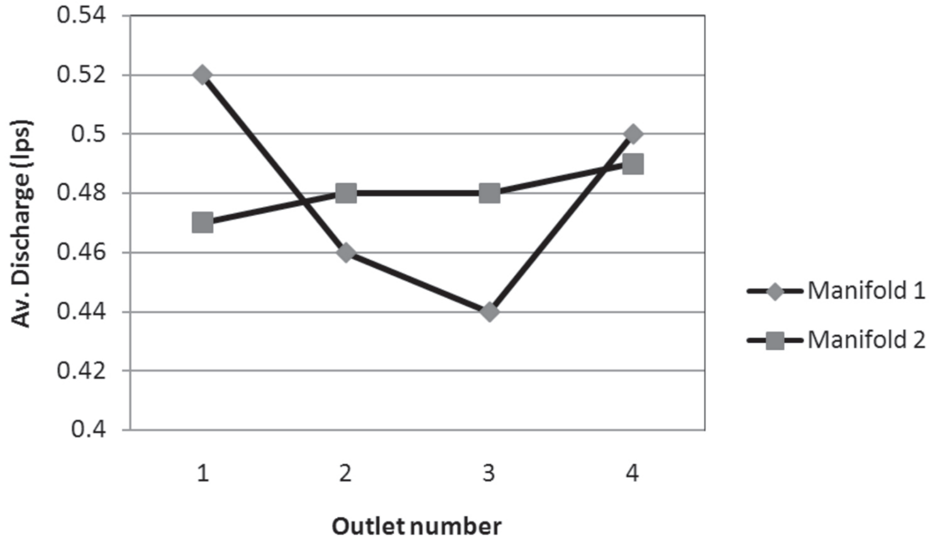

Fig. 2. Discharge from outlet at 0.5 kg/cm^2

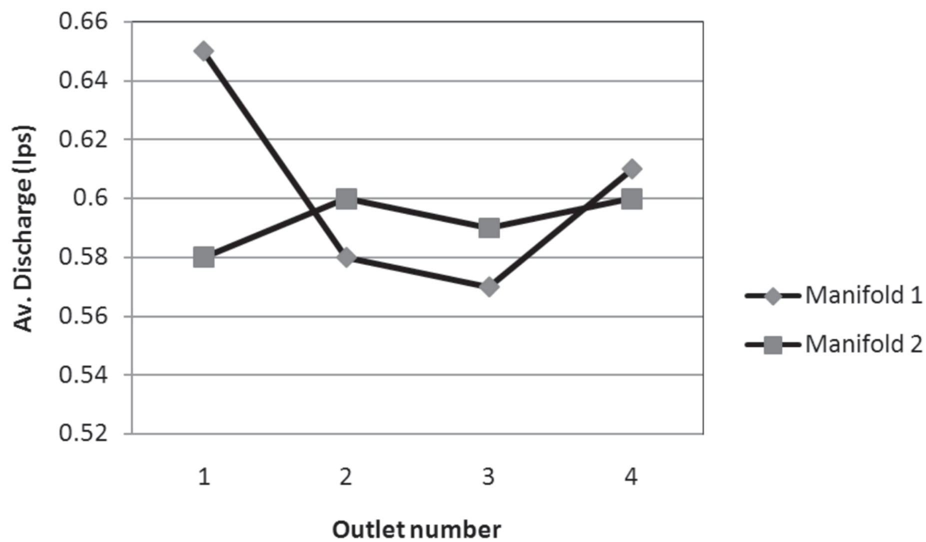

Fig. 3. Discharge from outlet at 0.75 kg/cm^2

rice, wheat and other similar close growing crops at low pressure. Since the sprinkler nozzle operates at high pressure, it was thought of designing water distributing devices that works at low pressure. Consequently, a prototype of device was developed that throws water at different points. To achieve this, a 2.54 cm diameter and 10cm long pipe section was divided into number of sections. The cross-sectional area of each section at the inlet was kept equal whereas it was varied at outlet assuming that varying cross-sectional area and number of sections will prevent concentration of flow at one point. The equal cross-sectional area at the inlet enables equal quantity of water through each section. Varying cross-section at the outlet helps in achieving different throw distance and thus covering more width. With above concepts the device having 4, 5, 6 and 7 sections were developed and tested (Fig. 4).

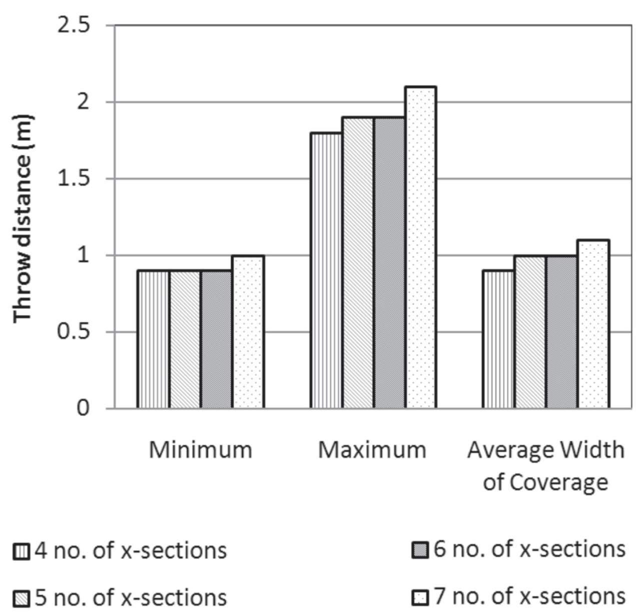

Fig. 4. Effect of x-sectional area on throw distance from

Table 1. Ratio of outlet to inlet cross sectional area for three different sections

Configuration	Ratio of outlet to inlet cross sectional area for different sections						
	1	2	3	4	5	6	7
A	0.16	0.33	0.37	0.41	0.61	0.76	4.23
B	0.16	0.46	0.53	0.60	0.82	0.94	3.50
C	0.26	0.49	0.55	0.51	0.82	1.00	3.32

Testing revealed that nozzle having 7 sections, performed better amongst all. Same prototype was further modified to develop (with different cross-sectional area of the outlet keeping the inlet area constant for each case). Different configurations were generated by varying the ratio of outlet to inlet cross sectional area (Table 1).

These developed configurations were tested for throw distance at different pressure. Testing reflected that increase in pressure resulted increase in throw distance. Since, the system is suppose to work at low pressure; it was tested at a maximum pressure of 0.4 kg/cm^2. Among the different configurations, the configuration "A" found to perform better in context of throw diameter (Table 2).

Table 2. Throw distance as a function of pressure

Pressure (kg/cm^2)	Throw distance of different nozzle configurations having 7 sections					
	A		B		C	
	Min	Max	Min	Max	Min	Max
0.10	0.6	1.65	0.7	1.60	0.7	1.60
0.25	1.05	2.75	1.0	2.85	1.16	2.55
0.40	1.35	4.30	1.43	4.05	1.53	3.85

The water distributing device developed could distribute the water to a larger width. The major problem encountered in its use was the soil erosion due to concentrated flow and large droplet sizes. It was observed that the total cross-sectional area of pipe into 7 sections was not sufficient enough to reduce the size of water droplets. The division of total cross-sectional area of pipe into more than 7 sections is not possible manually. Hence, an alternative was thought to have smaller diameter of holes throughout the pipe length. One of the advantages anticipated (where water is allowed to flow through entire width of the basin) over traditional method (where water is allowed to flow through one outlet) was to achieve higher application uniformity. Hence, next attempt was undertaken to develop a "Perforated pipe system".

Perforated pipe system: The perforated pipe system was developed with an aim to reduce the droplet sizes, increase in throw diameter and increase uniformity. To achieve this, holes of diameter 0.75mm were made on 7.5 cm diameter PVC pipes in three rows. The angles between two rows were kept at 22.5°. Testing was carried to measure the discharge of individual opening as well as the discharge of the perforated pipe at different pressure (0.2 kg/cm^2 to 0.6 kg /cm^2). This system was compared with traditional method of irrigation, field plots of 6m widths and 20m lengths were prepared and land was properly leveled. The field plot was divided into 2m X 2m square grids and elevation was recorded at each grid points for computation of the leveling index. Moisture contents at different depth (15 cm, 30 cm, 45 cm, 60 cm, 75 cm and 90 cm) both at the head and tail end of the plots were measured before and after irrigation to ascertain the depth of infiltrated water. The moisture content distributions by perforated pipe system were found better than the traditional method of irrigation. One of the major drawbacks observed was lodging of crop after 15 to 20 minutes of irrigation. This may be due to continuous application of water at one point.

Prototype of Low Energy Water Application device: On the basis of above experiences it was thought to develop a rotating device similar to impact sprinklers which can distribute water uniformly in various directions, do not facilitate soil erosion and lodging effects on crops if any. The proposed device should satisfactorily work at low pressure to fulfill irrigation objectives and be cost effective. As stated by Hillel (1989) that an advanced irrigation system for small holders should be: low cost, have simplicity in design and operation,reliability, longevity, few manufactured parts that must be imported, easy maintenances and low energy requirements. Hence, an attempt was initiated considering all these factors to develop a cost effective Low Energy Water Application device which by rotating simulates rain like condition similar to impact sprinkler nozzles.

Design Criteria

Based on the experiences and lessons learnt while developing the low-pressure water application device, following points were considered:

- If water droplets/ jets strikes same point repeatedly, there is every possibility of soil erosion. To avoid this there is a need to develop rotating mechanism that will prevent the water droplet to continuously strike the same point,
- When the moment of momentum of flow leaving a control volume is different from that of entering the control volume, it produces torque acting over the control volume (Fig. 5). Thus, if two holes are made in the opposite direction on a piece of pipe and pipe is pivoted at the centre, then due to change in moment of momentum produced by water jets coming out in opposite direction produces a torque. This enables the pipe to rotate which further breaks up the water streams coming out of the pipe. The rapidly rotating jet breakup into smaller water droplets and reduces probability of soil erosion or sagging effect on crops. However, finer droplets are more affected by wind and hence more evaporation and drift losses.
- The objective of irrigation is to apply required depth of water uniformly over the area under consideration. Thus if number of holes (more than two) are made on a pipe section, the water jets /droplets will cover number of points simultaneously resulting in more uniform application of irrigation water. As the number and size of holes is changed, the rotation speed also gets changed, which ultimately affects the application pattern.
- The trajectory angle of the sprinkler influences the water application pattern and hence application uniformity. In absence of air drag, a 45^0 trajectory angle would give the maximum wetted diameter for a given nozzle and pressure. Due to air resistance encountered by water jet, the trajectory angle at which maximum throw is achieved is generally less than 45^0 and is just over 30^0 (Solomon, 1990). Most of the sprinkler manufacturers have adopted 27^0 as "standard" trajectory angle.

Thus, the design of water application device considered here consists of rotating mechanism along with the design of water application component. Important factors which were taken into consideration were:

(a) Length of the rotating device;

(b) Size and number of holes;

(c) Arrangement of holes (location/spacing / trajectory angle of the holes).

Development of Prototype

To develop the prototype PVC pipe of 25mm diameter was used to develop a ***"Tee"*** shape device of different combinations as mentioned above and tested in the laboratory. Different combinations tried were;

(a) Length of the rotating device: 10 cm, 20cm, 30 cm, and 40cm,

(b) Size and number of holes: 0.75mm, 1mm, and 1.5 mm diameter (initially number of holes were kept constant) and

(c) Location (trajectory angle) of the holes: only one line of holes located at the middle of the pipe (angle 0^0 with horizontal) and five rows with different trajectory angles.

A socket and bush arrangement of brass was also developed which facilitates the rotation when fixed on riser pipe.

Effect of different parameters on device performances

(a) Device length: Initially testing was carried with device length of 10, 20, 30 and 40 cm having equal number of holes arranged in a single line. It was observed that device starts rotating at 0.2 Kg/cm^2 in few cases. There was no or slow rotation when the device length was 10 cm or 20 cm with all hole sizes. Whereas, when the length of device increased to 30 cm or 40 cm the rotation can be observed for all hole sizes. Hence, for designing purpose the minimum device length selected was 30to 40 cm.

(b) Hole size: To evaluate the effect of hole diameter on water application pattern, different

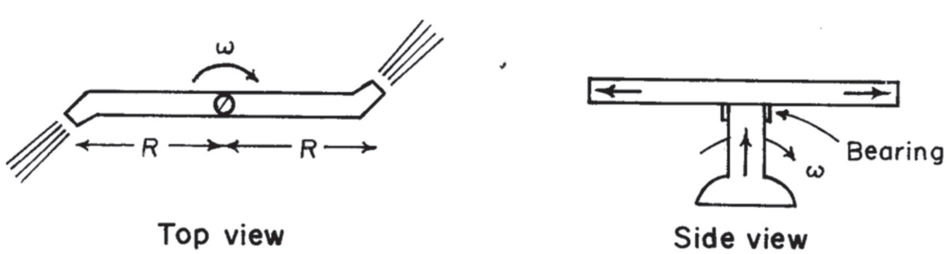

Fig. 5. Principle of couple adopted to develop LEWA

hole diameters (0.75mm, 1.0mm, and 1.5mm) were considered. In general, it was observed that as the diameter of the hole increases application rate increases. A peak was observed in every case which was highest when hole diameter was 1.5 mm. Frequent choking in holes can be observed while operating the device when hole diameter was 0.75 mm and to some extent incase of 1.0 mm. Hence, for design purposes hole sizes 1 mm or greater was preferred.

(c) Arrangement of holes: Two arrangements were studied. Firstly, holes were made in a single line placed parallel to horizontal axis of device whereas in other case holes were placed in five rows located at different trajectory angles. It was observed that when holes are placed in five rows, the throw distance is higher as well as water is distributed more uniformly over the wetted area. Hence, it was decided to consider arranging holes in more than one line.

(d) Number of holes: Attempt was made with 5numbers of holes at each side initially and was varied upto 15 number of holes at each side. It was observed that variation in number of holes on device affects the rate of discharge, droplet sizes as well as the rotational speed etc. Also, testing reflected that when the holes were less than 10 each side, the device either did not rotate or rotated very slow. There were instances that many times with increase in operating pressure device come out of the rotating mechanism. Whereas, at higher number of holes approximately 14 number or 15 number at each side of the device rotates freely. Though, this requires further investigation by keeping device length and hole diameter fixed, but for testing purposes 15 nos. of holes at each side was opted.

Finally, following dimensions, to initiate, the design of prototype was taken into account;

(a) Length of device = 30 cm (L1) and 40 cm (L2).
(b) Hole diameter = 1 mm (D1), 1.5 mm (D2) and 2.0 mm (D3).
(c) Hole Numbers = 15 numbers each side (total 30 holes)
(d) Arrangement of holes = holes arranged in five rows in opposite direction.

Several combinations were tested and performance of device for discharge rate and throw diameter by varying the operating pressure was observed and presented in Table 3.

The data in Table 3 reflects that the change in hole diameter and operating pressure is directly proportional to rate of discharge of the device. It was observed that at the same operating pressure and device length, the rate of discharge increases when hole diameter is increased. At the other hand

Table 3. Discharge and Throw Diameter at different Operating Pressure

Specifications	Trial No	Discharge (lps) at different pressures (kg/cm^2)			Wetted diameter (m) at different pressures (kg/cm^2)		
		0.2	0.4	0.6	0.2	0.4	0.6
L1D1	I	0.104	0.160	0.176	4.0	5.5	6.5
	II	0.112	0.164	0.188	4.0	6.0	6.5
	Average	0.108	0.162	0.182	4.0	5.75	6.5
L1D2	I	0.204	0.272	0.282	4.5	6.0	7.0
	II	0.214	0.288	0.292	4.5	6.0	7.5
	Average	0.210	0.280	0.288	4.5	6.0	7.25
L1D3	I	0.490	0.644	0.768	5.5	6.0	7.0
	II	0.444	0.576	0.600	5.0	6.5	8.5
	Average	0.468	0.610	0.684	5.0	6.25	7.75
L2D1	I	0.128	0.164	0.188	5.0	6.0	7.0
	II	0.120	0.168	0.182	4.5	6.5	7.0
	Average	0.124	0.162	0.186	4.75	6.25	7.0
L2D2	I	0.236	0.300	0.356	4.5	6.0	7.0
	II	0.212	0.276	0.292	5.0	6.5	8.0
	Average	0.224	0.288	0.324	4.75	6.25	7.5
L2D3	I	0.476	0.566	0.716	5.5	7.0	7.0
	II	0.426	0.548	0.656	6.0	8.0	8.5
	Average	0.452	0.555	0.686	5.75	7.5	7.75

same trend was also observed in case of throw diameter. The throw diameter increases with increase in hole diameter and operating pressure. The testing also revealed that droplets sizes were finer when hole size was 1.0 mm whereas larger incase of 2.0 mm hole diameter. Also, excessive ponding in very short duration took place in case of 2.0 mm hole diameter. Hence, for irrigation purpose device configuration of 40 cm in length having holes of 1.5 mm diameter arranged in more than one row placed at different trajectory angle from horizontal axis of device were found most appropriate.

CONCLUSIONS

Testing of various prototypes revealed that the rotating type or moving nozzle is more appropriate for irrigating crops and in achieving uniform wetting. This also minimizes excessive ponding at one place as well as lodging of crops. The operating pressure at nozzle is the governing factor of rate of discharge, wetted diameter, droplet sizes and rotational speed for given device length, number of holes, size of holes and location of holes. It was also observed that to achieve uniform distribution of water size of hole, number and its placing (trajectory angle of water jets) are the important parameters. Further testing and modification may lead to development of a low cost water and energy efficient sprinkling nozzle which can be fitted on pipe network similar to overhead impact sprinklers.

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Response of drip irrigated Spinach, Radish and Onion under variable irrigation

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ABSTRACT

Field experiments were conducted at the irrigation research farm of Allahabad Agricultural Institute-Deemed University, Allahabad, India during the crop growing season of November- February on clay loam soil in order to evaluate the effect of five irrigation levels (25, 75, 125, 175 and 225% of Pan Evaporation Replenishment) on yield, irrigation production efficiency and economic return of spinach, radish and onion under semi arid climate. The highest mean marketable yield of spinach (21.48 t/ha), radish (19.56 t/ha) & onion (33.07 t/ha) was recorded at 175 % of pan evaporation replenishment. A further increase in irrigation amount resulting from 225% of pan evaporation replenishment reduced the marketable yield of spinach, radish and onion. The mean irrigation production efficiency for spinach, radish and onion was significantly higher with irrigation at 25 % of pan evaporation replenishment and it decreased with the increase in irrigation level. Irrigation at 175 % of pan evaporation replenishment resulted in highest net return of spinach (Rs 53314.89/ha), radish (Rs 71125.09/ha) and onion (Rs 187410.49/ha). A further increase in irrigation resulting from 225% of pan evaporation replenishment reduced the net return of spinach, radish and onion. The seasonal water applied and marketable yield of spinach, radish and onion showed strong quadratic relationship (R^2 = 0.935 - 0.992), which can be used with no constraints of available land and the corresponding irrigation application and scheduling for optimizing economic return for these crops in the region.

Key words: Drip irrigation, Spinach, Radish, Onion, Irrigation scheduling

INTRODUCTION

The overgrowing population and the recent droughts are putting country water resources under immense pressure. In addition, due to slow adoption and lack of awareness about the improved water management practices, there is a big gap between ultimate potential created and utilization of available water resources. Further, due to liberalization of industrial policies and other developmental activities, the demand for water in industrial and domestic sector is increasing day by day, which forces to reduce the availability of water for agricultural sector. It is estimated that because of the competing demands of other sectors, the share of water allocated to agriculture is likely to decrease by 10-15% in the next 10-15 years. It is therefore imperative that available water is utilized judiciously and effectively to enhance crop production. It may be achieved by introducing modern method of irrigation having high water application efficiency.

Irrigation scheduling is a critical management input to ensure adequate soil moisture for optimum plant growth, yield, quality, water use efficiency and economic return. Therefore, it is important to develop irrigation scheduling techniques under prevailing climatic condition in order to utilize limited water resources efficiently. Numerous studies were carried out in the past on the development and evaluation of irrigation scheduling techniques under a wide range of irrigation system and management, soil, crop and climate conditions. The meteorological based irrigation scheduling approach such as pan evaporation replenishment, cumulative pan evaporation and ratio between irrigation water and cumulative pan evaporation etc. were used by many researchers due to its simplicity, data availability and higher degree of adaptability at the farmers level (Singh and Mohan, 1994; Srivastava *et al*., 1994; Imtiyaz *et al*., 2004).

Surface irrigation is the most common methods for field, vegetable, fruit and flower crops in this

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region. The overall efficiency of surface irrigation methods is considerably low as compared to modern irrigation method such as drip, microsprinkler and sprinkler. Due to increasing water scarcity caused by erratic rainfall and over-exploitation of ground water, farmers in this region have no option except to adopt advanced irrigation systems such as drip, microsprinkler and sprinkler in order to cultivate more land area under existing water recourses condition. spinach, radish and onion are the most important vegetable crops in Northern region of India. Due to lack of proper irrigation scheduling techniques and irrigation systems, the average yield of spinach, radish and onion are low. Inspite of government subsidy, farmers in this region are reluctant to adopt microirrigation technology mainly due to lack of information on irrigation management and economic viability of systems for vegetable and fruit production. Therefore, the objective of the present study was to investigate the effect of irrigation schedules on marketable yield, irrigation production efficiency and economic return of spinach, radish and onion under drip irrigation systems.

MATERIALS AND METHODS

Field experiments were carried in 2007-2009 crop growing season at Irrigation Research Farm of Allahabad Agricultural Institute-Deemed University, Allahabad which is located at 25^{o}27' N, 81^{o}44' E and 98 m above mean sea level. The mean monthly air temperature, wind velocity, sunshine, relative humidity and evaporation during the winter crop growing season (November – April) ranged from 13.94 to 25.38Ú C, 35.28 to 90.67 km/day, 4.92 to 8.64 h, 53.15 to 81.5 % and 1.16 to 5.34 mm/day, respectively. The average monthly rainfall (last four years) in November, December, January, February, March and April were 0.0, 2.8, 1.06, 0.0, 0.0 and 0.0 mm, respectively. The soil of the experimental field was fertile clay loam, (35.5% sand, 25.8% silt and 38.7% clay) with average bulk density of 1.31 g/cm^3. The moisture content at field capacity (1/3 bar) and wilting point (-15 bar) was 19.5% and 9.1% on an oven dry weight loss basis respectively. The plant available soil moisture was 136.2 mm/m.

The experiments for spinach, radish and onion were laid out separately in a single factor complete randomize block design with three replications of each plot. The area of each experimental plot was 14 m^2. The seedlings of spinach and radish were directly sown at a spacing of 0.1 m x 0.1 m plant to plant and row to row respectively whereas onion seedlings were transplanted at a spacing of 0.075 m x 0.20 m, respectively on 4th December, 2008 and 2009. The standard packages and practices were followed for growing these crops.

The irrigation treatments comprised of five levels of pan evaporation replenishment (25, 75, 125, 175 and 225 %). Crops were irrigated when the sum of the daily mean (5 years) of pan evaporation from USWB Class A pan minus current effective rainfall reached to approximately 16.3 mm (rooting depth in m x plant available soil moisture in mm/m x readily available soil moisture in fraction). The pan evaporation data for a period of last five years (2002-2006) were collected from Meteorological station of Allahabad Agricultural Institute – Deemed University. The crop was irrigated by the drip irrigation method. The drip irrigation system was designed and installed to meet the objectives of the research work.

The irrigation water was pumped from the concrete tank to the drip irrigation system. PVC pipes of 50 mm and LDPE pipes of 12 mm diameter were used for sub-main and lateral lines respectively. The sub main line was connected with water meter and control valve. The lateral line was laid alternate to each crop rows for spinach, radish and onion. Each experimental plot was connected with a control valve in order to deliver required amount of water in different treatments. Screen filter was installed on the main line in order to minimize dripper clogging. Plants were watered by 4 l/h non pressure compensated on-line drippers. During the first two weeks, all the treatments were irrigated daily at 100 % of pan evaporation replenishment (40.2 mm) in order to establish the plants. The standard cultural practices were performed during the crop growing season.

In order to assess the economic viability of drip irrigation system under variable irrigation, both fixed and operating costs were included. Total cost of production, gross return and net return under different irrigation levels was estimated on the following assumption.

Salvage value of the components = 0

Useful life of tube well, pump, motor and pump house = 25 years

Useful life of drip irrigation systems = 8 years

Useful life of weeding and spraying equipments = 7 years

Interest rate = 10%

Repair & maintenance = 2.5%

No. of crops/year = 2

The fixed cost including water development (tube-well, pump, motor, pump house and irrigation system etc.), PCV and LDPE pipes for main, sub main and laterals, filter, fertilizer unit, pressure gauges, water meter, drippers, spraying and weeding equipments and other accessories were calculated by the following approach (James and Lee, 1971);

$$CRF = \frac{i\,(1+i)^n}{(1+i)^n - 1} \qquad \ldots(1)$$

where, CRF = Capital Recovery Factor, i =Interest rate, (fraction), n = useful life of the components (years)

Annual fixed cost/ha = CFR x fixed cost/ha ...(2)

The operating cost including labour (system installation, fertilizer, chemical application and harvesting etc.), land preparation, seeds, fertilizers, chemical & water pumping were estimated. The gross return was calculated taking into consideration the marketable yield and current wholesale price of spinach, radish and onion. Subsequently the net return for spinach, radish and onion was calculated considering the total cost of production and gross return.

Net return (Rs/ha) = Gross return (Rs/ha) – Total cost of production (Rs/ha) ...(3)

The benefit cost ratio (B/C) was calculated as follows :

$$B/C = \frac{\text{Gross return (Rs/ha)}}{\text{Total cost of production (Rs/ha)}} \qquad \ldots(4)$$

RESULTS AND DISCUSSION

Yield and Irrigation Production Efficiency

The results of the study are given in Table 1, which reveal that irrigation levels significantly influenced the marketable yield of spinach. The highest marketable yield of spinach (21.48 t/ha) was observed when irrigation during the crop-growing season was performed at 175% of pan evaporation replenishment. A further increase in the amount of irrigation resulted from 225% of pan evaporation replenishment decreased the marketable yield significantly, which is due to the poor soil aeration and nutrient leaching caused by excessive soil moisture. The percentage reduction in the yield to 175% were estimated 37.43%, 19.045, 9.36% and 16.06% with irrigation at 25, 75, 125 and 225% of pan evaporation replenishment respectively. The irrigation production efficiency of spinach was also influenced by irrigation levels as it decreased significantly with the increase in irrigation levels because increase in yield was lower than the seasonal water applied. The highest irrigation production efficiency (20.05 kg/m^3) was recorded at 25% of pan evaporation replenishment, because reduction in the seasonal water applied was higher than the yield. Irrigation at 225% of pan evaporation replenishment resulted in minimum irrigation production efficiency (2.95 kg/m^3), because it increased the seasonal water application considerably but decreased the yield.

In case of radish, Irrigation at different irrigation level had significant effect on the marketable yield and irrigation production efficiency (Table 2). The marketable yield of radish also increased significantly with increase in irrigation levels upto 175% of pan evaporation replenishment. The highest marketable yield of radish (19.56 t/ha) was recorded at 175% of pan evaporation replenishment. Loss of nutrient caused by excessive irrigation at 25, 75, 125 and 225% of

Table 1. Effect of variable irrigation on seasonal water applied, marketable yield and irrigation production efficiency of Spinach

Treatments (Pan Evaporation Replenishment, %)	Seasonal water applied (mm)			Mean marketable yield (t/ha)			Mean irrigation production efficiency (kg/m^3)		
	2007-08	08-09	Mean	2007-08	08-09	Mean	2007-08	08-09	Mean
25	65.5	68.5	67.0	12.89	13.99	13.44	19.88	21.12	20.05
75	199.9	206.1	203.0	17.01	17.77	17.39	7.99	9.23	8.61
125	338.6	339.4	339.0	18.55	20.39	19.47	9.49	9.69	9.59
175	477.3	480.7	479.0	20.08	22.88	21.48	4.38	4.58	4.48
225	610.1	611.9	611.0	16.95	19.65	18.03	2.87	3.03	2.95
CD (0.05)	-	-	-	-	-	0.722	-	-	0.186

Table 2. Effect of variable irrigation on seasonal water applied, marketable yield and irrigation production efficiency of Radish

Treatments (Pan Evaporation Replenishment, %)	Seasonal water applied (mm)			Mean marketable yield (t/ha)			Mean irrigation production efficiency (kg/m^3)		
	2007-08	08-09	Mean	2007-08	08-09	Mean	2007-08	08-09	Mean
25	72.9	73.1	73.0	12.33	12.21	12.27	16.66	16.94	16.80
75	207.5	210.5	209.0	13.97	14.52	14.21	6.71	6.87	6.79
125	479.3	482.7	481.0	17.89	16.55	17.22	4.19	3.93	4.06
175	619.8	614.2	617.0	19.55	19.57	19.56	2.89	2.99	2.94
225	842.8	847.2	845.0	17.89	18.49	18.19	1.98	2.08	2.03
CD (0.05)	-	-	-	-	-	0.466	-	-	0.169

Table 3. Effect of variable irrigation on seasonal water applied, marketable bulb yield and irrigation production efficiency of Onion

Treatments (Pan Evaporation Replenishment, %)	Seasonal water applied (mm)			Mean marketable yield (t/ha)			Mean irrigation production efficiency (kg/m^3)		
	2007-08	08-09	Mean	2007-08	08-09	Mean	2007-08	08-09	Mean
25	94.3	95.7	95.0	12.88	13.12	13.00	13.51	13.86	13.68
75	272.9	277.1	275.0	21.59	23.59	22.59	8.07	8.35	8.21
125	453.8	456.2	455.0	30.00	30.50	30.25	6.51	6.73	6.62
175	639.7	630.3	635.0	33.88	32.26	33.07	5.35	5.09	5.22
225	814.1	815.9	815.0	29.48	29.68	29.58	3.56	3.68	3.62
CD (0.05)	-	-	-	-	-	0.068	-	-	0.171

pan evaporation replenishment resulted decrease in marketable yield significantly.

The mean marketable yield of onion for different irrigation treatments are also given in Table 3. The results of the study reveals that yield of onion ranged from 13.00 to 33.07 t/ha and the significantly highest marketable yield (33.07 t/ha) was obtained with irrigation at 175% of pan evaporation replenishment. A further increase in the irrigation level resulting from 225% of pan evaporation replenishment decreased the marketable yield significantly. The percentage reduction in the yield with irrigation at 25, 75, 125 and 225% of pan evaporation replenishment were 60.69%, 31.69%, 8.52 % and 10.55% respectively. The irrigation production efficiency of onion decreased significantly with the increase in irrigation levels because increase in yield was lower than the seasonal water applied. The highest irrigation production efficiency (13.68 kg/m^3) was recorded at 25% of pan evaporation replenishment, because reduction in the seasonal water applied was higher than the yield. Irrigation at 225% of pan evaporation replenishment resulted in minimum irrigation production efficiency (3.62 kg/m^3), because it increased the seasonal water application considerably but decreased the yield.

The overall results clearly revealed that irrigation at 175% of pan evaporation replenishment resulted in higher marketable yield of spinach, radish and onion but irrigation production efficiency was higher at 25% of pan evaporation replenishment. Imtiyaz *et al*. (2000) reported higher marketable yield of winter broccoli, carrot and cabbage at 80 % of pan evaporation replenishment.

Economic Return

The total cost of production, net return and benefit cost ratio (B/C) for spinach, radish and onion at different irrigation levels are presented in Table 2. The total cost of production (fixed and operating costs) increased slightly with an increase in pan evaporation replenishment (irrigation levels), because the pumping cost was insignificant as compared to other expenses. The net return and B/C ratio for spinach, radish and onion increased with an increase in irrigation levels upto 175 % of pan evaporation replenishment. A further increase in irrigation level resulting from 225 % of pan evaporation replenishment decreased the net return and B/C ratio, because it increased the total cost of production but reduced the marketable yield. The maximum net return for spinach, radish and onion was Rs. 53314.89/ha, Rs. 71125.09/ha and Rs.

Table 4. Economic Analysis of Spinach, Radish & Onion under variable Irrigation

Treatments (Pan evaporation replenishment, %)	Spinach				Radish				Onion			
	Total cost of production (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Benefit cost ratio (B/C)	Total cost of production (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Benefit cost ratio (B/C)	Total cost of production (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Benefit cost ratio (B/C)
25	71526.31	81080	9553.69	1.133	71585.71	92025	20439.29	1.286	71803.51	104026.67	32196.49	1.449
75	72872.71	104360	31487.29	1.432	72932.11	106575	33642.89	1.461	73585.51	180720.00	107134.49	2.456
125	74219.11	116860	42640.89	1.575	74278.51	129150	54871.49	1.739	75367.51	242053.33	166632.49	3.212
175	75565.11	128880	53314.89	1.706	75624.91	146750	71125.09	1.941	77149.51	264560.00	187410.49	3.429
225	76911.91	108200	31288.09	1.407	76971.31	136425	59453.69	1.772	78931.51	236666.67	157708.49	2.998

*Whole Sale Price of Spinach, Radish and Onion were taken as 5.0, 2.5 and 6.0 Rs/kg respectively.

187410.49/ha respectively at 175% of pan evaporation replenishment. The results revealed that onion is a more remunerative crop followed by radish and spinach (Table 2). Similar results were reported by some researchers under wide variety of irrigation system, water regimes, crop and climatic condition (Shrivastava *et al*., 1994; Tiwari and Reddy, 1997).

Water Supply and Crop Yield

The relationship between seasonal water applied and marketable yield of spinach, radish and onion are presented in Fig. 1 - 3. The seasonal water applied for spinach, radish and onion ranged from 95 to 855mm, whereas marketable yield ranged from 13.44 to 21.48t/ha, 12.27 to 19.56t/ha and 13.00

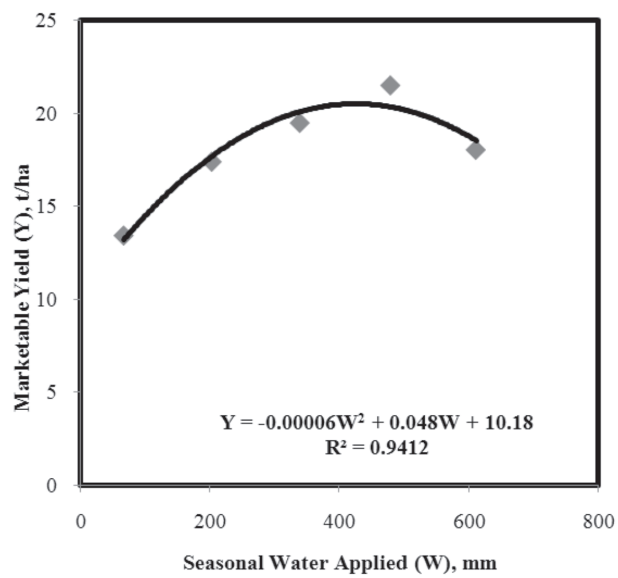

Fig. 1. Relationship between Marketable yield and Seasonal water applied of Spinach under variable Irrigation

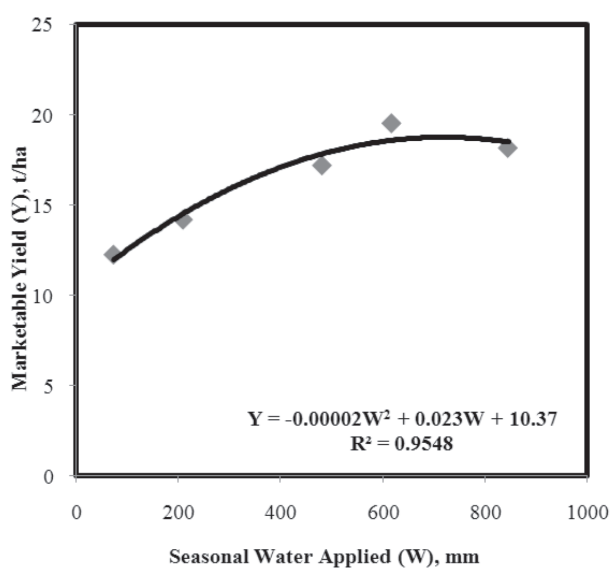

Fig. 2. Relationship between Marketable Yield and Seasonal water applied of Radish under variable Irrigation

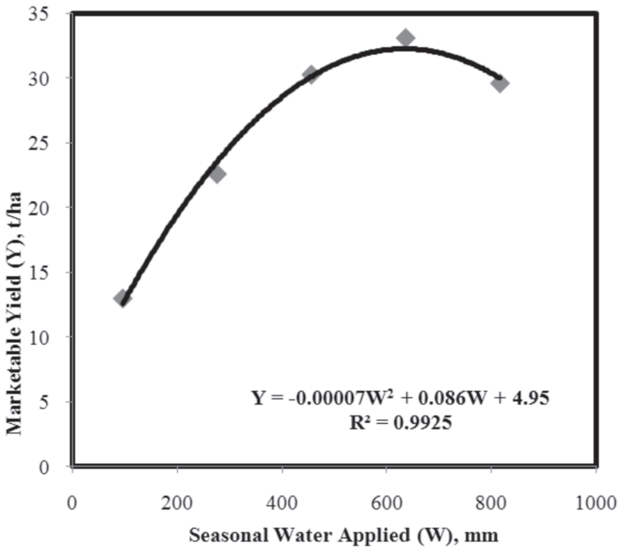

Fig. 3. Relationship between Marketable Yield and Seasonal water applied of Onion under variable Irrigation

to 33.07 t/ha, respectively. The seasonal water applied and marketable yield of spinach (R^2 = 0.9412), radish (R^2 = 0.9548) and onion (R^2 = 0.9925) exhibited strong quadratic relationship. The marketable yield of spinach, radish and onion increased with an increase in seasonal water applied approximately upto 400, 575 and 614 mm respectively and thereafter yield tend to decline. The quadratic water applied and yield relationship results were probably due to nutrients leaching through deep percolation and poor aeration caused by excessive soil moisture. The results reveled that the fitted regression models could be used for efficient allocation of limited water resources within and between the crops, comparing irrigation production efficiency and economic analysis. Imtiyaz *et al.* (2000) reported the quadratic relationship between seasonal water applied & marketable yield of vegetable crop under both drip and sprinkler irrigation systems. Many researchers have reported a quadratic relationship between yield and seasonal irrigation / seasonal water applied for vegetable and field crops under a wide range of irrigation systems and regimes soil and climatic condition (Howell *et al.*, 1997; Zhang and Oweis, 1999; Imtiyaz *et al.*, 2004).

Water Supply and Net Returns

The relationship between seasonal water applied and Net return of spinach, radish and onion for different Irrigation levels are presented in Fig:4, Fig: 5 & Fig: 6 respectively. The seasonal water applied for different irrigation levels ranged from 67 to 611 mm, 73 to 845 mm, 95 to 815 mm for spinach, radish and onion respectively, whereas the Net return of spinach, radish and onion ranged from 9553.69 to 53314.89 Rs/ha, 20439.29 to 71125.09 Rs/ha and 32196.49 to 187410.49 Rs/ha respectively. The seasonal water applied and Net return of

Table 5. Various components of fixed and variable cost considered in economic analysis

Component		Useful life / Area covered/ Season per year	Cost (Rs.)
Fixed Cost			
(a)	Water DevelopmentTubewell , Pump and motor, Pump house, Water storage tank, main conveyance system and accessories and fittings	25 years/ 8 ha/ 2 crops per year	4,01,500-00
(b)	Weeding and Intercultural equipments5 Sprayer, 5 hoes, 5 rakes, 7 khurpi	7 years	7000-00
(c)	Cost of irrigation systemDrip Irrigation (PVC main and sub main pipes, LDPE lateral pipes, Drippers, Fertilizer unit, filter, water meter and accessories	8 years/ 2 crops per year	3,06,047-00
Variable Cost			
(a)	Pumping cost (cost of energy)	-	Rs. 0.99/m^3 of discharge
(b)	Fertilizer (Urea, SSP and MOP)	-	7901-46
(c)	Seed		400-00
(d)	Land Preparation		Rs. 2250/ha
(e)	Labour cost (planting, bed preparation, irrigation , fertilizer application, weeding and harvesting 0	-	Rs. 20,000-00/ha
(f)	Chemicals	-	Rs. 600-00/ha
(g)	Land Rent	-	Rs. 2500/ha/season
(h)	Repair and maintenance	-	7.5% of total fixed cost

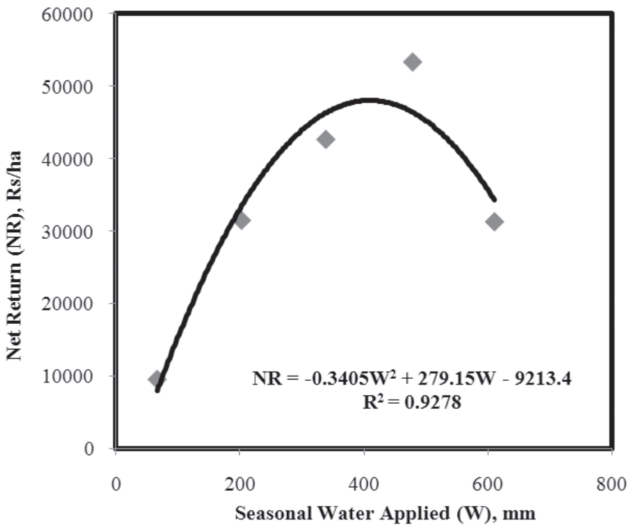

Fig. 4. Relationship between Net Return and Seasonal water applied of Spinach under variable Irrigation

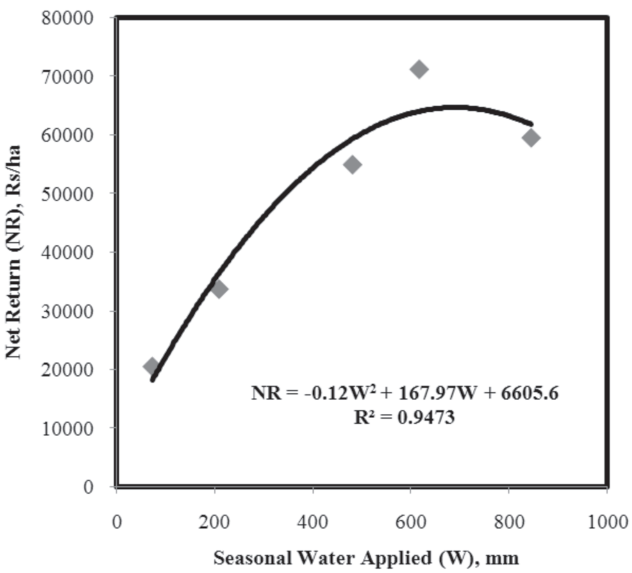

Fig. 5. Relationship between Net Return and Seasonal water applied of Radish under variable Irrigation

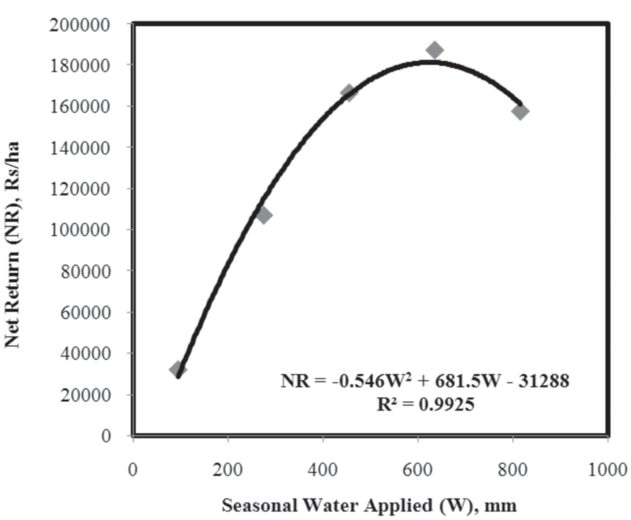

Fig. 6. Relationship between Net Return and Seasonal water applied of Onion under variable Irrigation

spinach(R^2= 0.9278), radish (R^2= 0.9473) and onion (R^2= 0.9925) exhibited a strong quadratic relationship. The Net return of spinach, radish and onion increased with an increase in seasonal water applied approximately upto 410, 700 and 624 mm, respectively and there after it tended to decline. Similar results were reported by Satyendra Kumar *et al*. (2008).

CONCLUSION

Pan evaporation is the most simple and practical approach for irrigation scheduling of crops. Since long term data of USWB Class A pan evaporation is available in India , field extension personnel can prepare irrigation scheduling calendar that can be easily adopted by the farmers. The overall result revealed that irrigation at 175 % of pan evaporation replenishment for clay loam soil for maximum marketable yield with corresponding irrigation production efficiency, net return and benefit cost ratio from spinach, radish and onion under the semi arid climate of northern India. However for optimal net return and corresponding irrigation amount and schedule one have to conduct a linear programming analysis.

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Enhancing harvested rainwater productivity in North-West Himalayas by irrigation scheduling and organic manuring

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ABSTRACT

A two-year study was conducted to evaluate the productivity of rainwater, harvested in an earthen dam, for vegetable crop production under wet temperate climate at Palampur in North-West India. Okra-cabbage-potato cropping sequence was tested for total water use with harvested pond water. The water use efficiency using irrigation scheduling at 0.6, 0.8 and 1.0 IW/CPE (irrigation water / cumulative pan evaporation) ratios and at matric suction of 300 and 450 cm of water were the tested variables. Along with irrigation, chemical fertilizer and farmyard manure treatments which included chemical fertilizers alone (F_1), recommended chemical fertilizers + farmyard manure (F_2), and double the recommended rate of farmyard manure (F_3) were also evaluated for their effects on soil quality parameters. The study revealed that at least 60 cm of rainwater harvesting is needed to sustain okra-cabbage-potato crop sequence in the region. For irrigation in cabbage and potato, scheduling irrigation with IW/CPE (Irrigation Water/ Cumulative Pan Evaporation) ratio of 1.0 and matric suction of 300 cm water was most suitable, as highest water use efficiency was obtained using these schedules. Irrigation scheduling coupled with increased rates of FYM improved soil parameters with respect to moisture retention, available water capacity, porosity, infiltration and hydraulic conductivity.

Key words: Rainwater harvesting, Earthen dam, Farm yard manure water use, Farm pond, Irrigation scheduling

INTRODUCTION

The impact of green revolution has spread in vast area of Indo-Gangetic plain whereas it has hardly affected the agricultural scenario in the hilly and mountainous regions. It is mainly because of the difficulty in development of irrigation resources in these regions, due to undulating topography and high costs of implementing advanced irrigation schemes.

In Himachal Pradesh, only about 17 per cent area is irrigated leaving behind approximately 83 per cent of net cropped area at the mercy of rains. Barring cold deserts, the State receives annual rainfall ranging from 1,100-3,000 mm. A major portion (80 %) of this precipitation is received during 3 to 4 months of monsoon season (June-September). In spite of excess rainwater during monsoon, the scarcity of water is experienced now and then during rest of the year for *kharif* as wells as *rabi* crops. Rainwater harvesting, storage and its use to provide lifesaving irrigations in the dry period is one of the most important needs of agriculture in the hilly regions of India. Rainwater harvesting not only reduces dependence on other sources of water but also reduces the money spent on water. It also reduces the offsite flooding and erosion by holding rainwater at the site (Waterfall, 2004). Also the farming systems in mountains assume greater significance in comparison to low-lands for the reasons of fragility of environment. Runoff water not only erodes soil with it but also removes the added chemical nutrients with it, which ultimately enter the food cycle through the water bodies (Lal and Mishra, 2015, Meyer *et al.*, 1975).

The concept of organic farming also suits well to these regions for various reasons like availability of manure at household level, poor socio-economic condition of the farmers, subsistence farming system with small land holdings etc. Surface crusting is very common which contributes to high runoff and erosion. Addition of FYM may change the physical properties of soil by increasing organic carbon content (Rasool *et al.*, 2008; Haynes and Naidu, 1998). Most studies with FYM application have reported an increase in soil water retention

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(Lal and Mishra, 2015, Unger and Stewart, 1974; Bembi *et al.,* 1998) and plant available water (Rose, 1991), but with variable responses. Improvement in seasonal field water content has also been reported with manure application (Song *et al.*, 2010; Martens and Frankenberger, 1992). Similar responses have been reported for infiltration with either no effect (Sommerfeldt and Chang, 1987) or a positive effect (Bhattacharyya et al., 2006, Miller *et al.,* 2002), and for saturated hydraulic conductivity (Miller *et al.,* 2002; Benbi *et al.*, 1998).

Making the farming system self-sustainable at farm level with development of small to medium rainwater harvesting structures and on-farm resource recycling can alleviate the dependence of farmers on external inputs. Irrigation scheduling at appropriate interval can minimize wastage of stored water. Irrigation scheduling along with irrigation methods has been widely reported to save water and energy (Singh *et al.*, 2014; Paul *et al.*, 2014). While soil moisture is usually not readily controlled by the farmer, there are easier opportunities for increasing the soil organic matter content with the possible benefits of such action in reducing the sensitivity of plants to moisture stress. Vegetable crops are recently assuming greater significance in the region due to higher returns per unit area, but on the other hand require greater fertilizer and nitrogen irrigation inputs. Volume of water harvested in the farm ponds and earthen dams is also limited due to rainfall distribution characteristics and pond area required for storage. Considering these limitations and imperatives, we investigated the effect of farm yard manure at recommended and enhanced rates, and irrigation with harvested rainwater on the productivity of most sought after vegetable sequence in the region *i.e.* okra (*Abelmoschus esculentus* L.)-cabbage (*Brassica oleracea*)-potato (*Solanum tuberosum* L.).

MATERIALS AND METHODS

Soil and site characteristics

This study was conducted on a site at CSK Himachal Pradesh Agricultural University, Palampur, which lies in the 'high rainfall mid-hill wet-temperate agro climatic zone' of Himachal Pradesh in North-West Himalayas. The soils were of the order typic Hapludalf. Annual mean temperature varied from 8.2°C in winters to around 28.0°C during summer months. The annual rainfall of the area ranged from 2500 to 3000 mm. About 80 per cent of it is received during mid-June to mid-September. Torrential and high intensity storms during monsoon create serious problems of soil erosion and nutrient losses. On the other hand, short duration dry spell at later stages of kharif (rainy season) crops and long dry periods during rabi (winter and spring season) crops result in severe moisture stress to the crops. The ground water potential of the region is generally poor. The physical and chemical properties of soil (prior to start of experiment) are presented in Table 1.

Table 1. Selected Physical and Chemical properties of the soil of the experimental area

Parameter	Value
Physical and Chemical properties	
Sand (g kg^{-1})	165
Silt (g kg^{-1})	525
Clay (g kg^{-1})	310
pH (1:2.5)	5.8
Organic carbon (g kg^{-1})	8.5
CEC[c mol $(P)^{+}$ kg^{-1}]	11.5
Available N (mg kg^{-1})	131
Available P (mg kg^{-1})	7.68
Available K (mg kg^{-1})	80
Rainwater harvesting reservoir specifications	
Length of embankment (m)	60
Height of embankment (m)	5
Storage capacity (m^3)	6300
Top width Free board (m)	3
Free board (m)	0.5
Upstream side slope (m)	3:1
Downstream side slope	2:1

Experimental Setup

The tested crop sequence was okra-cabbage-potato. The experiment was laid in a split plot design with irrigation scheduling treatments in the main plots and nutrient management treatments in the sub plots. Okra crop was taken during first week of June to first week of October followed by cabbage immediately transplanted until first week of February, and then potato from first week of February to May end during both cropping cycles. Five irrigation levels tested were: IW/CPE (Irrigation Water/ Cumulative Pan Evaporation) ratio of 0.6 (I_1), 0.8 (I_2) and 1.0 (I_3), and matric suctions of 300 (I_4) and 450 (I_5) cm water. Metric suction was measured with field tensiometers. Nutrient management treatments were: NPK alone at recommended rate (F_c), NPK + FYM at recommended rates (F_{cm}) and FYM at double the recommended rates (F_m). The recommended rates of nitrogen, phosphorus and potassium for the crops were 75:50:50 (okra), 125:100:50 (cabbage)and 120:100:100 (potato) kg ha^{-1}.For FYM recommended rates were 10, 20 and 20 t ha^{-1} for okra, cabbage and potato, respectively. All possible combinations of treatments were imposed in 3 replications of 3.0 X 2.25 m^2 experimental plots).

Rainwater used for irrigating the crop was harvested in an earthen dam. The main characteristic features of the rainwater harvesting structure, the earthen dam, are given in Table 1. Irrigation was done by pumping out water using hosepipe of 25 mm internal diameter. Water use for each crop was calculated by summation of each irrigation event. Each irrigation episode was of 3 cm depth. Open pan evaporation was recorded from the U.S. Pan Evaporimeter for calculating Cumulative Pan Evaporation (CPE). In case of treatments where irrigation scheduling was done on the basis of matric suction, mercury manometer type tensiometers were installed at 15 cm depth.

Bulk density of the soil was determined after first and second cropping cycles by using standard core method. Bulk density of soil aggregates was determined by mercury displacement method. The total porosity of whole soil and soil aggregates (2-8mm diameter) was determined in May at potato harvest after each cropping cycle, from their respective particle and bulk density values. Soil core samples (0.03 m long and 0.054 m diameter) were collected in duplicate from each plot for 0.00-0.03m, 0.03-0.06m, 0.06-0.09m, 0.09-0.12m soil layers. The soil moisture characteristics were determined using pressure plate apparatus. The available water capacity AWC was determined using the procedure given by Soil Survey Division Staff, USDA, 1996. The soil moisture characteristic data was used to determined pore-size distribution using capillary rise equation. The volume of each pore range was calculated by determining the volume of water retained by the soil between the equivalent suction values using pressure plate apparatus (Premium plate apparatus, Soil Moisture Equipment Co., Santa Barbara, USA). Based on these values, volume of transmission pores (>50μm), water retention pores (50-0.5 μm), and residual pores (<0.5 μm) was determined (Greenland, 1979). The infiltration was measured using double ring infiltrometers. The water intake rate (i) as well as cumulative intake (I) was plotted on a simple scale as a function of time. Mercury manometer type tensiometers were installed at 0.15 m depth to monitor the changes in soil water potential and hydraulic gradients during the growth of vegetable crops.

The saturated hydraulic conductivity (Ks) was determined after first and second cropping cycles. Undisturbed soil samples were collected in duplicate from each plot in metal cores of 0.115m lengths and 0.08m diameter. The Ks was determined by constant water head method of Klute (1965):

$$Ks = Q\,L / A\,T\,(L+H)$$

where, Ks is the saturated hydraulic conductivity, Q is the amount of water passing through the soil sample of cross-sectional area, A, and length, L, in time, T. H the depth of water maintained at the soil surface.

Crop yield was recorded as pod yield (Mg ha^{-1}) in Okra, marketable heads without non-wrapper leaves (Mg ha^{-1}) in cabbage and tuber yield (Mg ha^{-1}) in potato crop.

Statistical Analysis

The studies were conducted in three replicates, and the differences of the means and the interaction between studied parameters were tested using analysis of variance (ANOVA) using split plot design. The data were analyzed statistically at the 0.05 significance level.

RESULTS AND DISCUSSION

There was no requirement of irrigation for okra crop during both the seasons due to sufficiency of rainwater. For the cabbage crop, the number of irrigations varied from 7 to 18 during first cropping cycle, while it was 5 to 12 during second cropping cycle. During both the cropping cycles I_1 (IW/CPE=0.6) treatment received minimum number of irrigations while I_4 (300 cm water) received maximum number of irrigations (Table 2). Similar trends were seen in the total depth of irrigation water applied. The total water depth applied during the first cropping cycle was between 21 cm in I_1 to 54 cm in I_4 treatment while it was 15 cm and 36 cm, respectively, during the first cropping cycle. The effects of manurial management could also be seen in the irrigation scheduling and variation of 2-3 irrigations was observed due to fertilizer/FYM treatments. More number of irrigations was taken by treatments in which no farmyard manure was applied (F_c). The least number of irrigations were received by treatments with double the rate of FYM (F_m). Similar trends in the irrigation requirement were observed in potato crop too, although the number of irrigations varied. Maximum number of irrigations (13) were given to I_3 and I_4 treatments, resulting in maximum depth of water i.e. 39 cm. and minimum number of irrigations (8) were applied to I_1 and I_5F_3 treatment (consequently

Table 2. Water use and water productivity

Treatment	Total Water Use (cm)				Water Use Efficiency (q $ha^{-1}cm^{-1}$)			
	Cabbage		Potato		Cabbage		Potato	
	I^{st} cycle	2^{nd} cycle	I^{st} cycle	2^{nd} cycle	I^{st} cycle	2^{nd} cycle	I^{st} cycle	2^{nd} cycle
I_1F_1	25.49	19.92	35.93	39.22	7.55	5.22	5.65	4.01
I_1F_2	25.49	19.92	35.93	39.22	9.76	9.90	6.24	6.78
I_1F_3	25.49	19.92	35.93	39.22	10.23	10.96	6.74	6.92
I_2F_1	31.49	22.92	41.93	45.22	7.66	6.95	5.59	4.60
I_2F_2	31.49	22.92	41.93	45.22	9.69	9.85	6.05	6.56
I_2F_3	31.49	22.92	41.93	45.22	10.06	11.59	6.74	7.01
I_3F_1	34.49	28.92	50.93	54.22	7.59	6.01	5.21	4.72
I_3F_2	34.49	28.92	50.93	54.22	10.24	10.48	5.78	6.18
I_3F_3	34.49	28.92	50.93	54.22	11.15	12.75	5.99	6.52
I_4F_1	58.49	40.92	50.93	45.22	5.10	5.23	5.15	5.00
I_4F_2	52.49	37.92	44.93	36.22	7.34	9.57	6.16	7.63
I_4F_3	49.49	31.92	41.93	33.22	8.42	12.32	6.95	8.51
I_5F_1	46.49	34.92	41.93	39.22	6.13	5.19	5.38	4.58
I_5F_2	43.49	31.92	41.93	36.22	8.72	9.37	5.78	6.95
I_5F_3	40.49	28.92	35.93	33.22	9.65	12.30	6.90	7.72

minimum depth of water i.e. 24 cm), during the first cropping cycle. The number of irrigations varied between 7 (I_5F_3) to 14 (I_3) for the second cropping cycle, maximum being in I_3 treatment and minimum in I_5F_3 treatment (Table 2). The differences between treatments, in number of irrigations and amount of total water applied, was a result of irrigation scheduling method and organic manure applied as FYM. In treatments with irrigation scheduling based on IW/CPE ratio, the irrigations were given irrespective of soil moisture status or water deficit. Therefore, the irrigations were equal for all fertilizer/ FYM applications. In treatments with irrigation based on matric suction, there were differences in irrigation frequency, and thus in total water applied.

During the first cropping season of cabbage, the maximum WUE was observed in treatment I_3F_m (11.15 q $ha^{-1}cm^{-1}$) followed by I_3F_{cm} (10.24 q ha^{-1} cm^{-1}) and I_2F_{cm} (10.06 q $ha^{-1}cm^{-1}$). In general, the water use efficiency in all treatments varied from 5.10 to 11.15 q $ha^{-1}cm^{-1}$. During the second cropping season WUE varied from 5.19 to 12.75, the maximum value being for I_3F_m followed by I_4F_m and I_5F_m with WUE values of 12.32 and 12.30 q ha^{-1} cm^{-1}, respectively. During both cropping seasons of cabbage highest WUE was obtained in I_3 (IW/CPE = 1.0) treatment with 34 cm of total water use during first and second cropping cycles (Table 2). In potato crop, the water use efficiency ranged between 5.15 and 6.95 q$ha^{-1}cm^{-1}$ for first cropping season, and between 4.01 and 8.51 q $ha^{-1}cm^{-1}$ for second cropping season. During the first cropping season, the maximum WUE was observed in I_4F_m (6.95 q ha^{-1} cm^{-1}) followed by I_5F_m (6.90 q $ha^{-1}cm^{-1}$) and I_4F_{cm} (6.16 q $ha^{-1}cm^{-1}$), while during second cropping season it was maximum in I_4F_m (8.51 q $ha^{-1}cm^{-1}$) followed by I_5F_m (7.72 q $ha^{-1}cm^{-1}$) and I_4F_{cm} (7.63 q $ha^{-1}cm^{-1}$). In potato crop, I_4 (matric suction = 300 cm H_2O) treatment gave highest water use efficiency during both seasons. Addition of farmyard manure increased the efficiency at all levels of irrigation during all seasons (Table 2).

Organic matter enhanced the water retention of soil and therefore the duration between two irrigation episodes was stretched. The bulk density of whole soil (0-0.15m) and soil aggregates significantly decreased with the addition of farmyard manure (FYM), the effect being proportional to the quantity added. Since the bulk density of organic matter (FYM) is much less than the inorganic mineral matter, the overall reduction in the bulk density of whole soil was due to dilution effect of organic matter on soil matrix and partly due to improvement in aggregate stability (Macrae and Mehuys, 1985). Bulk density of soil aggregates was also significantly reduced by addition of FYM. There was a decrease of 7.4 to 11.9 per cent with recommended rate and 14.8 to 17.2 per cent with double the recommended rate of FYM, over the absence of FYM. Organic matter, along with roots, fungal hyphae and other biological filaments, has the capacity to bind soil matrix in the same way as geo-textiles (filament effect) in engineering. In soil aggregates the decrease might also be due to structurally well woven soil components with increased void space. There was a decrease in residual pores (<0.5 μm) and an increase in storage

Table 3. Bulk density and total porosity of soil and soil aggregates with fertilizer and farmyard manure management

Treatment	Bulk density(Mg m^{-3})				Total porosity(%)			
	Soil (0-0.15 m)		Soil aggregates		Soil (0-0.15m)		Soil aggregates	
	Ist cycle	2nd cycle	Ist cycle	2nd cycle	Ist cycle	2nd cycle	Ist cycle	2nd cycle
F_1	1.35	1.33	1.51	1.49	48.62	51.49	42.53	42.33
F_2	1.26	1.26	1.33	1.38	50.79	54.78	46.03	47.26
F_3	1.13	1.14	1.25	1.27	55.57	59.29	52.49	53.73
$LSD_{0.05}$	0.07	0.06	0.08	0.10	2.00	2.85	3.26	4.15

pores (0.5-50 µm) and transmission pores (50 µm) with the addition of FYM at both recommended and double rates. The increase in total porosity of soils can be attributed to reorientation of soil particles into a well-structured loose packing and even the lower particle density of organic materials (Klemetti and Keys, 1983).

The highest values of bulk density were obtained for F_c treatment (only chemical fertilizers) followed by F_{cm} (recommended fertilizer + FYM) and F_m (only FYM at double the recommended rate) treatments, respectively. Thus the bulk density of whole soil at 0-0.15 m depth followed the trend of F_c>F_{cm}>F_m treatment. On an average the bulk density of soil at 0-0.15 depth was reduced by5.26 and 14.28 per cent in F_m and F_{cm}, respectively over F_c treatment at the end of second season. The treatments with addition of FYM had significant increase in porosity over the treatment with no FYM addition (Table 3). There was an increase of 14.29 and 4.46 per cent in F_m and F_{cm}, respectively over F_c treatment at the end of first cropping cycle, and 15.14 and 6.38 % in F_m and F_{cm}, respectively over F_c at the end of second cropping cycle. The increase in the total porosity of soil aggregates was 23.41 and 26.93 per cent in F_m, and 8.22 and 11.64 % in F_{cm} over F_c treatment during the first and second cropping cycles. There were no significant differences in porosity of either whole soil or aggregates due to irrigation treatments. At 0-0.15m depth there was a decrease of 11.42-13.48 per cent in the residual pores, increase of 11.76-13.71 per cent in the storage pores and increase of 1.59-5.94 per cent in the transmission pores with the addition of FYM. At 0.15-0.30 m depth there was an increase of 12.84-17.43 per cent in storage pores with FYM additions, but no general trend was noticed in residual and transmission pores with noticeable decrease in residual pores in F_{cm} and transmission pores in F_m treatment.

The soil moisture retention increased with the addition of FYM at all suction values from 10 to 1500 kPa (Table 4). The increase was more at lower than higher suction values. FYM addition increased water retention at lower suctions, while there was no effect on retention at higher suctions at 0-0.15 m depth. At lower depth (0.15-0.30m), there was a general increase in water retention with FYM addition at all suction values, the effect being more pronounced in F3 treatment. Available water capacity (AWC) increased significantly with the addition of FYM at both 0-0.15 and 0.15-0.30m depths. At 0-15 cm depth, the increase was 12.49 to 17.13 % for F_{cm} and F_m, respectively after first cropping cycle, while it was 16.75 to 40.28 % after second cropping cycle when expressed on volume basis (v v^{-1}). At 0.15-0.30m depths, the differences in AWC were lower than those in the 0-0.15m depth of soil. During the first cropping cycle, the increase in AWC was 16.73 to 17.07 % (v v^{-1}) for F_{cm} and F_m, respectively, while during second cropping cycle it was only 11.55 to 19.60 % (w w^{-1}) and 2.88 to 6.92 % (v v^{-1}).

The infiltration rates for first cropping cycle were 25.18, 30.21 and 56.15 µm sec^{-1} in F_c, F_{cm} and F_m, respectively. The values at the end of second

Table 4. Soil water retention characteristics and available water capacity of soils with fertilizer and farmyard manure management

Treatment	Soil Water Retention Characteristics(kPa)*				Available Water Capacity(%, v v^{-1})			
	0-0.15m				0-0.15m		0.15-0.30	
	10	100	500	1500	Ist cycle	2nd cycle	Ist cycle	2nd cycle
F_1	36.20	30.54	22.32	20.89	18.09	16.94	14.76	14.88
F_2	37.20	32.39	22.94	21.40	20.35	18.86	17.23	15.31
F_3	43.27	36.52	26.12	24.96	21.19	21.98	17.28	15.91
$LSD_{0.05}$	2.01	1.35	0.92	0.83	1.20	1.31	0.76	0.53

*After two cropping cycles

Table 5. Infiltration characteristics and hydraulic conductivity effects of fertilizer and farmyard manure management.

Treatment	Infiltration Rate (μm sec^{-1})		Cumulative Infiltration (m)		Saturated Hydraulic Conductivity (μm sec^{-1})	
	Ist cycle	2nd cycle	Ist cycle	2nd cycle	Ist cycle	2nd cycle
F_1	25.18 (±4.21)	22.10 (±-3.33)	1.33 (±0.50)	1.26 (±0.43)	27.85 (±6.21)	28.03 (±8.25)
F_2	30.21 (±5.30)	31.19 (±5.40)	1.74 (±0.68)	1.84 (±0.70)	39.45 (±5.32)	42.00 (±6.42)
F_3	56.15 (±9.45)	60.46 (±10.61)	2.90 (±0.78)	3.35 (±0.86)	78.58 (±15.53)	72.63 (±11.23)

*Figures in parenthesis indicate the standard deviation.

cropping cycle were 22.10, 31.19 and 60.46 μm sec^{-1} for F_c, F_{cm} and F_m treatments, respectively (Table 5). The cumulative infiltration values were 1.33, 1.74 and 2.90 m after first cropping cycle, and 1.26, 1.84 and 3.35 m after second cropping cycle for F_c, F_{cm} and F_m treatments, respectively. At the end of second cropping cycle the Ks values were 28.03, 42.00 and 72.63 μm sec^{-1} in F_c, F_{cm} and F_m, respectively, with an increase of 50 to 160 per cent with FYM addition (F_{cm} and F_m, respectively) during this period (Table 5).

The increase in pore space was mainly due to conversion of residual pores into storage and transmission pores, which ultimately has bearing on the plant available water and other hydraulic properties. An increase of 19.9 to 122.9 per cent with the addition of FYM during 2001 and 41.3 to 173.57 per cent during 2002 was noticed in the final infiltrability. Water infiltrability into the soil is a function of the surface condition of the soil and pore size distribution, while the conductivity is solely dependent on the type and size of the pores within. It might be the surface roughness or presence of abundant biopores (pores continuous from surface to lower depths) in soils amended with FYM, which led to increased infiltration rate. The moisture retention characteristics of soils depend upon the bulk density, total porosity, size distribution of pores and the specific surface area of soil. Water retention at higher potentials (100 to 0 kPa) depends primarily upon the capillary effect and the pore-size distribution, and is strongly affected by soil structure. At the same time, water retention at lower potentials (1500 to 100 kPa) is mainly due to adsorption. It is more affected by texture and specific surface area of the soil material (Hillel, 1982). The organic matter affects both these properties by increasing the number of pores, including macro pores (storage and transmission pores) and even the surface area of soil.

After two cropping cycles, the increase in AWC was 12.5 to 17.1 per cent at 0-0.15 m and 2.9 to 6.9 per cent at 0.15-0.30 m depth. The increase was noticeably more in surface layer than at lower depth. Vegetable crops in particular are very sensitive to soil moisture regime, and better moisture condition throughout the growth period resulted in increased yields. The role of organic matter, added through FYM, in water conservation and its subsequent impact on yields was visible from the fact that F_m treatment gave highest yields even under low irrigation frequencies.

The yield of okra was maximum in F_{cm} treatment with 190.21 q ha^{-1} followed by F_m and F_c treatment with 160.92 and 148.45 q ha^{-1} during first cropping cycle (Table 6). Yield in F_c and F_m treatments were statistically at par with other during this period, except that the latter one was an organic produce. During second cropping cycle F_{cm} (153.96 q ha^{-1}) and F_m (155.35 q ha^{-1}) treatments were statistically at par with each other followed by F_c (127.37 q ha^{-1}) treatment. The pooled analysis found F_{cm} to be the best treatment followed by F_m and F_c treatments, respectively.

In cabbage crop, during the first cropping cycle, I_4, was the best irrigation treatment with yield of 366.91 q ha^{-1} followed by I_5, I_3, I_2 and I_1 treatments with mean yield of 351.93, 333.35, 287.93 and 234.15 q ha^{-1}, respectively. Similar trends were observed during second cropping cycle except that I_5 and I_3 treatments were at par with each other. Head yield in all irrigation treatments was statistically different from each other during both cropping seasons except I_3 and I_5 treatments which were at par after second cropping cycle. F_m treatment had the highest yield of 354.04 q ha^{-1} followed by F_{cm} and F_c treatments with yield of 334.58 and 255.93 q ha^{-1}, respectively, during first cropping cycle. Similar trends were observed during the second cropping cycle with average yield of 320.48, 283.34 and 166.64 q ha^{-1} in F_m, F_{cm} and F_c, respectively. The interaction effects of irrigation and fertilizer / FYM treatments were also significant in cabbage crop during both the cropping cycles. F_m treatment performed the best at all irrigation levels during both the cropping cycles. At I_1, I_2 and I_5 levels of irrigation, F_m and F_{cm} treatments performed the best and were statistically at par with each other. At I_3 and I_4 levels of

Table 6. Irrigation management, and fertilizer and farmyard manure management effects on crop yields.

Treatment	Marketable yield (q ha^{-1})					
	Okra		Cabbage		Potato	
	Ist cycle	2nd cycle	Ist cycle	2nd cycle	Ist cycle	2nd cycle
Irrigation						
I_1	168.91	146.22	234.15	173.30	223.30	231.66
I_2	167.80	149.79	287.93	217.00	257.05	273.58
I_3	165.67	139.60	333.35	281.98	288.66	315.25
I_4	159.15	152.57	366.91	323.61	277.04	261.86
I_5	155.10	139.62	351.93	288.20	238.75	229.47
$LSD_{0.05}$	16.87	17.68	12.91	14.41	15.68	25.88
Fertilizer/FYM						
F_1	148.45	127.37	255.93	166.64	238.37	205.58
F_2	190.21	153.96	334.58	283.34	258.52	285.10
F_3	160.92	155.35	354.04	320.48	273.99	296.41
$LSD_{0.05}$	18.31	13.37	12.07	17.78	13.49	17.15

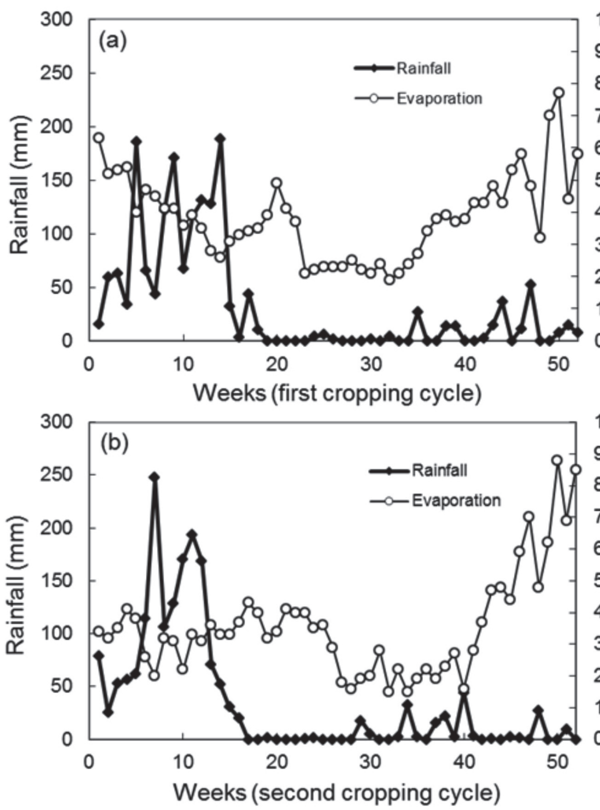

Fig. 1. Mean weekly rainfall and evaporation during: (a) first cropping cycle and (b) second cropping cycle

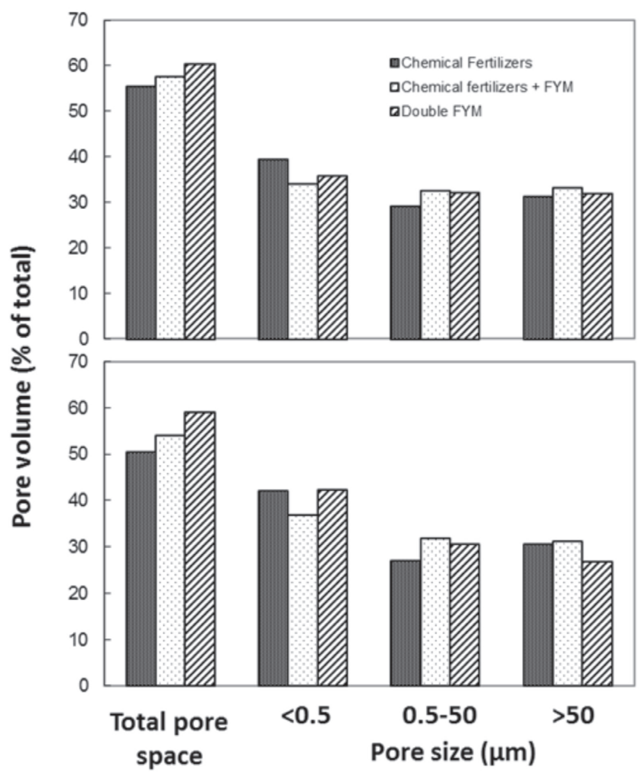

Fig. 2. Effect of fertilizer/ FYM treatments on pore size distribution at 0-0.15 and 0.15-0.30 m soil depths

irrigation, F_m treatment performed the best followed by F_{cm} and F_c treatment. During the first cropping cycle, I_4F_m (416.74 q ha^{-1}) gave the highest head yield followed by I_5F_m (390.96 q ha^{-1}) and I_4F_{cm} (385.48 q ha^{-1}), which were statistically at par with each other. During second cropping cycle, at I_1, I_4 and I_5 levels of irrigation the effect of FYM addition on head yield was significant up to F_{cm} level. F_{cm} and F_m treatments were statistically at par at these irrigation levels.

In potato crop, during the first cropping cycle, I_3 and I_4 treatments were the best with average yield of 288.66 and 277.04 qha^{-1}, which were statistically at par with each other (Table 6). The next best treatment was found to be I_2 with yield of 257.05 q ha^{-1} followed by I_5 and I_1 treatments, which were statistically at par with yields of 238.75 and 223.30 qha^{-1}, respectively. During the second cropping season, I_3 treatment was found to be the best with 315.25 q ha^{-1} yield followed by I_2, I_4, I_1 and I_5 with 273.58, 261.86, 231.66 and 229.47 q ha^{-1} yields. The yields in treatments I_2 and I_4 were found to be at par statistically. Pooled data showed that I_3 and I_4 treatments were the best and statistically at par with each other followed by I_2, I_5 and I_1. During both the cropping cycles, F_m treatment produced highest quantity of tubers followed by F_{cm} and F_c treatments. The average yields during first cropping season were 273.99, 258.52 and 238.37 q ha^{-1}. In second cropping season, these were 296.41, 285.10 and 205.58 q ha^{-1} in F_m, F_{cm} and F_c treatments, respectively. The interaction effect of irrigation and fertilizer/FYM treatments on yield of potato during first cropping season indicated that F_m treatment gave the highest tuber yield and was at par with F_{cm} at all irrigation levels except I_2. The F_c treatment gave lowest tuber yield amongst all fertilizer/FYM treatments, but it was also statistically at par with F_{cm} at I_1, I_2, I_4 and I_5 irrigation levels. During second cropping season, F_m was the best treatment at all the tested levels of irrigation and was statistically at par with F_{cm} treatment at I_1, I_4, I_5 levels of irrigation. Lowest yield was obtained in F_c treatment at all levels of irrigation.

CONCLUSION

There was considerable saving of water with application of enhanced levels of farmyard manure. It led to 15-20% saving of irrigation water in cabbage while in potato it was 20-27%. Harvested water when coupled with proper irrigation scheduling techniques and *in situ* water conservation via farmyard manure addition could sustain the tested cropping cycle i.e. okra – cabbage – potato in mid-hill wet temperate agro-climatic zone of Himachal Pradesh.

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Changes in micronutrient status on submergence of basmati growing soils of Jammu

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ABSTRACT

An incubation study on 20 representative basmati growing soils of Jammu was carried out for 15, 30, 45 and 60 days submergence to record changes in the availability of micronutrients (Zn, Cu, Fe and Mn). The soils under study were sufficient in DTPA extractable Cu, Fe and Mn, but 95% soil samples were deficient in Zn. The availability of Fe and Mn increased by 60-65% and 200-250% after 30 and 45 days of incubation, respectively whereas Zn and Cu decreased upto 34 & 74%, respectively. Both simple and multiple correlation and regression analysis showed variable contribution of physico-chemical properties. Management of Zn and Cu for better nutrition, production and productivity of famous basmati rice growing soils in rice-wheat agro-ecosystem of Jammu is needed.

Key words: Basmati, soils, submergence, micro-nutrients, sufficient, deficient

INTRODUCTION

Micronutrients are not only important for better crop productivity but also essential for sustaining human and animal health. The world health organization has estimated that globally some two billion people are affected by iron deficiency (WHO, 2006). The deficiency of Zn is increasingly recognized as an important public health problem (Rattan *et al.,* 2009). The inadequate and imbalanced fertilizer use coupled with no addition of organic manures has led to the emergence of multi-nutrient deficiencies in many areas. The deficiencies of micronutrients, particularly of zinc and boron, are becoming more conspicuous in some areas (Mondal *et al*., 2006; 2007).

The availability of micronutrients is particularly sensitive to changes in soil environment. The factors that affect the contents of such micronutrients are organic matter, soil pH, lime content, sand, silt, and clay contents. Flooding of rice fields causes major chemical changes in the soil that affect the transformation and availability of nutrients, carbon dynamics, and growth of rice and subsequent crops (Ponnamperuma, 1972). Upon flooding, a molecule of oxygen is depleted, and NO_3^-, Fe (III), Mn (IV), and SO_4^{2-} are chemically reduced. Flooded soils differ from others in the control of acidity and alkalinity because the partial pressure of CO_2 in floodwater buffers carbonate and lowers pH. Soils that are initially acid when flooded tend to equilibrate with the floodwater and become less acidic within a few days, while those that are initially alkaline and sodic move towards neutrality, but more slowly. These pH changes alter chemical equilibria and consequently the availability of nutrients. Basmati is especially grown for its world famous fragrance in R. S. Pura and Bishnah blocks of Jammu district. An earlier study has revealed deficiency of Zn and other major nutrients in these soils but no work on the transformation of micronutrients in these submerged soils has been conducted. The deficiency has aggravated due to high analysis, imbalanced use of fertilizers, besides no regular addition of Zn in rice-wheat crop sequence. Therefore, it was considered worthwhile to undertake the present investigation.

Divergent textured seventy five surface soil samples (0-15cm), ranging from clayey to sandy clay loam were collected from basmati growing areas of R S Pura and Bishnah blocks of Jammu district and analysed for different physico chemical properties. Collected soils were air dried, powdered with wooden mortar and pestle processed and passed through 2 mm nylon sieve and subsequently analysed for pH, EC, organic carbon, cation exchange capacity (CEC), and mechanical separates (clay, silt and sand) following standard method of Jackson (1973) and di-ethylene tri-amine penta

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acetic acid (DTPA) extractable micronutrients Zn, Cu, Fe and Mn following the method outlined by Lindsay and Norvell (1978). Out of 75 samples analysed, 20 representative surface soil samples of different locations and variable properties as depicted in Table 1 were selected for incubation study.

Laboratory incubation studies: To study the submergence effect, 12.5 g portions of each of the processed soil samples were kept in a number of small containers (25 x 150mm) made of glass and submerged with 25ml double distilled water to a height of 5 + 0.5 cm above the soil surface and were incubated in the laboratory at the ambient temperature for 15, 30, 45 and 60 days. There were three replications of each soil sample. Any losses of water through evaporation were compensated for by periodic addition of double distilled water. After different days of incubation, the soil samples were and analysed for available zinc, copper, iron and manganese to record any change in these micronutrients. The changes in pH were also determined at different days of incubation. The physico-chemical properties, *viz.*, pH, EC, OC, CEC and texture etc. of soils were determined following standard methods. Both initial and final available micronutrients after submergence were extracted with DTPA extractant and determined following the method as suggested earlier. Correlation and regression analysis were also carried out with SPSS-13 software to work out the relationships between soil physico-chemical properties and available micronutrients (Zn, Cu, Fe and Mn) under submerged conditions.

The reactions of the soils were generally acidic to neutral with few exceptions as alkaline. The values ranged from 5.36 at village Powa of R S Pura to 8.84 of village Laleyana Palsepora, with a mean value of 6.60. The soils were non saline in nature as the electrical conductivity (EC) ranged from 0.11 at village Krail of Bishnah to 0.47 of village Dabber Hassa, with a mean value of 0.28 (dSm^{-1}). The cation exchange capacity (CEC) ranged from 3.38 at village Krail of Bishnah to 28.02 at village Powa of R S Pura with a mean value of 13.11 cmol (p^+) kg^{-1}. The amount of organic matter content was medium to high. The organic carbon ranged from 0.53 to 1.28% (average 0.74%). The mechanical separates (%), clay content of soil ranged from 27.7 to 48.8% (average 34.9%). The silt content of soil ranged from 14.0 to

Table 1. Physico-chemical properties of soils

S. No.	Locations/villages	Physico-chemical properties				Mechanical separates (%)			
		pH (1:2.5)	EC ($dS\ m^{-1}$)	O.C. (%)	CEC $cmol(p^+)kg^{-1}$	Clay	Silt	Sand	Texture
1.	Chouhala	5.41	0.22	0.68	6.56	31.8	22.1	46.2	Sandy clay loam
2.	Chak Mohd Yar	7.02	0.25	0.98	10.70	33.8	30.2	36.1	Clay loam
3.	Jendlahr	7.69	0.29	0.83	9.64	31.8	37.8	30.4	Clay loam
4.	Baja Jana	6.08	0.31	0.83	8.60	33.7	25.9	40.4	Clay loam
5.	Salam Chak	7.32	0.41	0.83	10.70	29.7	34.2	36.1	Clay loam
6.	Colay	7.35	0.35	0.83	12.56	31.8	31.6	36.6	Clay loam
7.	Khothay	7.33	0.31	1.28	17.58	37.8	25.9	36.3	Clay loam
8.	Mamka	5.59	0.14	0.83	15.72	39.8	29.9	26.3	Clay loam
9.	Powa	5.36	0.19	0.90	28.02	48.8	22.0	23.2	Clay
10.	Phinder	5.45	0.41	0.68	14.61	33.8	22.2	44.0	Clay loam
11.	Makhanpur	5.72	0.25	0.68	12.62	37.8	28.0	34.2	Clay loam
12.	Laswara	7.59	0.43	0.53	9.46	29.7	14.0	56.3	Sandy clay loam
13.	Dabber Hassa	8.03	0.47	0.53	19.69	35.7	38.4	25.9	Clay loam
14.	Blande Khothy	7.04	0.23	0.83	23.80	43.7	36.3	20.0	Clay
15.	Lalyana Paslepora	8.84	0.19	0.53	14.30	29.7	26.1	44.2	Clay loam
16.	Ansala Chalk	5.49	0.12	0.68	10.59	29.7	30.3	40.0	Clay loam
17.	Taraf	6.14	0.36	0.53	9.49	29.8	24.2	46.0	Sandy clay loam
18.	Krail	5.41	0.11	0.53	3.38	27.7	15.6	56.7	Sandy clay loam
19.	Pachal	6.07	0.21	0.68	11.51	30.9	31.9	37.2	Clay loam
20.	Arnia	7.08	0.29	0.53	12.60	30.9	24.0	45.1	Sandy clay loam
	Range	5.36-8.84	0.11-0.47	0.53-1.28	3.38-28.02	27.7-48.8	14.0-38.4	20.0-56.7	
	Mean	6.60	0.28	0.74	13.11	33.9	27.5	38.1	

Table 2. Range and average values of initial micronutrients status of tested soil samples of Block R.S.Pura and Bishnah

Sr. No.	Micronutrients [$\mu g\ g^{-1}$]	Range	Average
1	Zn	0.18-0.62	0.33
2	Cu	0.85-4.99	2.43
3	Fe	15.53-80.65	46.84
4	Mn	5.26-64.88	22.47

38.4% (average 27.5%), and the sand ranged from 20.0 to 56.7% (average 38.1%). Considering textural classes, most of the sites were sandy clay loam and clay loam (Table 1).

Micronutrient status in soil

The available Zn, Cu, Fe and Mn as shown in Table 2, ranged from 0.18 to 0.62, 0.85 to 4.99, 15.53 to 80.65 and 5.26 to 64.88 with mean values of 0.33, 2.43, 46.84 and 22.47 $\mu g\ g^{-1}$, respectively. Considering the value of 0.60 $\mu g\ g^{-1}$ as the critical limits of DTPA extractable Zn, 95 per cent samples were deficient in available Zn (Takkar and Randhawa, 1978; Rai *et al*., 2014). All the soil samples were sufficient in available Cu, Fe and Mn as the values were above the critical limits of 0.40, 4.50 and 2.00$\mu g\ g^{-1}$ DTPA extractable Cu, Fe and Mn respectively, as suggested by Follet and Lindsay (1970).

Effect of submergence on pH

The initial pH of the soils ranged from 5.36 to 8.84 (average 6.60). After different days of submergence periods *viz*., 15, 30, 45, and 60 days, the pH range and average values changed from 6.83 to 7.77, 6.68 to 7.79, 6.65 to 7.78 and 6.64 to 7.68 with mean values of 7.38, 7.41, 7.41 and 7.35. The values of the soil samples are shown in the Table 3. The effect of submergence was manifested by increase of pH by about 1.81 units in acidic soils and on the contrary, it declined by 0.33 units in alkaline soils. In general, submergence caused the pH values of most acidic and alkaline soils to converge between 6 and 7, as described by Ponnamperuma (1972).

Effect of submergence in DTPA extractable Zn, Cu, Fe, and Mn

Both Zn and Cu decreased significantly after 15, 30, 45 and 60 days of submergence. The decrease continued up to 45 days and thereafter it remained almost constant. The initial mean value (0.33 $\mu g\ g^{-1}$) decreased to 0.23, 0.21, 0.15 and 0.17 $\mu g\ g^{-1}$ over days of corresponding submergence period. The highest decrease in available Zn (54.5%) was observed at 45 days of submergence. The results are in corroboration with the findings of Prasad *et al.* (1991). Similarly, mean value of Cu showed a decreasing trend up to 45 days and small increase thereafter. Similar findings have been reported by Singh and Nongkynrih (1999). There was up to 75% decrease in Cu availability after submergence (Table 4 and 5).

Table 3. Effect of submergence on soil pH

Locations	Days of submergence				
	0	15	30	45	60
1	5.41	6.83	6.68	6.65	6.64
2	7.02	7.37	7.46	7.42	7.44
3	7.69	7.47	7.60	7.68	7.60
4	6.08	7.77	7.79	7.78	7.66
5	7.32	7.46	7.51	7.59	7.51
6	7.35	7.18	7.15	7.14	7.14
7	7.33	7.43	7.34	7.30	7.28
8	5.59	7.61	7.44	7.58	7.49
9	5.36	7.40	7.51	7.51	7.50
10	5.45	7.21	7.26	7.21	7.20
11	5.72	7.07	7.17	7.16	7.10
12	7.59	7.36	7.51	7.42	7.32
13	8.03	7.73	7.78	7.70	7.68
14	7.04	7.77	7.50	7.55	7.61
15	8.84	7.51	7.59	7.46	7.42
16	5.49	7.44	7.44	7.40	7.37
17	6.14	7.57	7.72	7.68	7.60
18	5.41	7.29	7.45	7.46	7.30
19	6.07	6.93	7.08	7.20	7.02
20	7.08	7.12	7.26	7.33	7.18
Range	5.36-8.84	6.83-7.77	6.68-7.79	6.65-7.78	6.64-7.68
Mean	6.60	7.38	7.41	7.41	7.35

A reverse trend was observed with respect to Fe and Mn. Submergence increased DTPA extractable Fe with time. The initial mean value of 46.84 $\mu g\ g^{-1}$ increased to 74.66 $\mu g\ g^{-1}$ at 60 days after submergence. The highest increase in available Fe (65.28%) was observed at 30 days of submergence as compared to 60 days submergence. Similar findings were reported by Prasad et al 1991 in old alluvial rice soils of Bihar. Similarly, DTPA extractable Mn increased from an initial mean value (22.47$\mu g\ g^{-1}$) to 68.37 $\mu g\ g^{-1}$ after 60 days of submergence. The men magnitude of increase ranged from 202% to 251%. The increase in magnitude was highest (251%) up to 15 days of submergence which decreased thereafter up to 60

Table 4. Effect of Submergence on DTPA extractable Zn (μg g^{-1})

S. No.	Days of submergence 0	15	30	45	60
1	0.40	0.17	0.12	0.09	0.13
2	0.22	0.21	0.20	0.16	0.16
3	0.29	0.26	0.25	0.17	0.17
4	0.21	0.20	0.24	0.14	0.20
5	0.43	0.26	0.22	0.15	0.20
6	0.58	0.41	0.36	0.27	0.26
7	0.31	0.27	0.24	0.20	0.19
8	0.18	0.16	0.16	0.11	0.13
9	0.20	0.16	0.14	0.10	0.10
10	0.47	0.31	0.27	0.21	0.20
11	0.25	0.17	0.14	0.08	0.11
12	0.27	0.19	0.19	0.13	0.14
13	0.36	0.17	0.15	0.09	0.10
14	0.22	0.17	0.18	0.12	0.14
15	0.41	0.25	0.25	0.15	0.18
16	0.33	0.23	0.22	0.15	0.19
17	0.37	0.23	0.18	0.14	0.14
18	0.20	0.19	0.17	0.15	0.18
19	0.26	0.16	0.15	0.13	0.11
20	0.62	0.40	0.35	0.29	0.29
Range	0.18-0.62	0.16-0.41	0.12-0.36	0.08-0.29	0.10-0.29
Mean	0.33	0.23	0.21	0.15	0.17

Table 5. Effect of submergence on DTPA extractable Cu (μg g^{-1})

S. No.	Days of submergence 0	15	30	45	60
1	2.36	2.11	1.57	1.53	1.53
2	2.43	0.43	0.12	0.22	0.22
3	4.99	0.59	0.16	0.41	0.41
4	1.87	1.37	1.17	0.70	0.70
5	2.66	1.07	0.39	0.71	0.71
6	2.13	1.09	1.00	0.72	0.72
7	3.32	0.25	0.08	0.09	0.09
8	2.81	0.94	0.42	0.42	0.42
9	3.30	0.10	0.04	0.02	0.02
10	1.99	0.85	0.60	0.36	0.36
11	2.73	1.07	0.58	0.53	0.53
12	0.85	1.01	0.87	0.72	0.72
13	2.74	1.90	1.01	0.61	0.61
14	3.40	0.70	0.19	0.16	0.16
15	1.69	0.60	0.58	0.31	0.31
16	1.95	0.17	0.08	0.18	0.18
17	1.52	1.97	1.51	1.42	1.42
18	1.25	0.49	0.53	0.75	0.75
19	2.10	1.27	0.82	0.67	0.67
20	2.47	2.87	2.56	1.98	1.98
Range	0.85-4.99	0.10-2.87	0.04-2.56	0.02-1.98	0.05-2.40
Mean	2.43	1.04	0.71	0.62	0.82

days. This suggests that reduction of Fe and Mn were faster at the initial period of submergence as compared to later stages. Studies carried out by Prasad et al 1991 and Maji *et al* (1993) also reported augmentation of available Fe and Mn in rice soils of South Bihar and Wet Bengal (Table 6 and 7).

Relationship of physico-chemical properties and extractable Zn, Cu, Fe and Mn

The pH showed a positive but non significant correlation with Zn (r = 0.312) and Cu (r= 0.151) which explains an increase in pH associated with decrease in Zn and Cu content after submergence. However, highly significant coefficient was observed between pH and Fe (r= -0.924**) and between pH and Mn (r= -0.716**) which explains declined soil pH associated with increased availability of Fe and Mn. Similar observations have been reported in some benchmark soils of Kashmir by Jalali *et al* (1989). Similarly different soil properties showed varied relation with the availability of micronutrients in the soils under study.

The multiple regression analysis recorded 46.75% variation in DTPA extractable Zn

Table 6. Effect of submergence on DTPA extractable Fe (μg g^{-1})

S. No.	Days of submergence 0	15	30	45	60
1	75.85	80.0	80.8	81.3	78.7
2	29.00	77.9	77.8	78.5	80.9
3	22.63	78.4	78.1	80.7	80.7
4	57.06	80.0	82.2	80.3	79.9
5	24.32	80.0	82.9	78.4	79.0
6	37.35	79.3	83.0	80.9	66.9
7	37.99	74.9	80.3	76.9	77.6
8	79.16	74.9	79.8	76.7	76.4
9	80.65	74.9	78.8	77.4	76.7
10	66.94	78.4	82.0	80.0	79.5
11	71.96	77.6	82.1	79.1	80.0
12	17.14	33.3	43.3	42.3	46.8
13	15.53	66.9	77.8	72.0	76.3
14	40.11	77.8	83.6	78.6	77.9
15	19.41	77.5	77.2	78.5	77.0
16	51.03	73.9	82.7	77.5	76.6
17	55.31	74.6	68.7	70.1	65.5
18	69.78	73.3	84.3	81.1	80.4
19	49.79	78.5	84.5	81.2	81.4
20	35.78	63.5	58.5	65.6	55.0
Range	15.53-80.65	33.3-80.0	43.3-84.5	42.3-81.3	46.8-81.4
Mean	46.84	73.78	77.42	75.86	74.66

Table 7. Effect of Submergence on DTPA extractable Mn (μg g^{-1})

S. No.	Days of submergence 0	15	30	45	60
1	14.63	46.34	42.94	39.13	34.19
2	12.80	81.79	70.85	68.95	68.74
3	9.12	67.81	58.81	54.74	60.30
4	12.72	61.30	56.34	51.81	53.15
5	7.66	82.68	68.59	65.11	69.37
6	10.74	78.93	69.08	65.02	61.38
7	12.87	90.38	81.76	80.23	81.26
8	49.78	90.28	82.61	81.40	81.48
9	64.88	89.25	82.25	82.35	81.73
10	36.37	89.37	82.37	80.87	81.13
11	41.44	89.8	81.54	80.52	81.20
12	6.44	60.75	61.30	48.68	38.59
13	6.18	87.33	75.56	72.13	75.60
14	19.13	90.00	82.64	82.13	81.91
15	5.26	79.77	73.17	63.27	68.36
16	55.82	88.64	82.49	81.96	81.56
17	24.87	75.59	71.92	70.26	87.20
18	15.47	52.34	41.06	39.16	40.24
19	22.36	86.70	70.39	70.23	72.79
20	20.88	90.22	82.63	79.40	67.26
Range	5.26-64.88	46.34-90.38	41.06-82.64	39.13-82.35	34.19-87.20
Mean	22.47	78.96	70.92	67.87	68.37

contributed by CEC, Clay, EC and pH of the soil. The contribution of sand, OC, CEC, pH, clay, EC and slit was 66.7% to the availability of Cu. Similarly, Fe was contributed by pH, OC, CEC, clay, EC, Sand and silt upto 91% whereas these properties except OC contributed 83% to Mn.

It may be concluded from the above results that 95% representative soils of basmati grown area were severely deficient in Zn and that submergence further aggravated the deficiency. Therefore there is utmost need to exercise regular supplementation of Zn through fertilizer management of basmati growing soils of Jammu district to obtain maximum production and productivity so that soil does not become severely deficient in micronutrient zinc. Further management of Fe and Mn is also required to be taken care of in these submerged soils so that levels of these micronutrients remain below toxic levels.

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Potential climate change impacts on surface water resources of Gomti River basin in India

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ABSTRACT

The impacts of climate change on surface water resources (SWRs) in Gomti River basin (India) were investigated by integrating a widely used hydrological model, Soil and Water Assessment Tool (SWAT) and MIROC (HiRes) GCM climate change projections. The SWAT model was calibrated and validated using monthly streamflow data of four spatially distributed gauging stations. Climate change scenarios were developed for A2, A1b and B1 emission scenarios for three future periods 2020s (2010–2039), 2050s (2040–2069) and 2080s (2070–2099). Mean annual rainfall were projected to increase by 10 to 18%, 15 to 47%, and 20 to 30% during the 2020s, 2050s and 2080s, respectively, and the associated SWRs of the basin in annual scale were also likely to increase by 7 to 29%, 17 to 35%, and 35 to 46% during the 2020s, 2050s and 2080s, respectively, compared to present day climate depending upon the emission scenarios. Simulation results also revealed greater changes in rainfall, and SWRs in the upstream sub-basin as compared to the downstream sub-basin.

Key words: Climate change, Gomti River basin, MIROC, Streamflow, Surface water resources, SWAT

INTRODUCTION

Availability of freshwater in India is fundamental to economic growth and social development as India is a large developing country with nearly two-thirds of the population depending directly on agriculture, which is highly climate sensitive. Any temporal and spatial variations in rainfall have reflective effect on water availability in both irrigated and rainfed areas, affecting the agriculture based economy of the region (Islam *et al*., 2011).The climate projections over India indicate that temperature rise is likely to be around 3 °C and rainfall increase is expected in the range of 10 – 20 % over central India by the end of this century (IPCC, 2007; Narsimlu *et al*., 2013). Such a change in temperature and rainfall would affect water availability for the different water sectors, particularly, agriculture with serious implications for livelihoods security. Therefore, estimation of spatial and temporal variability in water resources availability in the river basin or sub river basin scale is vital so as to prepare suitable location specific adaptation plans.

The most common method for assessing the magnitude of this impact is to run a hydrological model driven by various climate projections from general circulation models (GCMs, i.e. global-scale climate models) as input forcing data. IPCC published a set of emissions scenarios in the Special Report on Emissions Scenarios (SRES) (Nakicenovic *et al*., 2000) to serve as the basis for assessment of future climate change. Among all the SRES scenarios, most global climate modelling groups generally employ A2, A1b and B1 Green house Gas (GHG) emission scenarios representing high, medium and low emission scenarios respectively. In this study attempt has been made to assess the climate change impacts on surface water resources of the Gomti River basin, located in north India, using Soil and Water Assessment Tool – SWAT and MIROC (HiRes) GCM projected climate change scenarios for three different emission scenarios (i.e., A1b, A2 and B1).

SWAT is a commonly used semi distributed hydrological model for different water resource application including climate change analysis. Application of SWAT to Indian River basins is not scare (Raneesh and Santosh, 2011; Bharati *et al*., 2011; Gosain *et al*., 2011; Singh and Gosain, 2012;Narsimlu *et al*., 2013). However, it is rare to find published literature on the application of SWAT model to assess surface water resources in Indian River basins. This study evaluate climate

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change impacts on the surface water resources of Gomti river basin using SWAT model.

MATERIALS AND METHODS

Description of the study area

The Gomti River basin lies mainly in the Uttar Pradesh (UP) state in north India, and its area is estimated to be 30,437 km^2 (Dutta *et al.*, 2011). The topography of the basin is undulating, and the elevation ranges from 238m at origin to 58m at downstream (Fig. 1). The climate is semi-arid to sub-humid tropical with average annual rainfall varying between 850 and 1100 mm. The Gomti River originates from a lake '*Fulhaar Jheel*',about 3 km east of Pilibhit town and about 50 km south of the Himalayan foot-hills. This river is one of the important tributaries of the Ganga River and it meets it at Kaithi in Varanasi (UP) after flowing 960 km in south, south-east direction. The basin is intensively cultivated with rice-wheat being the dominant cropping system.

Modelling Tool

The SWAT is classified as a physically based basin-scale, continuous time and semi- distributed hydrologic model. The SWAT model has the capability to simulate hydrology, nutrients and pesticides dynamics and land management as well as plant growth on a daily time step (Neitsch *et al.*, 2011). It is also considered as one of the promising models for long-term simulations in predominantly agricultural watersheds. In SWAT, the watershed is divided into a large number of sub-watersheds that are then subdivided into hydrologic response units (HRUs) based on unique soil, land-use and slope characteristics which allow a high level of spatial detail simulation. The model simulates the hydrology at each HRU using the water balance equation. In present study, we used the latest version of SWAT (SWAT-2012.10_1.14), within ArcGIS (ver.10.1) interface.The SWAT model provides different methods to estimate surface runoff, evapotranspiration and channel routing. The present study used the SCS curve number procedure, the Penman–Monteith method, and variable storage coefficient methodfor the estimation of runoff, evapotranspiration and channel routing respectively. Actual evapotranspiration in the SWAT model was estimated based on methodology developed by Ritchie, 1972 (Neitsch *et al.*, 2011).

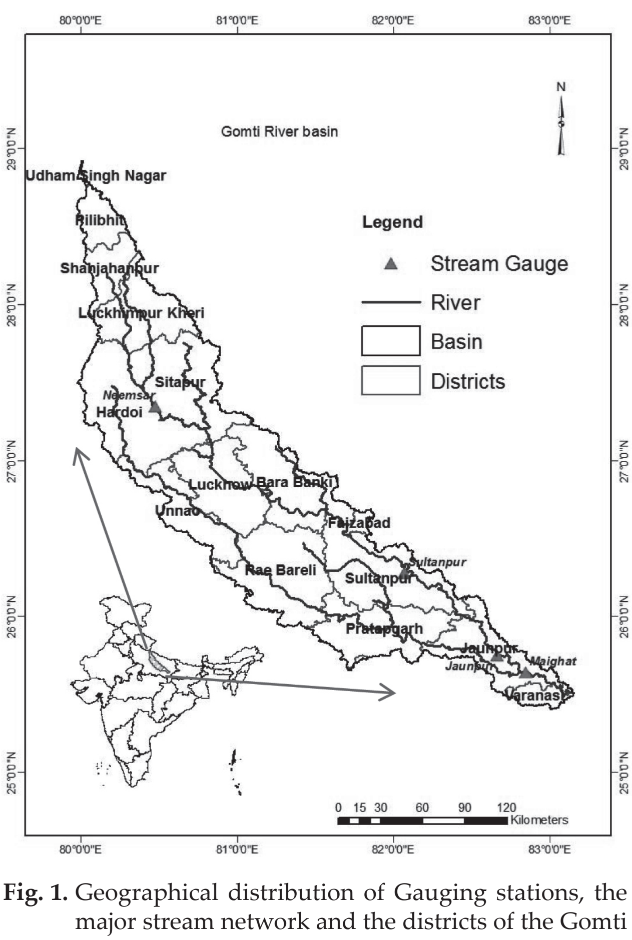


Fig. 1. Geographical distribution of Gauging stations, the major stream network and the districts of the Gomti River basin of India

SWAT Model Set-Up

For the SWAT simulation, the basin, sub basins and stream network were delineated from the 90 x 90 m resolution SRTM (Shuttle Radar Topography Mission) Digital Elevation Model (DEM) (http://gisdata.usgs.gov/website/Hydro- SHEDS/). Gomti River basin was sub divided into 21 sub – basins at the SWAT watershed delineation process and sub basin discretization. It was further divided into 296 Hydrological Response Units (HRUs) at HRU definition and analysis process. The SWAT model requires inputs on weather, topography, soils, land cover and land management. The land-cover map (56 x 56 m resolution) of the study area was obtained from International Water Management Institute. The predominant land use in this basin was agriculture and 59% of the area occupy irrigated conjunctive use double cropping (SWAT model class, R-08), and 32 % area was under irrigated surface water, double cropping (R-02) (Fig.2). The soil types of the study area were extracted from a soil map (78 x 78 m resolution) of the Ganga River basin (http://gisserver.civil.iitd.ac.in/grbmp/iitd.htm) which has been digitized from the soil map of National Bureau of Soil Survey and Land Use Planning (NBSSLUP), Indian Council of Agricultural Research (ICAR), Government of

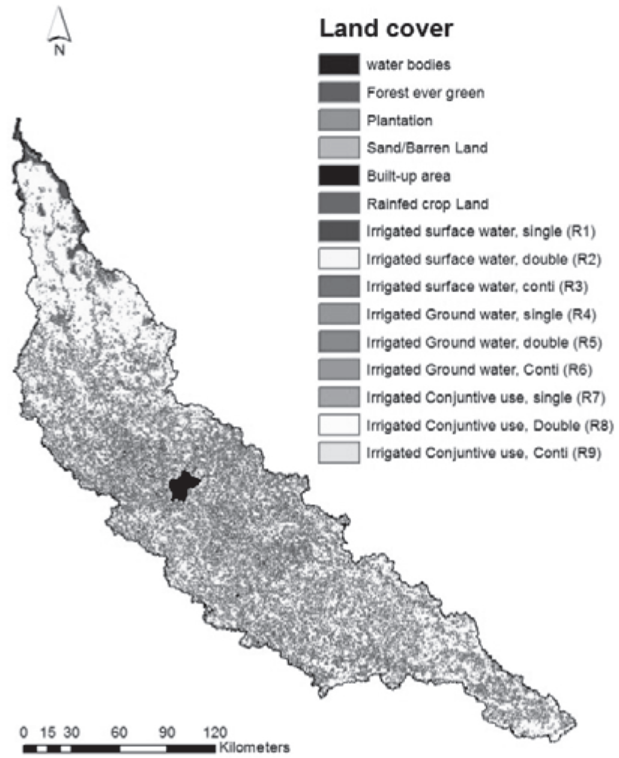


Fig. 2. Land cover map of Gomti River basin

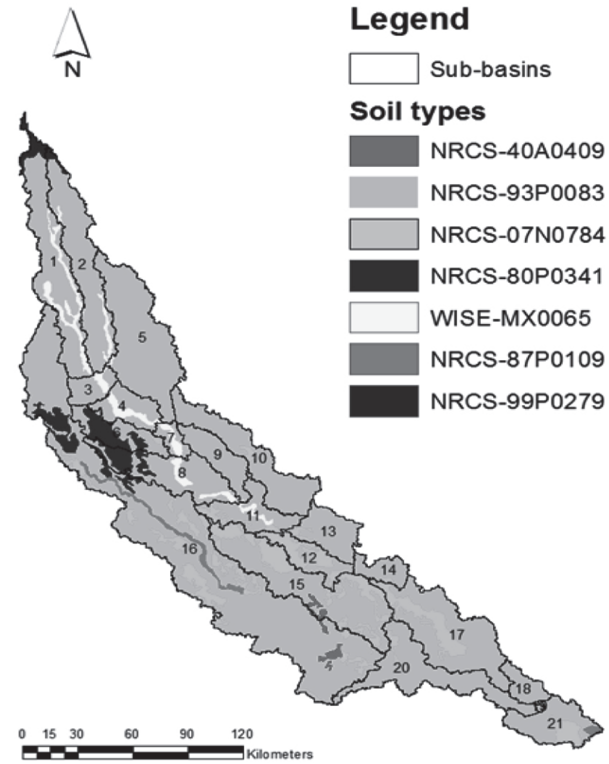


Fig. 3. Soil types and sub basins map of Gomti River basin (sub basins 1 – 21)

India (Fig. 3). Soils of the area were predominantly alluvial, deep soil. Soil properties have also been taken from the same NBSSLUPsoil map.

Climate data required by the model are daily precipitation, maximum and minimum air temperature, solar radiation, wind speed, and relative humidity. In this study, the historical daily precipitation and air temperatures of different districts covering the entire basin for the period 1982–2010 were obtained from the National Initiative on Climate Resilient Agriculture (NICRA) project web portal. Daily values of solar radiation, wind speed, and relative humidity were generated internally using the WXGEN weather generator (Sharpley and Williams, 1990) in the SWAT. The monthly climatic statistical information for driving the weather generator was developed for the basin based on long-term weather records of NICRA, India Meteorological Department data at Lucknow (1972 – 2011), Sultanpur (1972 – 2011) and Jaunpur (1972- 1980) weather station.

In order to improve the simulation of hydrology of the basin, we assigned crops to land use categories (Fig.2) considering the cropping pattern of Uttar Pradesh (UP) assessed using IRS-P6 (AWiFS) data (Singh *et al.*, 2011). They showed the order of the cropping pattern in UP in terms of areaas: rice-wheat > sugarcane > rice-pulses > sugarcane-wheat etc. Thus, rice-wheat is the major cropping sequence in the study area. Therefore, we considered the landuse category, 'irrigated conjunctive use double cropping' (R-08) as the irrigated rice and wheat grown area of the basin. 'Irrigated surface water, double cropping' (R-02) landuse category was considered as rice and pulses growing area; and sugarcane crop growing area was assigned to landuse category 'Irrigated surface water continuous' (R-03) land use type. R-08, R-02, and R-03 occupy 59.58, 32.45, and 1.38% area of the basin respectively. The management inputs on planting, harvesting and irrigation of individual crops were obtained from the available literature pertaining to the area (Hobbs *et al.*, 1991; Gangwar and Singh, 2011). Considerable part of the Gomti River basin is supplied with canal water from Sharda Sahayak canal system. Therefore, water source for the simulation of the rice, pulses, and sugarcane was considered as canal water in HRUs where canal is located, and SWAT recognized the source as outside unlimited source. For the other areas where canal is not located, source of irrigation was considered as shallow aquifer located in the same sub-basin for rice. For the irrigation of wheat, source of irrigation water was considered as shallow aquifer located in the same sub-basin where wheat is grown. Auto irrigation option was used to irrigate the crops and plant water demand was set as a water stress identifier, and water stress threshold that triggers irrigation was set as 0.9 in the model initially. We selected automatic fertilization option for fertilizing the crops simulated in this study because of the difficulty in obtaining fertilizer schedules for each crop at each HRUs.

Paddy fields in SWAT are treated as a pothole, like an impounded or depression area. The water balance component in pothole contains precipitation, irrigation, surface runoff concentration, evaporation, seepage and outflow (Neitsch *et al*., 2011). Impound operation was given before planting and release operation was given 5 days before harvesting paddy for each rice growing HRUs. Maximum volume of water stored in pothole was fixed to 60 mm and the fraction of area that drains to pothole was initially set as 0.8. Moreover, at the initial stage of the modelling, initial Leaf Area Index (LAI) and biomass of rice were set as 1.1 and 800 kg/ha, respectively, as rice is mostly a transplanted crop (Kaur *et al.*, 2003). However, these values were lowered to 0.9 to 1 and 700 to 780 kg/ha respectively while calibrating the rice crop. As the main objective of this paper is to assess the climate change impacts on water resources in the basin, detailed description on calibration and validation of crops and also climate change impacts on crop production in the basin are not presented in this paper.

Streamflow Calibration and Validation

The SWAT model was parameterized for stream flow at four spatially distributed CWC gauge stations (GS) of Neemsar, Sultanpur, Jaunpur and Maighat using their observed monthly average stream flow data (Fig.1). The SWAT simulations of initial three years period (1982-1985) were used only to stabilize the initial conditions of the model.Depending on the observed data records, model at Neemsar GS was calibrated using data of 1990-2000 and validated using data of 2001-2010. At Sultanpur and Jaunpur GSs, the model was calibrated using data of1985-2000period. It was validated using 2001-2010 data at Sultanpur and 2001-2008 at Jaunpur. At Maighat GS, the model was calibrated using1985-1994 data and validated using 1995-2003 data. Before, undertaking calibration and validation, model sensitivity analysis was also performed. Most sensitive parameters were then calibrated manually considering their limits and using SWAT CHECK module. The study used statistical parameters of Nash-Sutcliffe efficiency (NSE),RMSE-observations standard deviation ratio (RSR), Percent bias (PBIAS) and Coefficient of determination (R^2), to compare the simulated and observed streamflow.

Climate Change Scenario Generation

The Coupled Model Inter comparison Project Phase 3 (CMIP3) climate projections (monthly rainfall and temperature) of the Model of Interdisciplinary Research on Climate (MIROC) were used in this study to develop climate change scenarios. The MIROC3.2 model, developed at the National Institute for Environmental Studies of Japan, has two MIROC3.2 setups of different resolutions. The higher resolution (1.1° × 1.1°) setup is referred to as HI (HiRes), and the lower resolution (2.8° × 2.8°) setup is referred to as MID (medres).In this study, we used MIROC 3.2 (HiRes) projected monthly rainfall and temperature data for high (A2), mid-range (A1b) and low (B1) emission scenarios. We used perturbation (or delta change) method for generating climate change scenarios for the future periods of 2020s (2010–2039), 2050s (2040–2069) and 2080s (2070–2099). It is the most commonly used approach for generating future climate scenarios in climate change impact assessment studies (Sunyer *et al*., 2010; Khoi and Suetsugi, 2012). These perturbed rainfall and temperature data for the 12 stations, which were used as climatic station in the basin, were input to the calibrated and validated SWAT model and model was run for each of the emission scenarios and for each of the time periods, and subsequently results were analysed for each scenarios and time periods separately.

RESULTS AND DISCUSSION

Streamflow Calibration and Validation

In order to identify the most sensitive model parameters and to reduce the number of parameters in calibration, sensitivity analysis was performed for each of the four sub-catchment area using SUFI 2 in SWAT CUP 2012. Considering the literature review (e.g., van Griensven and Meixner, 2006; Tattari *et al*., 2009), 17 hydrological parameters were focused on the sensitivity analysis for the simulation of stream flow in the study area. Out of 17 hydrological parameters, 14 were identified as the most sensitive for all the four gauging stations. The lists of most sensitive flow parameters and their ûtted values at the calibration are shown in Table 1.Calibration and validation performance indicators for these four GS are presented in Table 2. During calibration period, the performance

Table 1. Calibrated values of sensitive hydrologic parameters of the SWAT model at four gauging stations in the Gomti River basin

Sensitivity rank	Parameter	Parameter description	Neemsar	Sultanpur	Jaunpur	Maighat	Absolute SWAT ranges
1	ALPHA_BF (days)	Base ûow alpha factor(days)	0.15 – 0.18	0.15 – 0.16	0.25	0.16 - 0.3	0 – 1
2	SOL_AWC (mm/mm)	Available water capacity (mm/mm)	0.1 – 0.25 *	0.18 - 0.37	0.20 - 0.24	0.20 - 0.24	0 -1
3	EPCO	Plant uptake compensation factor	0.95 – 0.98	0.6 – 0.7	0.8	0.8 - 0.9	0 - 1
4	GW_DELAY (days)	Delay of time for aquifer recharge (days)	70 - 80	50 - 70	80	60 - 70	0 – 500
5	RCHRG_Dp	Aquifer percolation coefficient	0.1 – 0.4	0.1 – 0.15	0.04	0.05 – 0.2	0 – 1
6	GW_REVAP	Groundwater 'revap' coefûcient	0.02	0.02	0.02	0.02	0.02 – 0.2
7	ESCO	Soil evaporation compensation factor	0.2	0.2 – 0.4	0.7	0.7	0 -1
8	CN2	Curve number	FRSE: 80, R02: 70, R08: 70	FRSE: 80, R02: 72, R08: 72, URBN- 85R03: 60	R02: 75 R08: 75	R02: 72-75, R08: 72-75	35 -98
9	GWQMIN (mm)	Threshold water depth in the shallow aquifer for ûow	0	0	0	0	0 – 5000
10	REVAPMIN (mm)	Threshold water level in shallow aquifer for revap	420	300 - 450	350	350 - 420	0 – 500
11	SOL_K (mm/hr)	Saturated hydraulic conductivity (mm/hr)	3.9 - 8	3.9 - 24.14	3.9 - 24	3.9 – 24	0 -2000
12	OV_N	Manning's "n" value for overland flow	0.6	0.1	0.14	0.14	0.01 -30
13	CANMAX (mm)	Maximum canopy storage	FRSE : 1.5	FRSE : 1.5R03: 1.1	-	-	0 – 100
14	CH_K2 (mm/hr)	Channel effective hydraulic conductivity	5.5	6.3	5.5 - 0.6	5.5 - 0.6	-0.01 - 500

*Range indicates values for different HRUs and depths.

Note [R-08: Irrigated conjunctive use double cropping areas , R-02: Irrigated surface water, double cropping areas, R03: Irrigated continuous cropping, FRSE : Forested area, URBN: Built-up area]

Table 2. Model calibration and validation performance statistics for monthly streamflows at the four gauging stations

	Calibration				Validation			
	NSE	RSR	PBIAS(%)	R^2	NSE	RSR	PBIAS (%)	R^2
Neemsar	0.72	0.52	3.2	0.74	0.71	0.54	-2.0	0.73
Sultanpur	0.61	0.60	16.0	0.67	0.63	0.60	- 0.81	0.69
Jaunpur	0.57	0.65	15.0	0.60	0.54	0.68	- 6.0	0.65
Maighat	0.58	0.64	17.0	0.60	0.66	0.57	4.0	0.68

indicators NSE, RSR, PBIAS, and R^2 values were in the range of 0.57 to 0.72, 0.52 to 0.65, 3.2 to 17 and 0.6 to 0.74 respectively. During validation period, the same indicators values ranged from 0.54 to 0.71, 0.54 to 0.68, - to 4, and 0.65 to 0.73 respectively (Table 2). According to the performance rating suggested by Moriasi *et al*. (2007), model performance was good during both calibration and validation phase for the upper most GS Neemsar, whereas, the model performance was satisfactory at other three GSs both during calibration and validation periods. Meanwhile, Parajuli (2010) suggested that model performance for monthly streamflow can be categorized into six classes according to a threshold R^2 value: excellent (e"0.90), very good (0.75–0.89), good (0.50–0.74), fair (0.25–0.49), poor (0–0.24), and unsatisfactory (<0). Based on these criteria, SWAT performed reasonably good in simulating the streamflow for the entire Gomti basin, with R^2 values e"0.6 for all most all the gauging stations during calibration and validation.

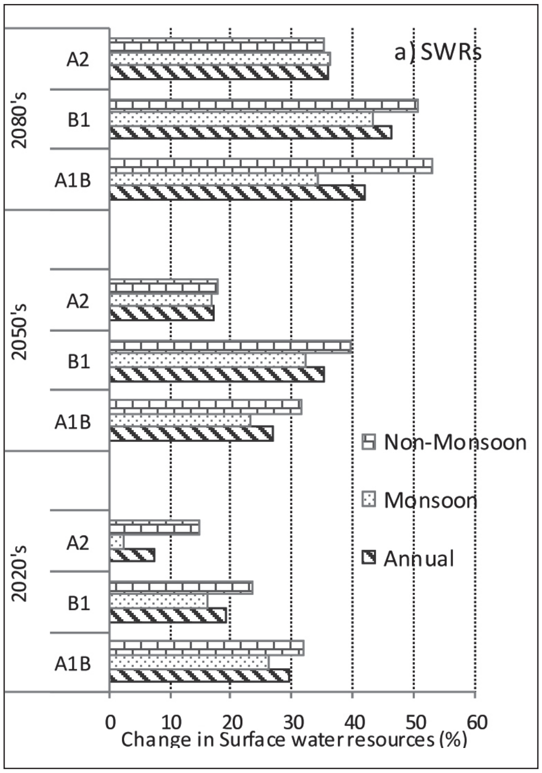
Sensitivity of Surface Water Resources to Climate Change

In this study, we considered the surface water resources (SWR) as the water flow contribution from sub basins to generate streamflow (Sun and Ren, 2013). The Water yield (WYLD) in the SWAT model is defined as the summation of the surface water flow (Qsurf), lateral flow contribution to streamflow (Qlat) and the water that returns to the stream from the shallow aquifer also known as groundwater contribution (Qgw) minus the total loss of water from the tributary channels as a transmission loss through the bed and finally reach the shallow aquifer as recharge (Arnold *et al*., 2012). Since there were no considerable surface water reservoirs in the basin, we considered WYLD in each sub basins as SWRs. We considered sub basins having min elevation > 105 m as upstream basins and rest of the sub basin as downstream sub basins for the analysis of future SWRs. Further SWRs were analysed on annual, monsoonal and non-monsoon seasonal scale.

According to SWAT simulation, average annual SWRs during base line period at upstream area was 283 mm per unit area of the basin with a CV of 38% whereas downstream area it was found to be 272 mm with a CV of 40 % per unit area of the basin. Moreover, mean SWRs during the monsoon season at upstream was 165mm per unit area (CV =50%) while it was 155 mm (CV = 50 %) at the downstream basin per unit area. However, mean SWRs during the non monsoon period was 117 mm (CV = 45%) per unit area of the entire river basin during the baseline period.

We analysed the future SWRs and rainfall and their association on the basis of upstream sub basins (sub basin under min elevation >105 m) and downstream sub basins (sub basin under min elevation <105 m) separately based on MIROC 3.2 future projected rainfall and temperature changes. Entire basin would experience increase in rainfall and SWRs under all the three emission scenarios. Figure 4,b and 5,b, show the percent changes of future rainfall over the base line period as a result of MIROC3.2 projections and SWAT simulation under different climate change scenarios. Mean annual rainfall at upstream area is likely to increase by 11 to 20%, 16 to 24%, and 11 to 29% during the 2020s, 2050s, and 2080s (Fig.4,b) and SWR at upstream sub basins also would increase by 7 to 29%, 17 to 26% and 35 to 46%, during the same future periods (Fig. 4, a). Similarly, mean annual rainfall at downstream area varied from 9 to 17 %, 15 to 74 %, and 23 to 32 % during the 2020s, 2050s, and 2080s respectively (Fig. 5, b). Change in SWRs at downstream sub-basins varied in the range of 7 to 28 %, 18 to 92 %, 34 to 56 % during the 2020s, 2050s, and 2080s respectively (Fig. 5, a). However, CV of change in rainfall is about 23 % in upstream basins and 18 % in downstream basins whereas CV of change in SWRs at upstream basins is about 40 % and it is 35 % at downstream sub- basins. It infers that variability of both rainfall and SWRs at upstream is higher than that of the downstream.

As such, slight rising trend of annual SWRs were projected for the entire Gomti River basin



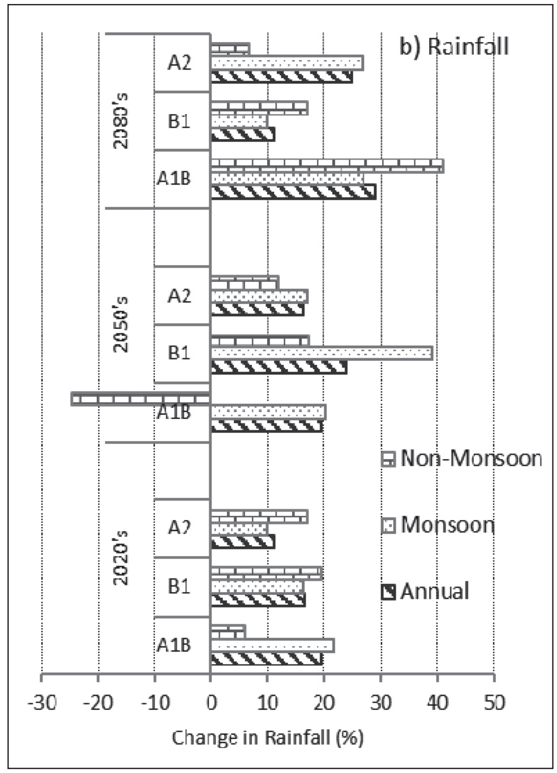


Fig. 4. Change in a) surface water resources and b) rainfall under different climate change senarios over the base line period at upstream area of the Gomti River basin

towards the end of the 21 century. Mean monsoonal change of rainfall is approximately consistent with the mean annual changes of rainfall. This pattern is also followed by the SWRs of the river basin. This is because more than 80% of the rainfall is received during the monsoon period in this basin. Both the changes of rainfall and SWRs during the non monsoon period are different from those of annual and monsoonal scale changes. As shown in Fig. 4,b, A1b scenario showed a decrease in rainfall during this period. However, SWRs during this period also projected to increase as simulated by SWAT even under A1b scenarios (Fig. 4,a), because of flow contribution from subsurface flow. Percent changes of SWRs during the non-monsoonal were considerably higher than annual and monsoonal changes. One reason is that the SWRs in the non-monsoon season are more sensitive to the denominator when computing the relative change than the SWR value in the wet season. Changes in SWRs are lesser under A2 emission scenarios as compared to that of the A1b and B1 emission scenarios. It may be because of A2 emission scenario projects more warming of the atmosphere, and relatively lesser increase (/change) in rainfall particularly during 2020s and 2050s (Fig. 4,b). Though our study indicates, increase in SWR , the previous study conducted by Gosain *et al*. (2011) projected a 0.5 % decrease in water yield during mid-century and 27% increase at the end of the century for the entire Ganga river basin using the PRECIS RCM A1b projected climate change scenario. Their study also showed 2.5% and 23 % increase in rainfall during mid-century and end century, respectively. Gomti River is one of the tributaries of Ganga River, but, our simulations based on SWAT and MIROC projections did not project a decrease in water yield in annual or seasonal scale. Though both the study used the same hydrological model SWAT, but this difference may be due to the difference in climate change projections used.

However, monthly analysis of projected changes in rainfall showed decrease in mean monthly rainfall in December, February, March, and April months under the A1b and B1 emission scenarios. Relative variation of rainfall in all months both at upstream and downstream of the basin are shown in Table 3 and 4. Maximum decrease was in December month both in upstream and downstream, followed by March, February and April. The decrease in mean rainfall during December month varied from 12 to 35%, 1 to 15%, and 26 to 34% during the 2020s, 2050s and 2080s, at upstream sub-basins; whereas at the downstream sub-basins, it varied from 7 to 40%, 1 to 29%, and

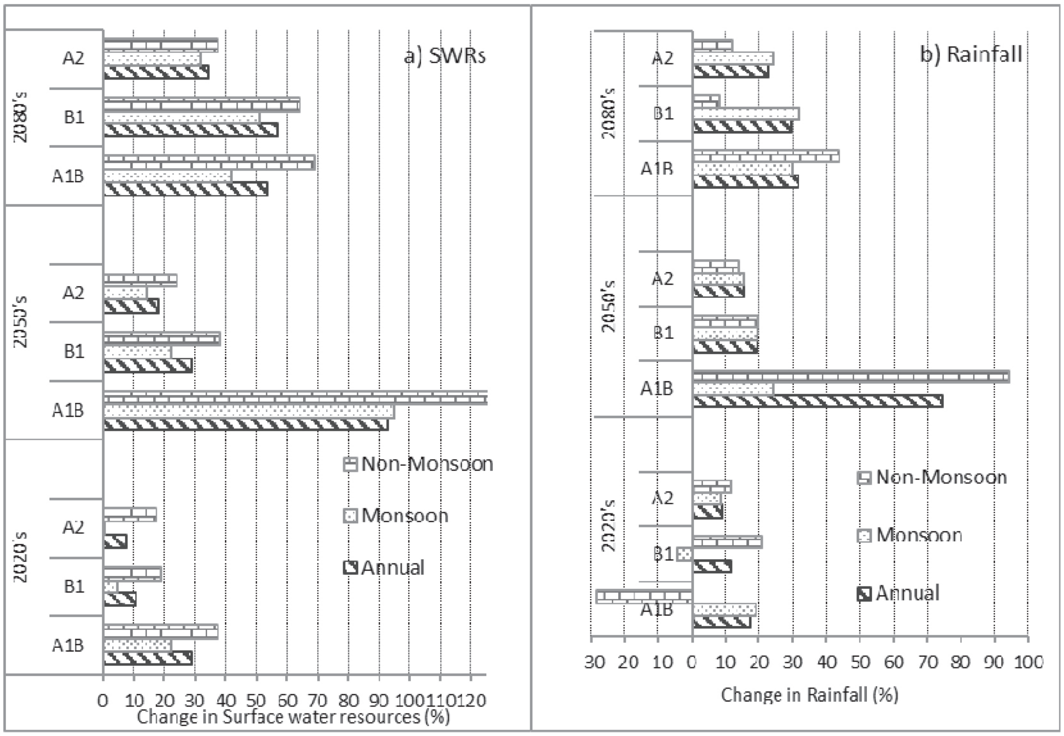


Fig. 5. Change in a) surface water resources b) rainfall under different climate change senarios over the baseline period at downstream basins in the Gomti River basin (Non monsoon, A1B value = 378%)

Table 3. Mean monthly changes of rainfall (%) over three emission scenarios during 2020s, 2050s, and 2080s at upstream of Gomti River basin

Future period	Scenario	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2020s	A1B	8.07	-31.01	-38.61	-2.63	69.31	35.21	18.94	9.93	32.54	-3.84	37.82	-35.33
	B1	24.38	-25.08	18.98	-30.63	76.09	48.03	12.36	3.60	18.07	20.39	-7.53	-11.92
	A2	2.18	3.71	-34.67	-11.62	92.36	24.23	10.51	-11.09	28.17	3.24	-1.45	-22.72
2050s	A1B	-8.43	-18.74	-26.94	-2.61	75.61	42.22	14.92	4.98	33.95	10.25	7.42	-1.32
	B1	7.46	-15.92	11.84	11.08	21.60	52.29	24.18	7.20	29.31	43.54	-6.06	2.79
	A2	15.83	-0.90	-7.37	15.20	71.55	63.21	16.68	-6.64	20.07	-11.44	-64.08	-15.84
2080s	A1B	3.51	-12.14	-44.40	-43.20	91.09	52.70	21.29	8.11	44.83	95.88	14.63	-26.31
	B1	15.87	-4.05	-21.18	-44.65	19.00	27.38	31.79	25.70	37.31	27.12	-51.79	-34.03
	A2	7.54	2.54	-12.15	9.19	17.10	59.52	31.36	5.61	31.42	14.03	14.71	-28.60

Table 4. Mean monthly changes of rainfall (%) over three emission scenarios during 2020s, 2050s, and 2080s at downstream of Gomti River basin

Future period	Scenario	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2020s	A1B	7.69	-41.92	-36.59	7.71	75.85	34.59	13.38	8.98	31.96	-1.59	33.45	-39.69
	B1	16.16	-27.84	12.25	-23.94	86.84	36.04	4.07	2.63	13.52	17.60	28.35	-7.24
	A2	-6.00	-7.41	-31.91	-0.39	89.24	20.39	9.30	-13.43	31.01	6.36	-32.95	-31.76
2050s	A1B	-11.85	-34.49	-55.91	205.32	255.54	40.73	16.23	7.83	46.01	23.93	61.11	-0.84
	B1	9.03	-23.85	-3.17	17.09	35.50	40.41	19.86	3.36	28.90	34.92	11.05	18.81
	A2	27.84	-3.34	-18.38	17.26	76.96	49.63	12.63	-1.75	23.01	4.42	-40.23	-29.41
2080s	A1B	3.83	-24.61	-32.22	-44.36	111.74	48.45	20.93	14.90	51.06	80.82	46.50	-16.57
	B1	16.37	-20.31	-18.48	-35.15	22.14	20.85	39.43	30.06	33.07	33.19	-42.61	-29.43
	A2	4.97	3.89	-16.03	3.14	22.23	50.41	31.15	8.35	21.33	27.44	44.43	-33.95

16 to 29%. This temporal and spatial variation in rainfall would affect the seasonal water resources availability in the different sub-basins, and would affect the rainfed winter crops in the basin.

Limitation

The simulated changes in SWRs for the future are based on the use of the same land use land cover and soil properties as at present. In addition, future developmental projects of irrigation and power etc. and probable increase of water abstractions were also not considered in this study. This assumption may have overestimated the SWRs for the future. Therefore, projected results must be viewed under the assumptions of static landuse condition. Thus, in future studies for better estimation of changes in water resources availability in the basin the above mentioned limitations need to be considered along with considerations of multiple hydrological models and GCMs to address the uncertainty associated with the hydrological model and GCM outputs.

CONCLUSIONS

This study evaluated the future potential climate change impacts on SWRs of the Gomti River basin in India using SWAT hydrological model and MIROC3.2 (HiRes) GCM climate projections for three different emission scenarios. Delta change method were used for generating rainfall and temperature change scenarios, for the 12 stations in the Gomti River basin, for the future periods of 2020s, 2050s and 2080s. The SWAT model was found to perform reasonably well during the calibration and validation periods for the Gomti River basin. This modelling study revealed that the average annual SWRs may increase considerably in future periods. Concerning the entire river basin, mean annual rainfall were projected to increase by 10 to 18%, 15 to 47% and 20 to 30% during the time period 2020s, 2050s and 2080s, respectively, and SWRs of the basin in annual scale were also likely to increase by 7 to 29%, 17 to 35%, and 35 to 46% during the 2020s, 2050s and 2080s respectively compared to present day climate. The present study also revealed that at the upstream sub-basin changes of rainfall and associated changes of SWRs were greater than the respective changes of downstream area of the basin, particularly concerning annual and monsoonal changes.

This study did not consider the possible changes of landuse and land cover, changes of future water abstraction, changes of other climatic parameters other than temperature and rainfall. It should also be noted that the future SWRs cannot be predicted exactly owing to uncertainty in the GCM outputs in climate change scenarios. There is therefore a need in the future to evaluate the uncertainty in the climate change impacts including the possible future land use changes and water abstractions on streamflow in this basin. However, the results obtained in this study could be useful for planning and managing water resources in Gomti River basin through enhanced the understanding of the impact of various climate change scenarios on SWRs.

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Precise farming and monitoring of agriculture through drone

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ABSTRACT

With the advent of drones, monitoring of farming has become easier and cost effective. The Unmanned aerial vehicles (UAVs), or drones have become a popular technology for the application of amounts of inputs like water, fertilizers, pesticides etc. at the correct time to the crop for increasing its productivity and maximizing its yields. Global Positioning System (GPS) technology is extensively used in precision agriculture. Drones are now a leading technology in agriculture which is set to invade agricultural world. The miniature unmanned aircrafts can be piloted by remote control from the ground by the operator via a computer program and can reach speeds of up to 50 km/h. These machines have a battery life of anywhere between 15 to 25 minutes of flight time and can reach ranges of as far as a kilometer away from the operator. Drone helps to keep a track on crop position, control farm subsidies, detect pests, monitor nutritional and water stress on the crops, and they can even spray fertilizer and pesticides on the crops from above. The use of this 21st century technology for the sake of agriculture is commendable and it will directly help farmers in the long run. We might find a lot of drones flying over the agricultural fields in the coming future and it will also double as a scarecrow.

Key words: Precision farming, Global positioning system, Kisan drone, Environmental monitoring, Water management, Forestry mapping

INTRODUCTION

India is characterized by small farms. More than 80% of total land holdings in the country are less than 2 ha (5 acres). Most of the crops are dependent on rain and only about 45% of the land is irrigated. According to an estimates, around 55% of total population of India depends on farming. Because of poor availability of funds, farm inputs, poor support price structure for the produce and almost no farm insurance, most of the farming is non-remunerative and more than 50% of the farmers in India always remains in debt. This is the main reason for a large number of farmer suicides. Precision agriculture is a boon to overcome such issues to some extent.

Precision agriculture as the name implies, refers to the application of precise and correct amounts of inputs like water, fertilizers, pesticides etc. at the correct time to the crop for increasing its productivity and maximizing its yields. Global Positioning System (GPS) technology is extensively used in precision agriculture. GPS allows precise mapping of the farms and together with appropriate software informs the farmer about the status of his crop and which part of the farm requires inputs such as water or fertilizer. The heavy farm machinery used for all the farm and field operations such as sowing, harvesting, weeding, etc. runs on fossil fuels and uses more than 60% of the total energy employed in farming. Besides, the heavy farm machinery also impacts the soil and makes it unproductive. Precision agriculture is ideal for small farms, on the other hand can use small farm machinery and robots which will not impacts the soil and may also run on renewable fuels like bio-oil, compressed biogas and electricity produced on farms by agricultural residues. For small farms, precision agriculture may include sub-surface drip irrigation for precise water and fertilizer application and robots for no-till sowing, weed removal, harvesting and other operations.

The Drones are becoming the eyes and ears of scientists which is widely used for surveying the ground for crop damage, and even providing knowledge about fertilizing, seeding, multi-spectral imaging capacity to farmers who want to maximize their crop yields and reduce the amount they pay for labour.

INDIAN SCENARIO

A. Commanding agricultural fields

It is a beneficial technology for states that have digitized land records or are in the process of digitizing. Pictures clicked by the unmanned aerial

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vehicles can be superimposed on digital maps of states and we can identify farms and crops sown. Drone helps to keep a track on crop position, control farm subsidies, detect pests, monitor nutritional and water stress on the crops, and they can even spray fertilizer and pesticides on the crops from above. The use of this 21st century technology for the sake of agriculture is commendable and it will directly help farmers in the long run. We might find a lot of drones flying over the agricultural fields in the coming future and it will also double as a scarecrow.

When the consumer drones first came into prominence, no one would have thought how it could lend a helping hand in almost every sector. Today drones are delivering parcels, are likely to reach moon to make way for rovers, and can be put to use for many commercial purposes. In India, these drones are now being put to use to learn about crop diseases and help to gather data to help agriculture in the country.

Drones can provide farmers with three types of detailed views.

(i) Seeing a crop from the air can reveal patterns that expose everything from irrigation problems to soil variation and even pest and fungal infestations that are not apparent at eye level.

(ii) Airborne cameras can take multispectral images, capturing data from the infrared as well as the visual spectrum, which can be combined to create a view of the crop that highlights differences between healthy and distressed plants in a way that can't be seen with the naked eye.

(iii) Drone can survey a crop every week, every day, or even every hour. Combined to create a time-series animation, that imagery can show changes in the crop, revealing trouble spots or opportunities for better crop management.

It is part of a trend toward increasingly data-driven agriculture. Farms today are bursting with engineering marvels, the result of years of automation and other innovations designed to grow more food with less labour. Tractors autonomously plant seeds within a few centimeters of their target locations, and GPS-guided harvesters reap the crops with equal accuracy. Extensive wireless networks backhaul data on soil hydration and environmental factors to faraway servers for analysis. But what if we could add to these capabilities the ability to more comprehensively assess the water content of soil, become more rigorous in our ability to spot irrigation and pest problems, and get a general sense of the state of the farm, every day or even every hour. Agricultural drones are becoming an effective tool and better data collected by drone can reduce water use and lower the chemical load in our environment and our food.

Agriculture Insurance Company of India along with Skymet, weather forecasting Company, conducted a brief demo in parts of Gujarat to test how drones can be supportive in the agriculture sector. The test led to the conclusion that drones allow the observation of agronomic indicators for every square meter, something a satellite cannot do. Remote sensing through unmanned aerial vehicles allows nondestructive sampling to observe agronomic indicators every square meter.

Farmers in Gujarat and Rajasthan could soon have an unmanned aerial vehicle flying over their

fields to survey their crops, helping them map crop diseases along with assisting insurance companies in settling claims. The technology has been in use in the United States and other developed countries to map crop position, control farm subsidies, detect pests, monitor nutritional and water stress on crops, and even spray fertilizer and pesticides on crops.

Skymet, along with the AIC and Gujarat government, used satellite remote sensing technologies and drones across 10 villages in *Morbi* district of Gujarat last year. Satellite's resolutions are less and if a cloud cover comes, then you can't use the images. At a time when land holdings are less and there is multi cropping, this technology help Gujarat government in monitoring of the agriculture area and crop yield. The data could help AIC in giving farmers claims.

B. Impact of drone in farming

The automatic and remote controlled UAVs cover 5 sq. km in a single flight, with generally two flights per day. UAVs send images every five seconds and provide geo referenced images. When farmers not declaring the correct crop for insurance, the technology helped them find out total area under a particular crop sown. UAVs are being used the world over. On a commercial basis, the technology is cheaper than sending people in fields. Skymet provides weather information to governments, companies, commodity markets, international organizations and banks.

Drones are now a leading technology in agriculture and set to invade agricultural world. By 2025, "agriculture drones" (farming drones) are expected to take up 80% of the commercial UAV market and generate 100,000 jobs according to a report by the Association for Unmanned Vehicle Systems International. After their successful debut in high-tech war against terrorism in strife-torn areas in the world, now they are coming to the aid of farmers. According to a report, agriculture drones are expected to take up a lion's share of the commercial unmanned aerial vehicles (UAV) market and generate thousands of jobs in world agriculture. Agriculture drones are unmanned aerial vehicles (UAV) used for *precision agriculture*, a modern farming method that relies on big data, aerial imagery and other means to optimize efficiency. After the drone collects images of the farm and makes a map that color-codes its areas by their health, the UAV Company analyzes them for the farmer. The Federal Aviation Administration's Section 333 exemption, which permits the use of commercial drones on an ad hoc basis. As restrictions have been relaxed, companies have started using farming drones to a great effect and some has become very successful also.

C. Kisan drone

A Raipur farmer has come up with genius innovations by building a drone by himself using garbage dump. It now helps him spray pesticides on his 15 acres of land in merely half an hour. A son of a farmer from Raipur in Chhattisgarh has made drones. This farmers drones, sprinkle the urea into the agricultural fields in a few minutes. Earlier for the same work performed by two workers taking full day to sprinkle the urea into the agricultural fields. Presently, he has three drones out of which two has been made by him. Mr Ramesh Chavda is engaged in farming for the last 15 years and during the monsoon season usually they do not get workers for their field even if by paying higher rates than usual. Mr Ramesh Chavda is having 25 acre farmhouse in Hrdi village (Berla Road) and to look after such a large area, it required a large number of workers. The drone has solved the problem of scarcity of agricultural workers. Simply graduate, Mr. Rahul has learned English from his friends in order to obtain drone parts from abroad. The drone parts gets from Japan, China and from US have been assembled by him successfully. He has three drones out of which two are made by himself. The first drone built at a cost of two million. This drone can easily be carried in a bag or suitcase.

When land holdings are less and there is multi-cropping, they will be able to help in monitoring agricultural area and crop yield. The data could help Agriculture Insurance Company in giving farmers their insurance claims. It can be used to check the quality of crop. Health Imaging system, you can view composite video showing the health of your crops. It can be used to spread pesticide on a field. Many countries are using UAV (Unmanned Ariel Vehicle) for precision farming. It can also help in assessing the exact nature/area of crop damage during natural calamities, saving precious time & money.

USES AND APPLICATIONS

Beyond the military applications of UAVs with which "Drones" became most associated, numerous civil aviation uses have been developed, including aerial surveying of crops, acrobatic aerial footage in filmmaking, search and rescue operations, inspecting power lines and pipelines, counting wildlife, delivering medical supplies to remote or otherwise inaccessible regions. Further uses include reconnaissance operations, border patrol missions, forest fire detection, surveillance, coordinating humanitarian aid, search & rescue missions, detection of illegal hunting, land surveying, fire and large-accident investigation, landslide measurement, illegal landfill detection, and crowd monitoring.

The commercial drones is a GPS-enabled remote control airplanes or helicopters with really advanced autopilot that can handle all aspects of a flight, from takeoff to landing. For such a straightforward idea, it has huge implications that could shake up a number of industries. But Indian regulators obviously want to make sure that drones can be employed safely.

A. Comprehensive uses and applications of drone in agriculture and allied sectors

1. Agriculture mapping
   - Land cover mapping
   - Forestry mapping
   - Biomass
   - Forest health
   - Disease detection
   - Environmental mapping
   - Hydrology & Geological Mapping
   - Water management support mapping
   - Wind Farm Mapping
   - Solar power plant mapping
   - Emergency response mapping
   - Disaster Site Monitoring and mapping
   - Archaeological Site Mapping
   - Soil Surveying
   - Mining & Resources
   - Tree Mapping
2. Environment and climate change
   - Land cover mapping
   - Carbon capping
   - Energy
   - Environmental Monitoring (dumping)
   - Waterway Monitoring
   - Ice Flow Monitoring
   - Wildlife Conservation
   - Wildlife counts / Mapping of animal population
   - Marine Biology
3. Search and Rescue
   - Marine Search and Rescue
   - Wildfire
   - Flooding
   - Damage assessment
   - Rapid response
   - Emergency Uses (delivery of equipment)
   - Fire Detection (e.g. fire towers)
4. Videography and photography
   - Home movies
   - Kids sporting events
   - Weddings
   - Golf Course
   - Promotional Videos for Products / Services
   - 360 Panoramas
   - Tourism Aerial landmark flyby
   - News
   - Sports Event Coverage
   - Live Event Coverage
   - Concerts
   - Traffic Reporting
   - Aerial cinematography for movies
   - Action/sports
   - Documentary / Expedition

B. Categories of drone

UAVs typically fall into six functional categories (although multi-role airframe platforms are becoming more prevalent) which are:

- *Target and decoy*: Provides ground and aerial gunnery a target that simulates an enemy aircraft or missile
- *Reconnaissance*: Provides battlefield intelligence
- *Combat*: Providing attack capability for high-risk missions
- *Logistics*: Specifically designed for cargo and logistics operation
- *Research and development*: used to further develop UAV technologies to be integrated into field deployed UAV aircraft

- *Civil and Commercial UAVs*: Specifically designed for civil and commercial applications

REGULATIONS AND CONCERNS

As air traffic growth in India puts pressure on available airspace, the country's unmanned aerial vehicle industry is calling for a centralized body to draft regulations and set standards for UAV systems. The need for central planning is increasingly being felt. In 2007 the Centre for Military Airworthiness and Certification (CEMILAC) has recommended that in future, all unmanned aerial vehicles (UAVs) should be cleared for their airworthiness. The recommendation is under consideration by the defence Ministry. Potential failures need to be anticipated, deviations in design and manufacture assessed, operational demands simulated and evaluated, and designs certified. If CEMILAC's insistence on airworthiness certification for UAVs is accepted, norms and procedures would have to be laid down. In addition, certification protocols and procedures must be worked out, so that they can be applied for the unmanned craft.

But an effective counter-issue is the collateral damage a UAV can cause if it spins out of control and crashes on human settlements. UAVs may be designed primarily for military use, but 90 per cent of Indian airspace is civilian, and restricting UAVs to military airspace could be impractical. Aeronautical Development Establishment organized its first international conference on autonomous unmanned vehicles in 2009 (ICAUV), and again in 2011. This has been the only government organized event in India till date exclusively on unmanned systems. Unmanned Systems Association of India (USAI) has been recently formed and is completely dedicated towards all the activities and regulations pertaining to the unmanned systems industry in India. Presently all UAV flying is done with permission from Directorate General of Civil Aviation (DGCA) and Ministry of Defence (MoD). This has been done since all the official UAV flying has been by the military and government agencies. Integrating the UAVs into civilian air space is a challenging job.

India is set to enter an exclusive club of just five countries worldwide with the Directorate General of Civil Aviation (DGCA) working on notifying regulations for commercial use of drones soon. Globally, Spain, Australia and New Zealand have notified provisional norms for civilian use of unmanned aerial vehicles (UAVs). The benefits of deploying drones for civilian applications are many. They can be used for surveillance in crowded places. It would help in checking untoward incidents of unrest. In October last year, India had banned private organizations and individuals from launching UAVs. Apart from DGCA approval, the move will require clearance from the air navigation service provider, the ministries of defence and home affairs and other concerned agencies. Once the DGCA's norms are in place, UAVs could open up a host of applications for civilians. The useful aspects of civilian drones are: agriculture, wildlife conservation, search and rescue, aerial photography, remote monitoring of utilities such as transmission towers, pipelines, highways, railways, etc, tracking of natural disasters and, doorstep delivery of products. However, drones also hold potential risks. Besides debates about their use for intrusive surveillance, battery failure or loss of navigational control could cause accidents. Given its multifarious applications and damage potential, ownership and operation of drones need to be licensed. Its size, capabilities, aerial route and end-use of collected data need to be monitored. The FAA's proposed rules permit certified operators to fly UAVs weighing up to 25 kg during the day. Commercial drones will be permitted to fly at a speed of up to 160 km per hour and at heights of up to 500 feet. Operators will have to renew their permit every two years. Spain approved a provisional regulatory framework to enable the civilian use of drones depending on their weight. The norms allow use of UAVs weighing up to 150 kg for investigation and development activities, agriculture-related treatments that require spreading substances over the surface or atmosphere, including products for extinguishing fires, aerial surveys, aerial observation and surveillance, including filming and forest fire surveillance activities, aerial advertising, radio and TV emissions, emergency operations, search and rescue, and other special functions.

A. Privacy concern

Privacy of an individual as well as society is a major issue linked with Drone. Privacy in the home is sacrosanct and one should not forget that new technologies will always push the boundaries and blur the line between private and public. Maintaining privacy in the home is a completely legitimate expectation and is in everyone interest. If drone operator are doing the wrong thing and harassing individuals in the street or trespassing over private property people can contact the Civil Aviation Safety Authority, who can issue infringement notices or commence prosecutions.

Flying Drone in India is banned. Considering other countries, Federal Aviation Administration in the US, grappling with coming up with laws to govern drones in the sky. The Directorate General of Civil Aviation in India went ahead and put a public notice stating that "No one will launch a UAV in India civilian airspace for any paupers whatsoever." Although at weeding the drone business seems to be doing brisk business though we need very clear headed laws for commercial purpose as well as hobbyists can easily fly their drones.

B. Increased Surveillance

Military drone manufacturers are looking for civilian uses for remote sensing drones to expand their markets and this includes the use of drones for domestic surveillance.With the convergence of other technologies it may even make possible to recognize the faces of machines, behaviours, and the monitoring of individual conversations.

India is developing UAVs that are capable of flying on solar power. This is developed by Defence Research and Development Organization (DRDO), New Delhi and Hindustan Aeronautics Limited (HAL), Bangalore. List of unmanned aerial vehicles developed and operated in India by DRDO are:

- DRDO Nishant
- DRDO Rustom
- Dhaksha
- Rustom 1
- Rustom-H
- Rustom 2
- Lakshya PTA
- DRDO AURA
- DRDO Netra
- Indian
- Unmanned Engineer
- Ulka
- Fluffy
- Pawan UAV
- Kapothaka

ADVANCED TECHNOLOGY

Normal Drones are the old things now which can only fly without any interesting features. New Drones comes up with some revolutionary features such as a *follow me* feature. It will stalk you where you go. In this technology, the UAV camera records even when you move fast. Feature in which a drone in the air can lock onto you and irrespective of how fast you move and where you go, follow and record you. Intel showcased 'sense and avoid' technology as a drone flew through a forest avoiding trees as well as people by itself. Drones with acrobatic features can do all the possible acrobat and become much more flexible in use.

The Mother of all the *drone DJI Phantom 3 Professional* which rewrites every rule. It has a 4K video camera mounted on a motorized gimbal (to shoot the smoothest video ever) and GPS so your drones will come back on its own and never get lost or fly away when you lose control. It has an auto take-off and auto land feature, returns to within inches from where it off when the battery runs low or losses connection with the remote. Drones with automatic software based Smart Shots, allowing to capture dynamic, cinematic video without the need for years of piloting experience. Automatically track your subject at speeds up to 55mph.

Octocopter is an advance drone designed specifically for agricultural science by the UK based scientist. Drone surveillance can take much of the drudgery and footwork. The octocopter can carry up to 9kg (including batteries) of cameras and payload. It can be controlled manually or fly itself via GPS, and is fitted with special cameras that can image crop growth, and probably much more.

The craft has a regular RGB (red blue green) imager as in a conventional digital camera. It also has a TIR (thermal infrared) camera which can be used to monitor the crop canopy or soil temperature. The canopy temperature can give an indication of crop stress, because when plants experience drought for example their temperature rises as they stop evaporating water from their leaves. The octocopter also carries a NIR (near infrared, also called multispectral) camera that takes images from which a measure called the Normalised Difference Vegetation Index (NDVI) can be calculated. NDVI gives an estimate of crop biomass, which is essentially the growth that scientists want to know when comparing different plant varieties or growing systems. The process by which individual photographs taken on the copter's boom are translated into growth data demonstrates just how far imaging technology has developed since the advent of the first digital cameras. In the first step, images are fed into software that aligns them to be geometrically uniform and true to scale in a process called ortho rectification. The images are then added around each other into a large mosaic. With up to 500 images of a single experiment, there is a lot of overlap and the software (Agisoft Photoscan) stiches the images together to make one large orthomosaic. Next, the image is geolocated so it is located in real space and has proper scale, and this means meaningful measurements can now be taken from the image. The geolocation uses permanent markers located within the experimental area, and accurately located by precision GPS.

FUTURE OF DRONE IN AGRICULTURAL MANAGEMENT

The drone age is coming. Agricultural applications will be one of the most important and popular civil uses of drones within the next decade. The ability for one person with a little technical knowledge to take over all surveying, fertilizing, seeding, and dusting will transform the agricultural industry.

Drones, including both fixed wing aircraft and quadcopters, are uniquely suited to provide affordable surveying and multi-spectral imaging capacity to farmers who want to maximize their crop yields and reduce the amount they pay for labour. Drones will greatly enhance farmers' ability to obtain and utilize multi-spectral and hyper-spectral imagining to detect issues with crops before they harm crop yields. Disease and nutrient deficiencies will become more preventable with the help of drones.

Drones also have the ability to automatically lay seeds, fertilize soil, and spray pesticides. All farmers will have to program the drones to fly a certain pattern over their fields. This will effectively automate most of the farming process, including harvesting which will be done by automatic tractors and other vehicles. Since drones will be able to fly at low altitudes too, the spraying of pesticides can be more exact, resulting in more precise spraying with less drift beyond the limits of the field sprayed. In addition, drones would be used by cattle farmers to keep count of their livestock either stolen or gone astray, or assist farmers in the herding of their cattle – keeping them in a safe area or driving them to market or to/from grazing areas. While animal welfare groups would use drones to monitor any wrong-doing at factory farms such as checking feedlots and gathering evidence where farming activities cause animals horrible distress.

There are many other uses for drones in agriculture. Farmers are using them to sow seeds and apply pesticides, and in forestry and national parks there are many applications, particularly in essential monitoring over very large areas. It is not too hard to see a future where an automated drone could search fields for areas of crop damage from pests, or see nutrient- or water-stressed plants from above that the human eye would miss. The drone could then feed the GPS co-ordinates to a farm worker, who could then manage the appropriate response.

CONCLUSION

When commercial drone will be used at common places, it will open new employment opportunity and innovative ideas. Agricultural applications will be one of the most important and popular uses of drones in terms of providing knowledge about fertilizing, seeding, multi-spectral imaging capacity to farmers who want to maximize their crop yields and reduce the amount they pay for labor. Drones will enhance farmers ability to obtain and utilize multi-spectral and hyper-spectral imagining to detect issues with crops before they harm crop yields. Drones also have the ability to autonomously lay seeds, fertilize soil, and spray pesticides. All farmers will have to do is program the drones to fly a certain pattern over their fields. This will effectively automate most of the farming process, including harvesting which will be done by autonomous tractors and other vehicles. Since drones will be able to fly at low altitudes too low for manned vehicles, the spraying of pesticides can be more exact, resulting in more precise spraying with less drift beyond the limits of the field sprayed. In addition, drones would be used by cattle farmers to keep count of their livestock.

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Short communication

Effect of rainwater harvesting technologies on groundnut-wheat cropping system in Hillocks area of watershed

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ABSTRACT

An experiment was conducted during 2009-10 and 2010-11 at hillocks and valley watershed area of Amarpur-Bedaura-Chamraua, situated in block Babina, Jhansi, C.S.Azad University of Agriculture and Technology, Kanpur. The soil of experimental field was sandy loam locally known as Rakhar having low fertility status. The treatments comprised of conventional system, sowing across the slope, sowing on contour alignment, sowing in submergence bunding, sowing with dead furrows, sowing with vegetative hedge of local material and sowing in nala bunding area. These treatments were applied to groundnut and wheat under groundnut-wheat cropping system. The highest pod yield of groundnut of 28.70 q ha^{-1} was reaped from sowing in nala bunding area in watershed. The sowing of wheat after groundnut in nala bunding area also gave highest grain yield of 42.66 q ha^{-1}. The growth and yield traits of both the crops were concordant to the yields.

Key words: Contour alignment, Cropping system, Hillocks and valley area, Nala bunding, Submergence bunding

Soil and water conservation structures are an important component in the watershed development programme especially in ravines and hillocks affected watershed. Such measures include contour bunding, submergence bunding, *nala* bunding or gully plugging, water storage structure etc. Although mechanical works are generally not in themselves productive in relation to yield increase but they are necessary in high sloping areas.

Mechanical practices are not alternative to agronomic practices but are complementary to each other, although each serves a separate purpose. It is well known fact that an integrated package of practices such as contour, tillage, mechanical measures, conservation agronomical practices not only reduce the soil erosion and runoff losses but also improve the crop yield. Singh (1997) reported that the implementation of water harvesting activities in different soil and water conservation measures, the shortage of food, fuel, fodder and water was in scarcity and the shortage was met from the outside area of watershed, but this gap has now been fully filled up by harvesting rainwater and recharging of ground water in agricultural dominated watershed. The surplus food and fuel produce was supplied to the outside watershed families.

For increasing the cropping intensity in erosion affected area from < 100 to 200 per cent through double cropping systems by utilizing the harvested rainwater is the major activity of the watershed programme. Singh (2011) reported that the sesame–wheat and black gram–wheat cropping system proved best for higher productivity due to three tier system of rainwater management (Contour cultivation + dead furrows + harvesting of excess rainwater for life saving irrigation) on reclaimed ravenous area.

Keeping the above points in view, the present study was under taken to judge the efficiency of different rainwater harvesting technologies on cropping system of groundnut–wheat in selected fields of the catchment area of Hillocks watershed.

The present experiment was conducted during rainy and winter season of 2009-10 and 2010-11 at the selected fields of Hillocks watershed of Jhansi district of Bundelkhand region, C.S. Azad University of Agriculture & Technology, Kanpur. The soil of experimental site was Rakar and degraded nature, having pH 8.5, organic carbon

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0.22%, total nitrogen 0.02%, available phosphorus 10.30 kg $ha^{-1}$and available potash 278 kg ha^{-1}. The treatment comprised of seven rain water harvesting practices i.e. conventional system, sowing across the slope, sowing on contour alignment, sowing in submergence bunding, sowing with dead furrows, sowing with vegetative hedge of local material and sowing in *nala* bunding area. These treatments were allocated in the pilot area, where the water storage structures were constructed. Each treatment was replicated on four farmers' fields in Randomized Block design. The groundnut–wheat cropping system was tried under different water harvesting structures. The recommended doses of nitrogen, phosphorus and potassium were supplied to groundnut @ 20 kg N, 30 kg P_2O_5 and 45 kg K_2O ha^{-1}, respectively, while 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} were given to wheat. One protective irrigation was given to groundnut at pegging stage and three protective irrigations at tillering, ear emergence and dough stage to wheat crop. Groundnut variety Dh-86 and wheat variety Malviya-234 were planted in groundnut-wheat cropping system. The groundnut was planted between 20-25 June, 2009 and 2010 and harvested between 25-30 October, 2009 and 2010. Wheat was planted between 15-25 November, 2009 and 2010 and harvested between 25 April to 10 May, 2010 and 2011. The other recommended conservation agronomical practices were also followed in both the crops.

The results obtained from the experiment are reported and discussed under appropriate heads on two years pooled basis.

Effect on groundnut

It is clear from the pooled results that the sowing of groundnut in nala bunding area produced higher number of pods/plant, weight of pods/plant, kernels/pod, kernels weight/plant and 100-kernels weight. The significantly maximum pod yield was recorded under sowing of groundnut in nala bunding area over conventional system, sowing across the slope, sowing on contour alignment, sowing in submergence bunding and sowing with dead furrows. The pod yield recorded under sowing in nala bunding area was higher by 11.45 per cent than the conventional system (Table 1). The increase in pod yield with sowing in nala bunding area may be attributed to significant increase in pods/plant, pod weight/plant, kernels/pod, kernels weight/plant and weight of 100-kernels. Improvement in all these parameters accompanied with good availability of soil moisture in sowing with nala bunding area treatment, which showed increment of 11.45 per cent in pod yield of groundnut over conventional system. These results are in conformity with the findings of Singh (2004), Senapati and Santra (2008) and Singh *et al*. (2012).

Effect on wheat

Wheat crop was raised after groundnut in succession on the same farmers fields of groundnut with same seven treatments. The results revealed that the sowing in nala bunding area recorded remarkably highest value of tiller/plant, grain/spike, grain weight/plant and weight of 1000-grains than the other tested moisture conservation practices. The highest seed yield (q ha^{-1}) of wheat was recorded at sowing in nala bunding area, which was found significantly superior to other treatments except sowing with vegetative hedge of local material. The percentage increase in sowing in nala bunding area over conventional system was 13.03 (Table 2).

Table 1. Yield traits and yield of groundnut under different rainwater harvesting practices (Pooled)

Treatment	Pods/ Plant	Pods weight/ plant	Kernels/ pod	Kernel weight/ plant (g)	100 – Kernel weight (g)	Pod yield (q ha^{-1})		
						2009-10	2010-11	Pooled
Conventional system (T_1)	18.62	25.87	1.57	19.34	35.25	28.09	23.42	25.75
Sowing across the slope (T_2)	18.71	26.38	1.57	19.78	35.68	28.27	24.48	26.38
Sowing on contour alignment (T_3)	18.85	26.72	1.70	20.00	36.12	28.72	24.62	26.67
Sowing in submergence bunding (T_4)	18.84	26.62	1.70	19.85	35.75	28.55	24.50	26.52
Sowing with dead furrows (T_5)	18.92	26.88	1.78	20.54	36.50	29.68	25.15	27.41
Sowing with vegetative hedge of local material (T_6)	19.09	27.31	1.78	21.04	37.62	30.65	25.42	28.04
Sowing in *nala* bunding area (T_7)	19.43	27.47	1.78	21.52	38.37	31.09	26.31	28.70
CD (P=0.05)	0.25	0.49	0.09	0.44	0.83	1.75	1.35	1.06

Table 2. Yield traits and yield of wheat under different rainwater harvesting systems after harvesting of groundnut (Pooled)

Treatment	Tillers/ plant	Grains/ spike	Grain weight/ plant (g)	1000 – Grain weight (g)	Seed yield (q ha^{-1})		
					2009-10	2010-11	Pooled
Conventional system (T_1)	9.83	40.33	10.55	40.27	38.31	37.30	37.74
Sowing across the slope (T_2)	10.28	40.91	10.74	40.64	38.66	37.63	38.08
Sowing on contour alignment (T_3)	11.33	41.87	12.65	41.28	40.56	39.41	39.98
Sowing in submergence bunding (T_4)	10.57	41.33	12.50	40.83	40.41	39.25	39.83
Sowing with dead furrows (T_5)	11.66	41.95	12.73	41.70	41.40	40.40	40.85
Sowing with vegetative hedge of local material (T_6)	11.87	42.37	13.00	41.98	42.57	41.67	42.12
Sowing in *nala* bunding area (T_7)	12.24	42.91	13.07	42.21	48.11	42.21	42.66
CD (P=0.05)	0.48	0.66	0.63	0.60	1.84	1.47	1.13

There had been considerable increase in number of productive tillers/plant, grains/spike, grain weight/plant, weight of 1000-grains with sowing in nala bunding area over all other treatments that contributed to increase the grain yield (q ha^{-1}) in pooled results of two years. These results confirm the findings of Singh (2004), Singh (1997), Singh (1999) and Singh (2011).

CONCLUSION

It is thus clear from the results that groundnut-wheat cropping system was certainly benefited with sowing of both crops in *nala* bunding area on light soils under moisture stress condition of dry eco–system. It will be better that from families having similar condition in hillocks and valley area may be advocated for the adoption of groundnut – wheat cropping system.

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Short communication

Effect of vermicompost on Black gram nutrition in Alfisol of Chhattishgarh

UMESH KUMAR PATEL[1], HEMLATA NIRALA[1] and JITENDRA SINHA[2]

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ABSTRACT

An experiment was conducted in 2011-2012 at the Instructional farm of Krishi Vigyan Kendra Anjora, Durg (C.G.), laid out in CRD with twelve treatments comprised of 25, 50 and 75 percent of recommended dose of nitrogen, and organic sources Vermicompost @ 2.5 & 5.0 t ha^{-1}, were applied in Black gram crop. The results showed that the increase in doses of vermicompost from 2.5 to 5 t ha^{-1} also significantly increased the plant dry matter as well as yield and the highest N and P content in plant were recorded in the treatment receiving 75 percent N as urea along with 5 t ha^{-1} vermicompost.

Key words: Vermicompost , Organic fertilizer, Inorganic fertilizer, Black gram, Alfisol

The increasing cost of chemical fertilizer growing environmental concern and energy crisis have created considerable interest for search of alternative cheap source of plant nutrient. The use of vermicompost, as a source of organic manure in supplementing chemical fertilizer is becoming popular among the farmers of the country. Increase in crop yield and nutrient status (Vasanthi and Swamy, 1996) and nutrient uptake (Sansamma and Raghavan, 1996) was reported due to application of vermicompost. Meager information is available on the effect of vermicompost of Black gram nutrition. An attempt was therefore made to study the effect of vermicompost alone and in combination with fertilizer nitrogen on growth and yield of Black gram.

A field experiment was conducted with an alfisol of the Krishi Vigyan Kendra Anjora farm, Durg during 2011-2012 using Black gram (cv.TAU-2) as a test crop. Five Kilograms of processed soil was taken in each earthen pot. Treatment Details are given in table 1. Some of the important properties of the soil are pH 6.9, organic carbon 6.4g kg^{-1} available N, P & K 310, 13.5 and 125 kg ha^{-1}, respectively and texture sandy loam. The vermicompost used had 11.5% organic carbon, 1.3% N, 1.3% P and 2.6% K. Treatment were replicated thrice in a completely Randomise Design (CRD). Vermicompost and FYM as per treatment were thoroughly mixed with the soil before filling the post. Six healthy seeds of Black gram (cv.TAU-2) were sown in each plot and after ten days of sowing, two plants were maintained in each pot. Sprinkling of water was done as and when necessary, recommended dose of P_2O_5 (35 kg ha^{-1}) as SSP was applied in all the pots. The phosphorus supplied by vermicompost was adjusted accordingly. Dry matter yield of plants for each pot was recorded at harvest and analyzed for nutrient content following standard procedure.

RESULTS AND DISSICUSSION

The crop was harvested at maturity stage. Application of vermicompost showed positive effect of yield and dry matter production of Black gram (Table 1). The height, dry matter and seed yield per plant were obtained with the application of 75% N as Urea along with 5 t ha^{-1} vermicompost and it was at par with the application of N as vermicompost. Dry matter yield range from 8.4 to14.7 g pot^{-1} the percent increase in dry matter production due to application of vermicompost and FYM were 54.2 and 32.1, respectively. Increase in doses of vermicompost from 2.5 to 5 t ha^{-1} also significantly increased the plant dry matter as well as yield. The prolonged availability of nutrients during the crop growth period from vermicompost might have enhance the plant growth, yield attributes of finally augmented the seed yield.

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Table 1. Effect of vermicompost on yield, root wt. nodule dry wt. and nutrient content of Black gram in Alfisol of Chhattishgarh

S.N.	Treatment	Yield (g pot^{-1})		Root weight (g plant^{-1})	Nodule dry wt. (mg plant^{-1})	Nutrient content(%) in plant		
		Seed	Dry matter			N	P	K
1	Control (No N)	3.0	8.4	0.15	12.1	1.23	0.37	0.82
2	RND*as urea	5.2	10.2	0.23	13.7	1.44	0.39	1.02
3	RND as vermicompost	7.7	13.8	0.56	26.1	1.49	0.42	1.10
4	RND as FYM	5.7	11.1	0.35	22.5	1.38	0.39	1.06
5	75%RND as urea +2.5 t ha^{-1} vermicompost	4.9	9.3	0.19	24.2	1.45	0.43	0.95
6	75% RND as urea +5.0 t ha^{-1} vermicompost	8.3	14.7	0.17	27.5	1.54	0.47	1.05
7	50% RND as urea +2.5 t ha^{-1} vermicompost	3.6	8.7	0.17	22.2	1.39	0.41	0.95
8	50% RND as urea + 5.0 t ha^{-1} vermicompost	4.6	8.5	0.19	23.1	1.33	0.43	0.98
9	25% RND as urea +2.5 t ha^{-1} vermicompost	3.4	9.0	0.15	17.5	1.38	0.41	1.02
10	25% RND as urea +5.0 t ha^{-1} vermicompost	3.9	8.5	0.18	20.5	1.35	0.37	1.05
11	RND as urea +2.5 t ha^{-1} vermicompost	3.9	8.7	0.19	24.5	1.40	0.39	0.95
12	RND as urea +5.0 t ha^{-1} vermicompost	5.8	10.3	0.22	26.9	1.42	0.40	0.98
	SEm+	0.277	0.666	0.010	0.629	0.061	0.013	0.021
	CD(p=0.05)	0.8	1.8	0.03	1.7	0.17	0.04	0.06

RND=Recommended dose of nitrogen

Significant increase in dry matter and yield of Blackgram due to application of vermicompost and FYM was also reported by Reddy and Mahesh (1995).

All the treatment significantly increased the root weight of Blackgram over control. Root weight varied from 0.15 to 0.56 g plant^{-1}. The highest root weight per plant recorded was application of N as vermicompost followed by FYM. The increase of root growth may be attributed to better N nutrition of the crop. Appreciable increase in nodule number and dry weight was observed following addition of organic manures. The number of nodules per plant varied from 6.0 to 19.7. Application of nitrogen through vermicompost produced the highest nodules number and dry weight per plant and was at par with the treatment was revised 75% N through urea along with 5 t ha^{-1} vermicompost. Increased biological activity in soil following addition of organic manures might have result in increased nodules number as well as nodule dry weight. Purkayastha and Manon (1984) also reported that incorporation of organic residues in low organic soil influence the various soil biologically activities leading to enhancement of growth and yield of crop.

Significant increase in nutrients content was plant was observed due to addition of vermicompost over control. The N and p content in plant varied from 1.23 to1.54 and 0.37 to0.47 percent respectively. The highest N and P content in plant were recorded in the treatment receiving 75 percent N as urea along with 5t ha^{-1} vermicompost. Nitrogen applied through vermicompost the plant p and k content by 13.5%and 32.5% over control, respectively. Result further revealed that increase in the doses of vermicompost from 2.5 to 5.0 t ha^{-1}also increased in plant nutrient content. The stases and increases availability of nutrient from vermicompost might have result in increased in uptake of nutrient by plant. The results were in accordance with the findings of Srinivasa Reddy and Uma Mahesh (1995).

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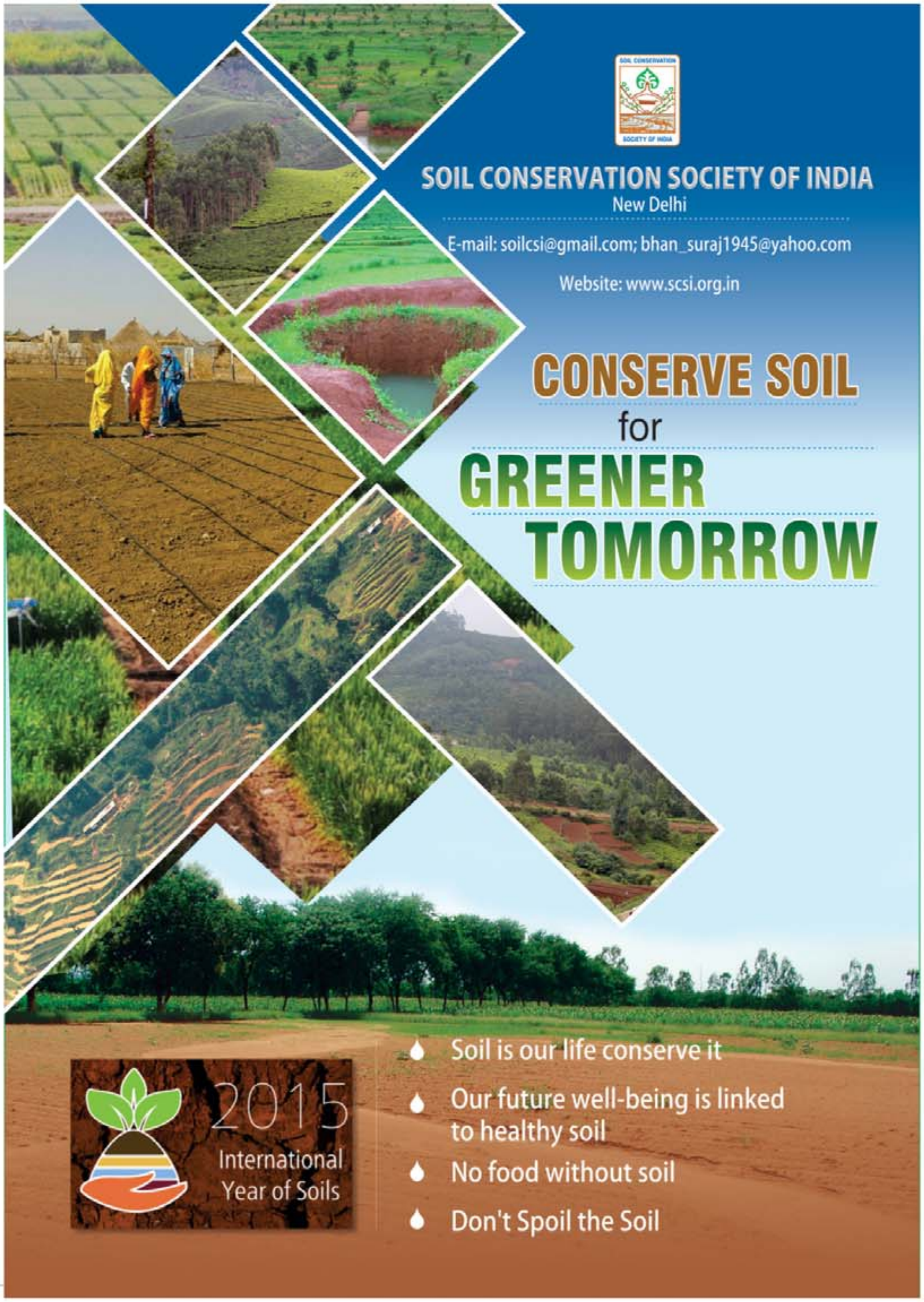

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