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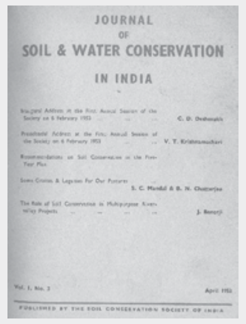

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Principal component analysis of soil properties in assessing erodibility indices in the Northern Brahmaputra plains of Assam

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ABSTRACT

Fifty soils representing six different landscape units of the Northern Brahmaputra plains of Assam were collected for evaluating their erosional status. After estimating the soil physico-chemical and fertility related properties, various erodibility indices like clay ratio, silt/clay ratio, modified clay ratio, dispersion ratio, erosion ratio and erosion index were computed based on the measured soil data. Principal component analysis was carried out using 29 characters which included 23 soil properties and 6 erodibility indices. The principal factor analysis synthesized five factors explaining 80.38 per cent variability. The first factor which accounted for 51.79 per cent of the total variability was strongly influenced by erodibility indices and a set of related physico-chemical and fertility parameters. Based on the calculated factor scores it was found that the soils of the old flood plain are the most stable landscape unit of the studied area while, the structural hill soils are the most erodible one. The ranking of the soils appeared to be in close agreement with soil analytical and computed data.

Key words: erodibility indices, Brahmaputra plains, principal component analysis, landscape units

INTRODUCTION

Soil erosion by water is a serious problem in the Brahmaputra valley of Assam. The region is ecologically fragile and, thereby, poses serious land degradation and environmental problems. As such information on spatial distribution of degraded/eroded lands and areas prone to degradation/soil erosion is needed for formulation of conservation plan for development of an area. Soil erosion depends on the erosivity of the rainfall and erodibility of soil. The soil erodibility depends primarily on the physical characteristics of the soils *viz.*, nature and amount of soil aggregates, organic matter content, particle size distribution etc.

Soil erodibility can be evaluated by using runoff plots, which is quite expensive, time consuming and is not feasible at all places. It can also be estimated using monograph developed by Wischmeier *et al.* (1971) but it may not be applicable in many situations. Another way to estimate soil erodibility is by using various soil erodibility indices based on soil characteristics. Amongst these indices, erosion ratio, dispersion ratio and erosion index are used most commonly under Indian conditions. Estimation of soil erosion based on soil erodibility factor saves considerable amount of time, labour and at the same time provides useful information helpful in recommending soil conservation measures. Kaur *et al.* (2003) while reviewing the work carried out on Indian soils found that erosion ratio was positively correlated with dispersion ratio, whereas negative correlations were found with water stable aggregates. Singh and Kundu (2008) observed a highly significant and negative relationship of erosion index with clay, silt + clay, maximum water holding capacity and highly significant, and positive relationship with sand and dispersion ratio in the soils of eastern India. Gupta *et al.* (2010) observed positive relationship between particle and bulk density in relation to soil erodibility under different land uses in foothills of Siwaliks in N-W India. Chukwuocha *et al.* (2014) observed non-significant relationship of clay, silt and moisture content and significant relationship of sand with soil erodibility in Nigerian soils.

In Assam the most common type of soil erosion is loss of topsoil through surface run-off under

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heavy precipitation and humid climate. As the Brahmaputra valley is comprised of undulating terrains so it is facing severe problem of soil erosion which has threatened the agricultural development in this region. Despite of that the available information on soil erosion status in these areas is very scanty. As such an attempt was made to estimate the status of soil erodibility of the Northern Brahmaputra plains of Assam using inherent soil properties for management of resources.

MATERIALS AND METHODS

The studied area, comprising an area of 23,106 ha, is located in the Sonitpur district which is a part of the Northern Brahmaputra plain zone of Assam. The area is situated between $93^{0}03'$ E to $93^{0}12'$ E longitude and $26^{0}41'$ N to $26^{0}56'$ N latitude. The drainage network of the area comprises Majuli, Bhimajuli, Dhullie, Diring, Patharijan, Pabhoi, Sadharu, Selakhati and Diplonga rivers and their tributaries originating from Arunachal hills and flowing through the studied area to meet the mighty Brahmaputra river. The studied area experiences humid sub-tropical climate with an average annual rainfall of 1940 mm. The mean annual temperature is more than 22^{0}C and the differences between mean summer temperature (27.3^{0}C) and mean winter temperature (18^{0}C) is more than 5^{0}C. Hence, the area qualifies for hyperthermic soil temperature regime. The soil moisture regime of the area is Udic.

Image interpretation of geocoded FCC of IRS-IC LISS-III data in conjunction with Survey of India toposheets (1:50,000) led to the recognition of six distinct physiographic units of the area which include structural hill, upper piedmont plain, lower piedmont plain, upper alluvial plain, lower alluvial plain and old flood plain. Major land units identified in the studied area include agricultural land, agricultural plantation, forest, forest plantation and tea estate. Fifty surface soil samples collected from different physiographic units were air dried and divided into two equal parts i.e. processed and unprocessed. The processed samples were analyzed in the laboratory according to the standard procedure (Soil Conservation Service, 1972). The unprocessed part of soil was used for estimation of water stable aggregates following the procedure outlined by Yodder (1936). Erodibility indices like silt/clay ratio (Chakrabarti, 1971), clay ratio (Buoyoucos, 1935) and modified clay ratio (Kumar *et al.*, 1995) as employed by different workers were determined to assess the soil erodibility. Dispersion ratio (DR) and erosion ratio (ER) were computed as per Middleton *et al.* (1930) and erosion index by Sahi *et al.* (1977). The threshold limits of 15, 10 and 2.8 were used for DR, ER and EI, respectively. Soils having values greater than these limits for a respective index were categorized as erodibile.

RESULTS AND DISCUSSION

Soil erodibility depends to a large extent on the water stability of soil aggregates. Besides its direct influence on dispersion of soil particles, soil aggregate stability also plays an important role in controlling the infiltration especially after a heavy rainfall or irrigation. When the aggregates break down easily and the soil particles are dispersed then the soil pores are clogged and thereby, permeability to water is reduced considerably. It results an increase in soil erodibility which can further be reduced by improving the structural condition of the soils. A perusal of the data (Table 1) revealed that the water stable aggregates greater than 0.25 mm diameter varied from 23.2 to 82.9 per cent (Mean value 55.4 per cent) in the studied soils. There was an increasing trend of macroaggregate from structural hill (Mean value 25.4 per cent) to old flood plain soils (Mean value 71.0 per cent). The upper piedmont plain soils mostly comprising a reserve forest showed relatively high value of macroaggregate (Mean 52.7 per cent). It might be due to better canopy, higher organic matter and predominance of burrowing animals and fungi in those soils (Bhatia and Sharma, 1976). Dominance of macroaggregate over microaggregate in old flood plain and alluvial plain soils could be explained from the view point of high clay and organic matter content which acted as binding agents for aggregate formation. The decreasing trend of macroaggregate towards upslope might be due to increase in sand content and decrease in organic matter content. The existence of a significant positive correlation of macroaggregate with clay ($r = 0.618^{**}$) and organic matter ($r = 0.591^{**}$) as well as negative correlation with sand ($r = 0.528^{**}$) substantiate the findings. Relative to macroaggregate, microaggregate showed a reverse trend and varied from 17.1 to 76.8 per cent with a mean value of 44.6 per cent. The value of microaggregate was highest in structural hill soils (Mean value 74.6 per cent) and lowest in the old flood plain soils (Mean value 29.1 per cent). The increasing trend of microaggregate towards structural hill might be interpreted in the light of existence of a significantly negative correlation with clay ($r = -0.618^{**}$) and organic matter ($r = -0.590^{**}$). The mean weight diameter

Table 1. Range and mean values of soil parameters in different physiographic units of Northern Brahmaputra plains of Assam

Soil parameters	Old flood plain		Lower alluvial plain		Upper alluvial plain		Lower piedmont plain		Upper piedmont plain		Structural hill	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Very fine sand (%)	14.2	7.4-18.7	13.6	6.4-26.5	13.2	6.3-35.5	44.8	36.5-54.3	35.0	31.7-38.3	56.4	55.6-57.2
Total sand (%)	42.8	20.0-54.5	47.8	18.8-73.2	28.8	15.0-85.5	75.5	60.0-80.8	64.2	58.4-70.0	80.1	79.0-81.2
Silt (%)	27.2	16.3-43.2	27.1	7.6-47.6	40.7	6.9-84.0	12.8	9.2-23.2	18.1	14..6-21.6	11.1	9.6-12.6
Clay (%)	30.0	21.0-37.0	24.9	17.0-33.6	30.5	7.6-40.0	11.8	8.4-17.6	17.7	15.4-20.0	8.8	8.4-9.2
Hydraulic conductivity (cm hr^{-1})	2.34	0.37-5.40	2.22	0.39-6.58	0.99	0.31-3.61	5.32	0.66-9.32	4.52	3.11-5.93	1.11	0.26-1.95
Field capacity	29.3	25.6-33.4	27.4	21.2-31.8	30.7	18.2-34.8	22.4	20.4-26.1	24.7	23.0-26.4	27.0	26.4-27.5
Permanent wilting point	7.1	5.6-8.4	6.1	4.5-8.3	5.5	4.8-8.9	7.3	3.9-8.9	5.8	5.1-6.5	8.1	7.8-8.3
Available water content	22.2	19.3-25.9	21.3	13.9-26.6	25.2	9.3-29.6	15.1	11.5-20.8	18.9	17.9-19.9	18.9	18.1-19.7
Water holding capacity	36.88	32.32-41.90	33.72	23.39-52.92	33.17	11.19-48.27	24.57	21.64-33.15	25.47	24.72-26.21	19.51	17.82-21.2
CEC [cmol (p+)kg^{-1}]	9.81	6.88-14.34	7.73	5.09-10.57	8.86	5.16-13.95	4.46	4.02-5.58	7.17	7.02-7.30	4.24	4.11-4.37
Bulk density (g cm^{-3})	1.36	1.30-1.42	1.36	1.12-1.60	1.38	1.27-1.26	1.51	1.43-1.60	1.46	1.39-1.53	1.53	1.44-1.62
pH	5.1	4.8-5.8	5.1	4.4-6.0	4.7	4.6-6.1	5.3	4.6-6.0	4.3	4.2-4.4	5.3	4.8-5.8
Base saturation (%)	53	43-64	55	44—66	50	41-58	49	41-50	41	39-42	45	41-48
Organic matter (%)	1.89	1.29-2.24	1.38	0.82-2.17	1.39	0.10-2.28	0.88	0.62-1.66	1.81	1.29-1.32	0.88	0.62-1.14
Available N (kg/ha)	397.71	263.45-558.10	287.20	62.8-376.30	359.38	272.51-470.32	285.52	188.16-351.20	319.88	288.51-351.25	295.55	270.95-326.15
Available P_2O_5 (kg/ha)	28.45	21.05-38.12	25.12	17.95-36.70	25.58	14.60-36.95	16.65	5.13-33.60	13.81	8.21-19.40	22.18	22.15-22.20
Available K_2O (kg/ha)	186.28	142.8-252.1	183.17	79.80-392.80	113.29	29.40-281.40	52.91	29.40-84.00	96.60	46.20-147.00	60.90	37.80-84.00
Relief (m)	46	34-52	66	55-74	84	78-92	116	105-132	157	140-182	292	286-312
Macro aggregate	71.0	57.3-82.9	59.2	41.4-84.8	57.5	34.6-79.3	44.4	35.2-54.7	52.7	40.2-48.9	25.4	23.2-27.6
Micro aggregate	29.1	17.1-42.7	40.9	15.2-58.6	42.5	20.7-65.4	55.6	45.3-64.8	47.4	51.1-59.8	74.6	72.4-76.8
Mean weight diameter (mm)	3.36	2.95-3.91	3.18	2.16-4.31	2.82	1.64-4.33	1.62	1.29-2.03	2.51	2.18-2.83	1.06	1.02-1.09
Silt/clay ratio	0.34	0.26-0.44	0.29	0.21-0.58	0.45	0.33-0.56	0.60	0.42-0.70	0.54	0.54-0.55	0.70	0.69-0.71
Clay ratio	2.48	1.70 -3.80	3.28	1.60-4.90	2.55	1.50-5.70	8.17	4.70-12.20	4.75	4.00-5.50	10.40	9.90-10.90
Modified clay ratio	2.79	1.81 -4.12	3.66	1.90-5.23	2.88	1.57-6.10	11.46	6.64-16.61	6.18	5.00-7.60	15.25	15.07-15.43
Dispersion ratio	26.45	17.00-36.00	25.63	16.80-25.63	25.94	17.40-46.60	43.75	33.80-73.10	23.85	22.70-25.00	84.15	83.80-84.50
Erosion ratio	19.57	14.00-24.50	22.44	12.20-32.30	22.53	12.30-46.90	56.84	40.10-88.90	25.85	22.40-29.30	181.40	166.30-196.50
Erosion index	17.28	10.60-22.30	18.13	7.40-27.40	15.08	9.10-15.08	47.45	24.40-73.30	17.30	16.40-18.20	93.15	88.90-97.40
Factor score F1)	-2.92	-4.08 to -2.12	-1.65	-4.26 to 1.50	-2.43	-5.77 to 1.36	4.87	2.33 to 8.08	1.32	0.95 to 1.68	8.48	8.14 to 8.82

ranged from 1.02 to 4.33 mm (Mean value 2.67 mm) in the studied soils. There was an increasing trend of mean weight diameter of soil aggregates from structural hill (Mean value 1.06) to old flood plain (Mean value 3.36) soils. The increase in mean weight diameter indicated better aggregation which might be brought about by organic matter and clay. The existence of a significant positive correlation of mean weight diameter with organic matter ($r = 0.608^{**}$) and clay ($r = 0.752^{**}$) support their similar pattern of spatial distribution.

Soil erodibility indices

The physical and chemical properties of soil play an important role in determining soil erosion. These properties which are routinely investigated in soil survey work could be used to estimate the erodibility indices of soils. The studied soils showed wide variability in their physico-chemical properties (Table 1). The results on various soil erodibility indices indicated a wide range of variations which are presented in Table 1.

Silt/Clay Ratio (SCR): The value of silt/clay ratio ranged from 0.21 to 0.71 with a mean value of 0.49. However, no definite trend was observed in respect of silt/clay ratio in different physiographic divisions of the studied soils.

Clay Ratio (CR): The clay ratio in the studied soils varied from 1.50 to 10.90 with a mean value of 5.27. The variation in the clay ratio was quite wide in the soil groups of different physiographic units. The structural hill (Mean value 10.40) and lower piedmont plain (Mean value 8.17) soils showed higher clay ratio, while the ratio was lower in old flood plain (Mean value 2.48), lower alluvial plain (Mean value 3.28), upper alluvial plain (Mean value 2.55) and upper piedmont plain (Mean value 4.75) soils. The lower the clay ratio the more would be the clay accumulation which in turn reduced erosion. This corroborates the findings that fine textured soils were less erodible than the soils of light texture (Datta *et al*., 1990).

Modified Clay Ratio (MCR): The value of modified clay ratio ranged from 1.57 to 16.61 with a mean value of 5.68. The structural hill (Mean value 15.25) and lower piedmont plain (Mean value 11.46) soils showed higher MCR value, while the ratio was lower in old flood plain (Mean value 2.79), lower alluvial plain (Mean value 3.66), upper alluvial plain (Mean value 2.88) and upper piedmont plain (Mean value 6.18) soils.

Dispersion Ratio (DR): High dispersion ratio (Mean value 38.30) was observed in all the soils and it varied from 16.80 to 84.50. In the studied watershed area, the structural hill soils were found to have very high dispersion ratio (Mean value 84.15). Dispersion ratio was also higher in lower piedmont plain soils (Mean value 43.75), whereas it was relatively lower in old flood plain (Mean value 26.45), lower alluvial plain (Mean value 25.63), upper alluvial plain (Mean value 25.94) and upper piedmont plain (Mean value 23.85) soils. The greater the dispersion ratio value, the more easily the soil could be eroded (Baver *et al*., 1978). Using the criteria of Middleton (1930), a soil having DR>15.0 is considered to be erodible. As all the studied soils had dispersion ratio values above 15, they may be considered as erodible.

Erosion Ratio (ER): A wide range of variation in soil erosion ratio was found in the studied soils. The ratio varied from 12.20 to 196.50 with a mean value of 36.2. All the soils under present study had erosion ratio values above 10 and, thereby, these were erodible as per the criteria of Middleton (1930). However, the soils differed in the degree of erodibility to a great extent. It is known that the soils with high sand and low organic matter content are more erodible. In the studied area the upper piedmont plain soils despite containing fairly higher amount of sand were found to be relatively less erodible. This could be due to presence of somewhat higher content of organic matter which overcomes the effect of sand. Higher amount of organic matter increased the water holding capacity of soils, which in turn increased storage of water and thereby, reduced runoff (Singh and Prakash, 1985). Water holding capacity and moisture equivalents were positively related to organic carbon content, and negatively related to erosion and dispersion ratio (Gupta *et al*., 2010).

Erosion Index (EI): Erosion index of the studied soils were found to vary widely (7.40 to 97.40) with a mean value of 26.80. Further, the data revealed that values of erosion index were always lower than the corresponding values of erosion ratio. An increase in erosion index was observed from nearly level plain areas to moderately slopping hilly soils. The higher values of erosion index in the soils of structural hill (Mean value 93.15) and lower piedmont plain (Mean value 47.45) might be due to higher sand content. According to Agbu *et al.* (1983), erodibility of a soil varied directly with sand content. However, despite the coarse texture of the soils in the upper piedmont plains, the erosion index value was low (Mean value17.30). This might be explained in the light of the fact that relatively high organic matter content and clay increased aggregation of these soils and thereby, masked the effect of sand fraction on erosion index. The soils of other physiographic units exhibited low erosion index values.

Principal component analysis

Principal component analysis of the studied soils was carried out using 29 characters which included 23 soil properties and 6 erodibility indices. Since the variability was distributed amongst 29 soil characters, only five number of eigen values were extracted (Table 2). The sum of these five eigen values explained 80.38 per cent of the total variance. If the number of characters being considered were less to explain 100 per cent variability, the number of eigen values would have been less, as the total variability would have got distributed within few characters only (Anderson and Furley, 1975). The factor loadings for the first five components which are the correlation of individual characters with the respective components are also given in Table 3.

It was observed that the first factor which accounted for 51.79 per cent of the total variability had the highest eigen value of 13.98. The eigen value went on decreasing along with the percentage of variance with the increase in component number. The second, third, fourth and fifth components explained 11.66, 6.76, 5.81, and 4.36 per cent of the total variability, respectively.

Results showed that very fine sand, total sand, hydraulic conductivity, permanent wilting point, bulk density, microaggregate and relief had high positive loadings for the first factor; whereas silt, clay, field capacity, available water content, water holding capacity, cation exchange capacity, organic matter, available P_2O_5, available K_2O, macroaggregate and mean weight diameter exhibited high negative loadings for the first factor.

All the erodibility indices *viz.* Silt/Clay Ratio, Clay Ratio, modified clay ratio, dispersion ratio, erosion ratio and erosion index showed high positive loadings in the first factor. It depicts that all the erodibility indices are negatively related to silt, clay, field capacity, available water content, water holding capacity, cation exchange capacity, organic matter, available P_2O_5, available K_2O,

Table 2. List of characters, eigen values with cumulative percentage of variance and matrix factor loading

Principal factor number	1	2	3	4	5
Eigen value	13.98	3.15	1.82	1.57	1.18
Variability (%)	51.79	11.66	6.76	5.81	4.36
Cumulative (%)	51.79	63.45	70.21	76.02	80.38
Very fine sand	0.89	-0.21	-0.21	-0.01	0.09
Total sand	0.87	0.25	-0.19	0.03	0.26
Silt	-0.68	-0.21	0.31	-0.11	-0.32
Clay	-0.91	-0.24	0.00	0.08	-0.13
Hydraulic conductivity	0.54	0.39	-0.41	-0.27	-0.18
Field capacity	-0.75	-0.46	0.08	0.28	-0.14
Permanent wilting point	0.49	0.20	-0.41	0.34	-0.40
Available water content	-0.79	-0.46	0.19	0.14	0.00
Water holding capacity	-0.76	0.00	-0.27	0.14	0.07
CEC	-0.77	-0.22	-0.15	0.17	-0.27
Bulk density	0.76	0.08	-0.07	-0.14	0.03
pH	0.37	0.68	0.24	0.31	-0.09
Base saturation	-0.20	0.81	0.30	0.25	0.07
Organic matter	-0.66	-0.14	-0.36	0.16	0.24
Available N	-0.24	-0.20	-0.40	0.15	0.57
Available P_2O_5	-0.48	0.06	0.03	0.47	0.39
Available K_2O	-0.53	0.46	0.18	0.34	0.09
Macro aggregate	-0.73	0.20	-0.51	0.04	-0.15
Micro aggregate	0.73	-0.20	0.51	-0.04	0.15
Mean weight diameter	-0.82	0.17	-0.27	0.15	-0.16
Relief	0.71	-0.52	0.06	0.23	0.04
Silt/clay ratio	0.60	-0.59	-0.17	-0.11	-0.03
Clay ratio	0.95	0.06	-0.12	0.09	-0.06
Modified clay ratio	0.96	0.00	-0.14	0.09	-0.06
Dispersion ratio	0.81	-0.18	0.09	0.44	-0.18
Erosion ratio	0.79	-0.31	0.10	0.48	-0.07
Erosion index	0.88	-0.13	-0.13	0.35	-0.12

Table 3. Correlation matrix of important soil parameters with erodibility indices

Soil properties	Silt/Clay Ratio	Clay Ratio	Modified clay ratio	Dispersion ratio	Erosion ratio	Erosion index
Very fine sand	0.832	0.825	0.877	0.684	0.713	0.805
Total sand	0.403	0.836	0.837	0.590	0.580	0.719
Silt	-0.372	-0.638	-0.664	-0.439	-0.441	-0.559
Clay	-0.353	-0.900	-0.869	-0.651	-0.628	-0.760
Hydraulic conductivity	0.267	0.564	0.564	0.161	0.121	0.397
Field capacity	-0.152	-0.736	-0.690	-0.429	-0.323	-0.518
Permanent wilting point	0.126	0.577	0.561	0.545	0.430	0.609
Available water content	-0.167	-0.801	-0.757	-0.528	-0.403	-0.623
Water holding capacity	-0.416	-0.670	-0.658	-0.642	-0.567	-0.503
Cation exchange capacity	-0.247	-0.729	-0.697	-0.506	-0.487	-0.580
Bulk density	0.524	0.665	0.695	0.550	0.471	0.558
pH	-0.104	0.380	0.370	0.337	0.244	0.314
Base saturation	-0.575	-0.168	-0.207	-0.181	-0.257	-0.246
Organic matter	-0.292	-0.610	-0.616	-0.487	-0.425	-0.494
Available N	-0.016	-0.166	-0.157	-0.197	-0.137	-0.140
Available P_2O_5	-0.410	-0.455	-0.472	-0.273	-0.242	-0.320
Available K_2O	-0.583	-0.489	-0.515	-0.434	-0.388	-0.460
Macro aggregate	-0.440	-0.601	-0.608	-0.587	-0.609	-0.557
Micro aggregate	0.439	0.600	0.607	0.587	0.609	0.556
Mean weight diameter	-0.578	-0.723	-0.737	-0.620	-0.626	-0.653
Relief	0.705	0.644	0.684	0.734	0.872	0.754

macroaggregate and mean weight diameter and positively related to very fine sand, total sand, hydraulic conductivity, permanent wilting point, bulk density, microaggregate and relief. Thus the first factor was strongly influenced by erodibility indices and a set of related physico-chemical and fertility parameters as reflected in the correlation studies (Table 2). So, the first factor was easily interpretable and could be designated as 'Erodibility indices factor'.

The second factor was highly loaded with pH and base saturation which were very highly correlated with each other. Moderately high negative loadings of silt/clay ratio in this factor indicate that more bases in soil can lessen the soil erosion. This factor could be regarded as 'base factor'.

The third principal component exhibits moderate positively loading of micro aggregate and a moderate negative contribution of macro aggregate, hydraulic conductivity and permanent wilting point. This indicates that water stable aggregates of lesser than 0.25 mm diameter can reduce water movement in soil which eventually increases soil erosion. The third factor showing the dominance of water stable aggregate could be termed as 'aggregate factor'.

The fourth factor was found to have moderately high positive loading from dispersion ratio, erosion ratio and erosion index. Also this factor showed moderately high negative loadings of available P_2O_5 and available K_2O. This explains the negative impact of erodibility indices on soil fertility which was also clearly evident in the first factor.

Available nitrogen was observed to have moderately high positive loading on the fifth factor and thus indicated the contribution of nitrogen. This factor could be referred to as 'nitrogen factor'. However, this factor did not exhibit any relation with the erodibilty indices which is also evident from the correlation study.

Soil erosional ranking of soils

Amongst the five factors, the soil erosional status was found to be quite easily interpretable from the first factor. As such the 'factor scores' for the individual soils with respect to first factor (F1) were computed which are presented in physiography wise through mean and range (Table 1). The old flood plain soils showed lowest value in factor 1 (Mean value -2.92), which indicates that these soils are the most stable soils followed by upper alluvial plain (-2.43) and lower alluvial plain (-1.65) soils. The upper piedmont plain soils (Mean value 1.32), could be ranked fourth while, the lower piedmont plain soils (Mean value 4.87), could be ranked fifth from soil stability point of view. The structural hill soils ranked at the top with regard to factor 1 (Mean value 8.48) and thereby, could be termed as most erodible soils of the studied area.

REFERENCES

Agbu, P.A., Ojanuga, A.G. and Olson, K.R. 1983. Soil-landscape relationship in the Sokoto-Rima basin, Nigeria. *Soil Sci.* **148:** 132-139.

Anderson, K.E. and Furley, P.A. 1975. An assessment of the relationship between the surface properties of chalk soils and slope from using principal component analysis. *J. Soil Sci.* **26:** 130-143.

Baver, L.D., Gardner, W.H. and Gardner, W.R. 1978. *Soil physics*, Indian Reprint, Wiley Eastern Ltd., New Delhi.

Bhatia, K.S., Narain, B. and Nath, J. 1985. Erodibility of some Uttar Pradesh soils in relation to their nutritional behaviour, *Indian For.* **111:** 610-614.

Bhatia, K. S. and Sarma, N. 1976. Studies on the physical properties of some Assam soils in relation to their erodibility. *J. Indian Soc. Soil Sci.* **24:** 369-373.

Bouyoucos, G.J. 1935. The clay ratio as criterion of susceptibility of soils to erosion. *Journal of American Society of Agronomy* **27:** 738-741.

Chakrabarti, B.C. 1971. Investigation on erodibility and water stable aggregates of certain soils of Eastern Nepal. *J. Indian Soc. Soil Sci.* **19:** 441-446.

Chukwuocha, N., Amangabara, G.T. and Amaechi, C. 2014. Determination of the erodibility status of some soils in Ikeduru local government area of imo state, Nigeria. *International Journal of Geology, Earth and Environmental Sciences* **4**: 236-243.

Datta, M., Saha, P.K. and Chaudhary, H.P. 1990. Erodibility of soils in relation to soil characteristics and topography. *J. Indian Soc. Soil Sci.* **38:** 495-498.

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

Kaur, R., Srinivasan, R., Mishra, K., Dutta, D., Prasad, D. and Bansal, G. 2003. Assessment of A SWAT Model for Soil and Water Management in India, Land Use and Water Resources Research, No.3.

Kumar, K., Tripathi, S.K. and Bhatia, K.S. 1995. Erodibility characteristics of Rendhar watershed soils of Bundelkhand. *Indian Journal of Soil Conservation* **23**: 200-204.

Middleton, H.E. 1930. Properties of soils which influence erosion *USDA*, *Tech. Bull.* 173.

Sahi, B.P., Singh, S.N., Sinha, A.C. and Acharya, B. 1977. Erosion Index - A new index of soil erodibility. *J. Indian Soc. Soil Sci.* **25:** 7-10.

Singh, G.R. and Prakash, O. 1985. Characteristics and erodibility of some hill soils in Uttar Pradesh under varying land use, slope and terracing conditions. *J. Indian Soc. Soil Sci.* **33:** 858-864.

Singh, R. and Kundu, D. K. 2008. Erodibility of major soil sub-groups of eastern region of India. *Indian Journal of Soil Conservation* **36**: 172-178.

Soil Conservation Service 1972. *Soil Survey Information Report* 1, USDA, Washington D.C. USA.

Wischmeier, W.H., Johnson, C.G. and Cross, B.V. 1971. Soil erodibility monograph for farm land conservation sites. *J. Soil and Water Conservation* **26:** 189-193.

Yodder, R.E. 1936. A direct method of aggregate analysis and a study of the physical nature of erosion losses. *J. American Soc. Agron.* **28:** 337-351.

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Soil aggregation and erodibility indices under different land uses in Jorhat district of Assam

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ABSTRACT

Present investigation was conducted in soils under four different land uses *viz.* rice field, upland vegetable growing land, tea plantation area and natural forest land of Jorhat district, Assam to study the effect of land use on soil aggregation and erodibility. Soils varied in their physico-chemical properties such as texture, organic carbon, pH, CEC *etc.* Soils under natural forest and tea plantation exhibited the almost equal amount of water stable aggregate (weighted mean of profile 57.63 and 57.56 %) followed by rice soil (53.67%) and vegetable growing area (44.93%). The macroaggregates of the soils varied from 30.12 to 66.97 % and it was highest in rice soil (weighted mean 45.63 %) followed by tea plantation area and natural forest (38.96%) and vegetable growing area (30.99%). Microaggregate was found lowest in rice soils (weighted mean, 8.05%) and vegetable growing areas showed an intermediate value of 13.94%. It ranged from 4.10 to 24.02% which is significantly lower than the amount of macroaggregates. Highest value of mean weight diameter was found under forest land (3.30mm) and vegetable soil has the least value (0.30mm). Soil erodibility was measured through Dispersion ratio and Erosion ratio which varied from 14.1 to 31.8 and 7.29 to 19.38 respectively in the soils. Considering dispersion ratio and erosion ratio, erodibility of the soils was in the order rice soil > vegetable soil > tea soil > forest soil. Organic carbon and total exchangeable cations were found to be the most dominant factors contributing in soil aggregation in soils under all the land use systems.

Key words: land uses, water stable aggregate, macro-aggregate, micro-aggregate, soil erodibility

INTRODUCTION

Stable soil aggregates are one of the most important key indicators of soil quality and environment sustainability of agricultural management practices. Soil particles aggregate as a result of physical binding by roots and fungal hyphae "gluing" by bacterially produced polysaccharides and physical chemical interactions between silicate clay surfaces and functional groups of partially decomposed organic matter (Tisdall and Oades, 1979). Hence the process of soil aggregation can be defined as flocculation and cementation with numerous force and agents that stabilizes the floccules. Biophysical drivers of soil aggregation have been a focus within the scientific reign for decades. Earlier findings identified the key factors are organic matter, inorganic binding materials such as oxides and hydroxides of iron and aluminum soil mineral particles, soil bacterial community, effect of environmental variables, topographic influences and land use (Tan *et al.*, 2004). As of particular significance, land cover, or so to say land use, has a prominent effect on stable soil aggregate formation. Aggregate dynamics vary among different land use systems. Land use can influence aggregate stability by contribution of organic matter through amount, nature and composition of litter, plant root turnover, root exudates and rhizodeposition. Perennial crops generally improve soil structure and aggregation whereas annual crops often degrade the soil mainly due to soil structure destruction. In cultivated soil, tillage practices disturb the soil and destabilize aggregates releasing intra aggregate organic matter and increases decomposition (Bhatt and Arora, 2015).

In recent years, much of the natural vegetation (forest and pasture) has turned into agricultural lands which have an effect on features related to soil erodibility. The consequences of such changes in land use are the intensification of natural degradation processes such as soil erosion (Sharma

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and Arora, 2015). Soil erodibility is a measure of soil susceptibility to detachment and transport by the agents of erosion. It is the integrated effect of processes that regulate rainfall acceptance and the resistance of the soil to particle detachment and subsequent transport. Erodibility of soil depends on the stability of soil aggregates and the percentage of coarse primary particles that are resistant to erosion. Several indices have been developed by earlier researchers (Middleton, 1930; Sahi *et al*., 1977) to evaluate erodibility of soil *viz.* dispersion ratio, erosion ratio, erosion index *etc.* These indices are of particular significance in the high rainfall areas where degree of soil erosion is severe. Assam receives annual rainfall of about 2000 mm and due to this heavy rainfall the state is being faced by severe erosion problem. As assessed, average annual soil loss due to erosion is around 30 tons per ha. For scientific management of erosion problem, knowledge on soil aggregation as well as erodibility indices is of much importance (Gupta *et al*., 2010). However, information on these aspects, especially in the alluvium derived soils of Jorhat district is still lacking. Keeping this in view, the objective of the present research work was undertaken as to study soil aggregation and erodibility indices under different land uses of Jorhat district.

MATERIALS AND METHODS

Study sites and soils

The study area comprises of Jorhat district of Upper Brahmaputra valley zone of Assam. It is located in between latitude of 20°10´to 27°20´ N and longitude of 20°10´ to 27°20´ E. The region encounters high rainfall which normally goes up to 2077mm per annum, about 87 per cent of which falls between April and September and high humidity of more than 80 per cent persist in the district. Maximum temperature of the area rises up to 37^0C in July-August and minimum falls to 5^0C in January. The geographical area of Jorhat district is 2, 85,100 ha and out of that 53.63 % is cultivable area, 25.15% is under non agricultural use, 10.01% under forest, 9.75% barren or cultivable waste land, 2.35% under miscellaneous plantation and 1.53% area is under pasture. Soils are both old and new alluvium derived.

The study was carried out in soils under four different kinds of land use system viz. rice field, upland vegetable growing area, tea plantation and natural forest system. Soil profiles were exposed in each land use system and horizon wise samples were collected. Samples were allowed to air dry, then gently passed through 2 mm sieve and stored in room temperature for further analysis. The particle size distribution of the soils was determined by International Pipette method (Jackson, 1956; Piper, 1950). Bulk density of the soils was determined by clod method (Black, 1965), water holding capacity by Keen's box (Piper, 1950), organic carbon by wet digestion method (Walkley and Black, 1934), field capacity of the determined as per the procedure outlined by Richard (1948). Soil pH was measured in 1:2.5 soil water ratio using glass electrode. Total exchangeable cations and CEC was determined by following standard procedures as described by Jackson (1973). Based on morphological and physico chemical properties, soils under rice cultivation at Borhola area was placed under order Alfisol and classified at subgroup level as Oxyaquic Hapludalf. The soils under natural forest land (Gibbon wildlife sanctuary), vegetable land (Experimental Horticultural Farm, Assam Agricultural University, Jorhat) and Tea plantation (Experimental Tea Garden, Assam Agricultural University, Jorhat) was classified as Typic Dystrudepts in the subgroup level under the order Inceptisol.

Soil aggregate analysis

Yodder's wet sieving method (1936) was followed for soil aggregate analysis. Soil samples each weighing 300 g were equilibrated in a nest of sieves in water for about 30 minutes followed by collection of aggregates and coarse materials remained on each sieve and their oven dry weight was recorded. Then, soil mass retained on each sieve is dispersed in H_2O_2 and HCl and again the dispersed aggregates are passed through the same sieves on which they were retained earlier. The unaggregated soil particles on each sieve are then collected and oven dry weight is taken as per the procedure mentioned earlier. The size aggregates ranging from > 5mm to 0.25mm are considered as macro aggregates and <0.25mm size aggregates are considered as microaggregates. Mean weight diameter (MWD) was calculated as per the method described by Van Bavel (1949). According to the procedure it was calculated as:

$$\text{Mean Weight Diameter (MWD)} = \Sigma XiWi$$

Where X (in millimeter) is the average diameter of the openings of two consecutive sieves, and W is the weight ratio of aggregates remained on the i^{th} sieve. For determination of aggregate size distribution the weight ratio of aggregates of each sieve (>5, 5±2, 2±1, 1±0.5, 0.5±0.25 and <0.25 mm) to the total weight of aggregates was calculated.

Erodibility indices

Four soil indices *viz* dispersion ratio (DR), clay ratio (CR), modified clay ratio (MCR) and erosion ratio (ER) were evaluated to assess the soil erodibility status. Dispersion ratio was expressed as ratio between the amount of silt + clay dispersed in water to the amount of silt + clay obtained in complete dispersion method (Middleton, 1930). Soils with dispersion ratio above 15 are erodible and below 15 are non erodible. Water dispersion is done by taking 10 g soil dispersed in 1000 ml distilled water without any prior treatment. Silt and clay was collected depending upon the settling velocity time as mentioned under international pipette method (Piper, 1950). Clay Ratio (Bouyoucos, 1935) is expressed as ratio between the amounts of sand + silt percent in soil to percent clay obtained in complete dispersion. Modified clay ratio (Bryan, 1967) is expressed as ratio between the amounts of sand + silt percent in soil to the percent clay obtained in complete dispersion + organic matter content. Erosion ratio (Middleton, 1930) is expressed as the ratio between dispersion ratio and colloid moisture equivalent ratio (CMER).

$$\text{Where, CMER} = \frac{\text{(\% silt + clay) in complete dispersion}}{\text{Field capacity of the soil}}$$

RESULTS AND DISCUSSION

The particle size distribution along with bulk density and water holding capacity of the soils under different land uses are presented in Table 1. The particle size distribution data revealed a wide variation in sand, silt and clay content of the soils. Sand fraction of soils ranged from 23.6 to 66.8 per cent, highest being in Ap horizon of P2 (upland vegetable growing area) and lowest in Bt3 horizon of P1 (rice field). Contrary to this observation, the highest amount of clay (52.7%) was observed in the lower most horizon of P1 while the surface horizon of P2 was recorded for the lowest amount (15.6%). Sand fraction in all the profiles irrespective showed a decreasing trend along depth while clay fraction exhibited a complete reverse trend. Silt content of the soils ranged from 13.2 to 26.7 per cent, maximum in the Bw1 horizon of P4 (forest land) and minimum in the Bw3 horizon of P3 (Tea plantation). The texture of the soils varied from sandy loam to clayey. It ranged from clay loam to clay in rice soils (P1), where as in case of upland and forest land, it was sandy loam to sandy clay loam and sandy clay loam to clay loam respectively. The bulk density of the studied soils ranged from a minimum value of 1.19 gcc^{-1} in Ap

Table 1. Physical characteristics of the soils under different land uses

Horizon	Depth (cm)	Particle Size Distribution (%)			Texture	Bulk Density (g/cm^3)	Water Holding Capacity (%)
		Sand	Silt	Clay			
P1: Rice field (Oxyaquic Hapludalf)							
Ap	0-25	42.0	25.8	32.2	Clay loam	1.33	35.9
BA	25-55	40.5	24.7	34.8	Clay loam	1.27	38.6
Bt1	55-85	31.8	23.5	44.7	Clay	1.30	37.8
Bt2	85-125	27.4	22.0	50.6	Clay	1.19	41.5
Bt3	125-185	23.6	23.7	52.7	Clay	1.30	32.6
P2: Upland vegetable growing area (Typic Dystrudepts)							
Ap	0-15	66.8	17.6	15.6	Sandy loam	1.57	33.4
BA	15-35	62.1	18.3	19.5	Sandy loam	1.46	27.6
Bw1	35-55	55.8	20.8	23.3	Sandy clay loam	1.33	32.1
Bw2	55-105	54.2	20.0	25.8	Sandy clay loam	1.31	29.7
P3: Tea plantation (Typic Dystrudepts)							
A	0-20	61.6	17.5	21.8	Sandy clay loam	1.45	33.1
Bw1	20-50	55.0	15.6	29.4	Sandy clay loam	1.46	30.4
Bw2	50-90	52.3	15.0	32.7	Sandy clay loam	1.41	32.6
Bw3	90-120	52.9	13.2	33.9	Sandy clay loam	1.37	30.2
Bw4	120-150	50.7	14.5	34.8	Sandy clay loam	1.30	29.7
P4: Forest (Typic Dystrudepts)							
A1	0-5	57.3	23.7	19.0	Sandy clay loam	1.43	33.7
BA	5-20	50.2	26.1	23.6	Sandy clay loam	1.41	39.2
Bw1	20-45	47.3	26.7	26.0	Sandy clay loam	1.40	40.1
Bw2	45-80	44.1	24.0	31.7	Clay loam	1.38	41.1
Bw3	80-120	43.1	23.01	33.8	Clay loam	1.35	41.7

horizon of P2 to a maximum value of 1.57 gcc^{-1} in Bt2 horizon of P1. It showed a highly significant negative correlation with clay fraction (r = -0.69**). Water holding capacity ranged from 27.6 to 41.7 per cent, highest being in P4 (weighted mean 40.56%) and lowest in P2 (weighted mean 30.28%).

A perusal of the data presented in Table 2 indicated very strongly to strongly acid condition of the soils with a pH range of 4.5 to 5.0. The pH of the soils under rice land was quite higher (5.2 - 5.5) compared to the soils under other land uses (4.5 - 5.0). Comparatively higher pH in soils under rice land might be attributed to seasonal saturation with water. Organic carbon content of the soils ranged from a minimum value of 0.1 per cent in Bw2 horizon of P2 of upland vegetable soils to 2.06 per cent in the surface horizon P4 under forest soils. Surface horizons of all the pedons recorded the highest organic carbon content within a profile (0.76 – 2.06%) and it decreased regularly with the soil depth. Variation in organic carbon content in soils under various land uses is due to the varying nature of leaf litter, biomass amount, their nature and the rate of decomposition (Ray *et al.*, 2006). Total exchangeable bases of the soils were quite low (1.71 – 5.82 cmol $(p^+)kg^{-1}$ and found to be regularly decreased with the depth of the profile in all the soils. CEC of the soils are low ranging from 6.1 to 11.3 cmol $(p^+)kg^{-1}$. The variation of CEC in the studied soils was found to be mainly governed by the amount of clay as indicated by a significant and positive relation (r = 0.51*) between these two properties.

Soil aggregation

Soil aggregation was studied in terms of percent distribution of water stable aggregates, macroaggregates, microaggregates and mean weight diameter and values were presented in Table 2. The per cent water stable aggregate (WSA) of the studied soils was varied from 43.08 to 72.37 per cent. In Rice soil, the highest percentage of water stable aggregate (WSA) was recorded in both Bt1 and Bt2 horizon (57.18 %) at a depth of 55-125 cm while the lowest amount (50.73%) was observed just below this depth, at Bt3 horizon. Similar to the rice soil, the lower most horizon of vegetable growing area and tea plantation soils also exhibited the lowest water stable aggregates. But the surface horizon of all the soils except rice contained the

Table 2. Important chemical properties, distribution of different size fractions of Water Stable Aggregates (WSA) and Mean Weight Diameter (MWD) of the soils under different land uses

Horizon	Depth (cm)	pH	OC (%)	Total Exchangeable cation	CEC	Aggregate (%)	Macro Aggregate (%)	Micro Aggregate (%)	MWD (mm)
				cmol $(p^+)kg^{-1}$					
P1: Rice field (Oxyaquic Hapludalf)									
Ap	0-25	5.2	0.83	5.07	10.1	53.39	38.49	14.90	1.14
BA	25-55	5.3	0.46	4.34	9.6	51.64	43.46	8.18	1.03
Bt1	55-85	5.3	0.39	4.00	8.5	57.18	53.08	4.10	1.14
Bt2	85-125	5.2	0.22	3.87	10.5	57.19	51.08	6.11	0.79
Bt3	125-185	5.5	0.21	3.44	9.3	50.73	42.36	8.42	0.77
P2: Upland vegetable growing area (Typic Dystrudepts)									
Ap	0-15	4.7	0.76	2.92	7.0	59.04	45.40	13.64	1.70
BA	15-35	4.8	0.38	2.40	6.3	43.08	31.47	11.61	0.48
Bw1	35-55	4.6	0.14	2.19	6.3	48.76	41.20	7.56	0.58
Bw2	55-105	4.7	0.10	1.92	6.1	39.92	22.40	17.52	0.30
P3: Tea plantation (Typic Dystrudepts)									
A	0-20	4.6	1.23	4.23	9.6	63.87	56.24	7.63	3.19
Bw1	20-50	4.7	0.55	3.19	11.3	58.95	45.24	13.71	0.40
Bw2	50-90	4.5	0.48	2.63	7.8	57.55	33.53	24.02	0.37
Bw3	90-120	4.6	0.33	2.08	8.5	60.44	37.24	23.20	0.47
Bw4	120-150	4.9	0.34	2.31	10.1	49.13	30.12	19.01	0.37
P4: Forest (Typic Dystrudepts)									
A1	0-5	5.0	2.06	5.82	8.7	72.37	66.97	5.40	3.30
BA	5-20	4.5	0.64	3.81	7.6	50.36	37.75	12.61	0.75
Bw1	20-45	4.6	0.52	2.52	10.0	59.03	40.81	18.22	0.36
Bw2	45-80	5.0	0.40	2.30	7.8	56.11	36.09	20.02	0.48
Bw3	80-120	4.9	0.36	1.71	6.1	59.16	37.66	21.50	0.50

highest amount of water stable aggregates. The depth distribution trend of WSA is quite similar between P2 and P3. In forest soil, the trend was somewhat different. It showed maximum percentage of WSA in the A1 horizon (72.37%) to a depth of 5 cm and minimum (50.36%) in the BA horizon to a depth of 5-20 cm. It was observed that horizons of all the soil profiles showed more or less a decreasing trend in per cent WSA (Table 2) with depth, except for rice soil. Considering the weighted mean of the whole soil profile, soils under natural forest and tea plantation exhibited the equal amount of WSA (57.63 and 57.56 %) followed by rice soil (53.67%). Vegetable growing area was recorded for the lowest amount (44.93%) of WSA (Fig 1). Purported benefits of canopy cover under forest vegetation and tea plantation which results in accumulation of higher amount of organic matter including litter material, plant roots and thereby help in formation of higher amount of stable aggregates. The highest WSA in the surface horizon of P4 (natural forest) is attributed to the highest amount of organic carbon (2.06%) as well as total exchangeable cation (5.82 cmol $(p^+)kg^{-1}$) in that horizon. Organic carbon and total exchangeable cation was found to be the most influential factors affecting the soil aggregation in these alluvium derived soils as indicated by highly significant relationship between these two parameters with WSA (Table 4). Organic carbon content of a soil is one of the most important factor linked with stability of soil aggregates (Sparling *et al.*, 1992), which is because organic carbon and metal humus complexes are pivotal binding agents that helps in stable aggregate formation. Singh and Rathod (2003) also reported the effect of total exchangeable cations on soil aggregation.

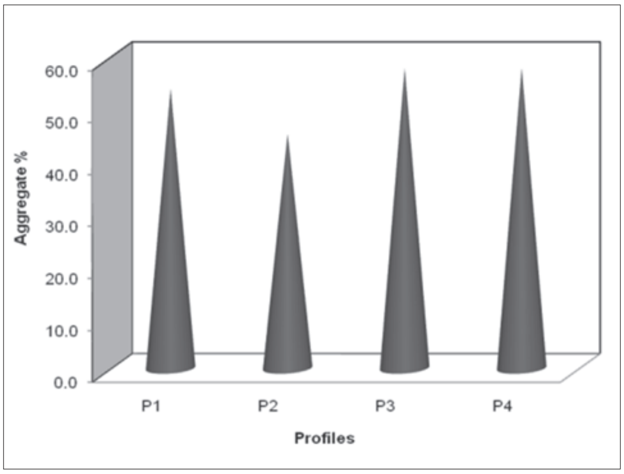


Fig 1. Percentage of water stable aggregates and distribution macro and micro aggregate in soil profiles (weighted mean)

The Water Stable Aggregates of the studied soils were divided in to two groups based on size of the aggregates. The size aggregates ranging from less than 5 mm to 0.25 mm are considered as macro aggregates and aggregates smaller than 0.25 mm size are considered as microaggregates. The macroaggregates of the soils varied from a minimum value of 30.12% in the Bw4 horizon of P3 (tea plantation) to the maximum value of 66.97 % in the surface horizon of P4 (natural forest). Baring soils under rice cultivation, this aggregate class showed more or less a decreasing trend with the depth of the soil (Table 2). The distribution of macro aggregate however showed a completely different picture to that of WSA if whole profile (weighted mean) was considered (Fig 2). It was highest in rice soil (45.63 %). The lowest value was recorded in vegetable growing land (30.99%) while soils under tea plantation and natural forest have equal amount of this type of aggregates (38.96%). Contrary to macroaggregate content, microaggregate was found lowest in rice soils (weighted mean, 8.05%) and vegetable growing areas showed an intermediate value of 13.94% (Fig 2). The other two soils exhibited equal percentage (18.65%) of microaggregate (Fig 2a). It ranged from 4.10 to 24.02% which is significantly lower than the amount of macroaggregates (Table 2). Microaggegate exhibited a distinctly increasing trend with the depth of the soil profile under tea plantation, natural forest system but trend was irregular in the two soils under cultivation (Table 2).

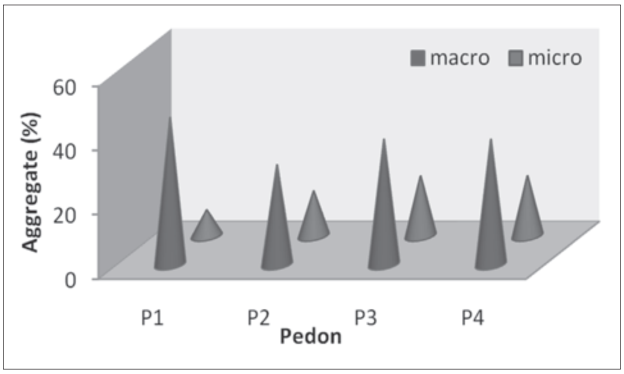


Fig 2. Distribution of macro and micro aggregates (weighted mean of profiles in percentage) of the soils

Gupta and Germida (1988) reported a greater proportion of macro aggregates in a natural system than in a cultivated system. This assumption holds true for the surface horizons of the soils studied. But aggregation in the whole profile gave a different picture. Disintegration and dispersion of macroaggregates during puddling operation in rice cultivation might be the reason behind the minimum percentage of macroaggregates in the surface horizon. The puddling operation carried out during rice cultivation year after year, may lead to destruction of macro aggregate in the surface and on the other hand increased compaction might lead to the formation of poorly porous cloddy aggregates in the sub surface horizon. The finding is also well supported by the observation of Gupta and Nagaraja Rao (1982). In cultivated land, the below ground food web is bacterially dominated while in case of forest it is fungally dominated. There are reports that fungi dominate in macro aggregates and bacteria in micro aggregates (Tisdall and Oades, 1982). Complete acidification of soils profile due to acid weathering processes as indicated by the pH values might have lead to dominance of fungi in the studied soils resulting in higher amount of macroaggregates. It was also found to be influenced by organic carbon and total exchangeable cation as reflected in the highly significant relationship between these two parameters with macroaggregates (Table 4). Such relationship was not observed in case of microaggregates probably due to the differences in the distribution pattern of organic carbon and exchangeable cations to that of macroaggregates under different land use systems. But highly significant relationship was observed between clay and microaggregates in soils (r = 0.91**) under tea plantation and natural forest which displayed the dominant role of the finer fraction in these undisturbed soils.

Across all depths, MWD found highest under surface soils of forest land (3.30 mm) and lowest in the lower most horizon of vegetable land (0.30 mm). MWD under the four land uses differed primarily in the surface horizons and followed the order forest land > tea land> vegetable land>rice land. As depth increases, MWD showed a decreasing trend to a certain depth and then increased again. MWD has positive and highly significant relationship with organic carbon, total exchangeable cations (Table 4), WSA (r = 0.64**) and macroaggregates (r = 0.80**). But it showed a negative significant relationship with microaggegates (r =0.55*).

Soil erodibility

Erodibility of soils under different land uses was compared on the basis of erodibility indices *viz.* dispersion ratio, erosion ratio, clay ratio and modified clay ratio (Table 3). Dispersion ratio (DR) ranged from 14.1 to 31.8 in these soils. The clay ratio (CR) and modified clay ratio (MCR) varied

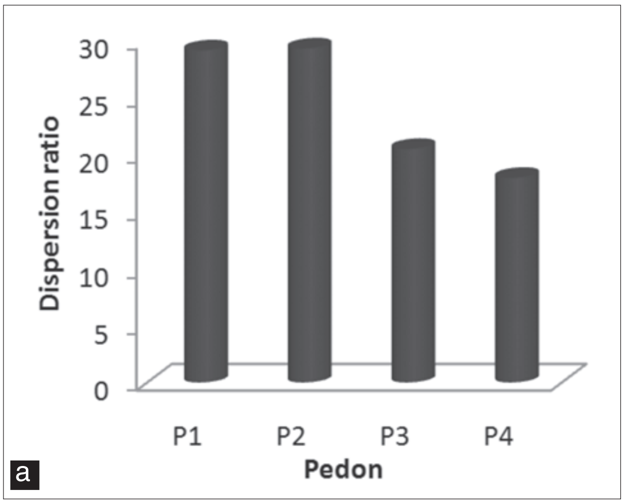
Table 3. Soil erodibility indices of soils under different land use systems

Horizon	Depth (cm)	Dispersion Ratio (DR)	Clay Ratio (CR)	Modified Clay Ratio (MCR)	Erosion Ratio (ER)
P1: Rice field (Oxyaquic Hapludalf)					
Ap	0-25	31.8	1.44	1.38	15.49
BA	25-55	27.9	1.24	1.21	13.32
Bt1	55-85	28.3	1.03	1.02	12.40
Bt2	85-125	28.8	0.89	0.88	10.88
Bt3	125-185	29.5	0.88	0.87	10.20
P2: Upland vegetable growing area (Typic Dystrudepts)					
Ap	0-15	30.4	5.29	4.76	19.54
BA	15-35	29.4	4.24	4.05	17.17
Bw1	35-55	30.5	3.90	3.84	13.54
Bw2	55-105	28.6	3.72	3.68	14.07
P3: Tea plantation (Typic Dystrudepts)					
A	0-20	16.4	4.40	3.81	9.53
Bw1	20-50	18.6	3.90	3.67	9.28
Bw2	50-90	22.0	3.19	3.04	10.46
Bw3	90-120	20.6	2.79	2.71	10.37
Bw4	120-150	23.1	2.62	2.54	10.41
P4: Forest (Typic Dystrudepts)					
A1	0-5	14.1	4.01	3.21	8.68
BA	5-20	15.4	3.17	2.99	7.29
Bw1	20-45	17.1	2.80	2.68	7.81
Bw2	45-85	17.9	2.23	2.17	8.08
Bw3	85-125	20.0	2.11	2.06	8.87

Table 4. Correlation coefficient between different physic chemical properties and aggregate stability parameters in the whole soil profile

	Sand	Silt	Clay	BD	WHC	pH	OC	Total Exch. cations	CEC
WSA	0.07	0.00	-0.08	0.31	0.29	-0.03	0.71**	0.45*	0.36
Macro aggregates	-0.08	0.22	0.01	0.11	0.25	0.27	0.70**	0.74**	0.38
Micro aggregates	0.22	-0.36	-0.11	0.18	-0.07	-0.47*	-0.30	-0.66**	-0.20
MWD	0.26	0.09	-0.33	0.32	0.00	0.08	0.88**	0.72**	0.15
ER	0.28	-0.18	-0.24	0.18	-0.39	0.11	-0.15	-0.03	-0.33
DR	-0.26	0.01	0.29	-0.35	-0.2	0.44	-0.50*	-0.01	-0.17

from 0.88 to 5.29 and 0.87 to 4.76, respectively. Erosion ratio of the soils also varied widely from 7.29 to 19.54. The highest average value of dispersion ratio (weighted mean of profile) was observed in vegetable area (29.37) followed by rice soil (27.10) and lowest value (17.96) in forest soils (Fig 3a). Erosion ratio was highest in upland soils (15.34) followed by rice soils (11.92), tea soils (10.07) and forest soils with a value of 8.2 (Fig 3b). The highest weighted mean of clay ratio was found in upland soils (4.07) followed by tea soils (3.29), forest soils (2.48) and rice soils (1.04). Modified clay ratio followed the same trend. Soils under forest land use were more stable as compared to the soils under cultivation and may ascribe to the higher organic carbon content resulting in more stability of soil aggregates. Higher clay content in rice land and largest amount of biomass in forest land might be the main reason of lowest value of CR and MCR in these two land use systems. Significant negative correlation of dispersion ratio was found with organic carbon (r= 0.50*) in these soils. This is in conformity with the findings of Gupta *et al*. (2010) and Saha *et al.* (2011).



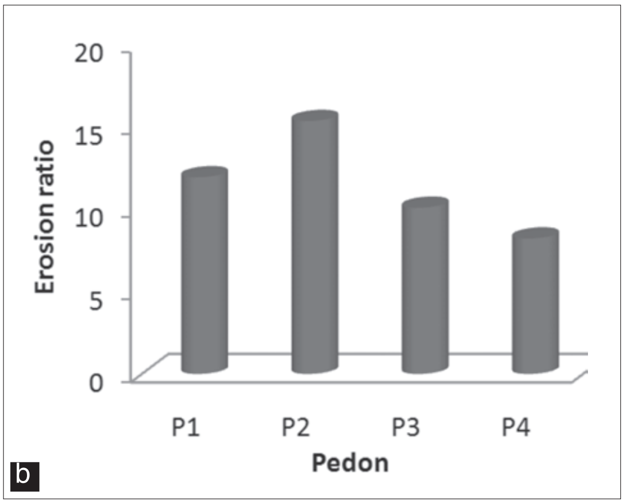


Fig 3. (a) Dispersion and (b) Erosion ratio of the soil profiles (weighted mean)

CONCLUSION

The present study clearly demonstrates the influence of land use systems on soil aggregation. This is because of the inputs of particular types of plant biomass, such as litter and fine roots, into the soil are very different under different land uses and the resulting aggregate content is also significantly different for different land uses. Organic carbon and total exchangeable cations was found to be the two main governing factors of soil aggregation in the present study area. Clay also found to have positive role in the process of microaggregation under stable land use system. Soils under disturbed conditions are prone to natural degradation processes as reflected in the soil erodibility indices. However future study on fractionation of organic carbon, individual cations, microbial population and pedogenic oxides under different land use system will be of great importance in understanding the precise role of all factors influencing the soil aggregation in these alluvium derives soils.

REFERENCES

Bhatt, R. and Arora, Sanjay 2015. Impact of tillage on soil bio-chemical properties, water storage and environment. *Journal of Soil and Water Conservation* **14**(3): 278-282.

Black, C.A. 1965. *Methods of Soil Analysis* part 2. Chemical and Microbiological properties. Am. Soc. Agronomy, Inc, Publisher, Madison, Wisconsin USA.

Bouyoucos, G.J. 1935. The clay ratio as a criterion of susceptibility of soils to erosion. *J. Amer. Soc. Agron*. **27**: 738-751.

Bryan, R.B. 1967. The development, use and efficiency of indices of soil erodibility. *Geoderma* **2**: 5-26.

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

Gupta, R.P. and Nagaraja Rao, Y. 1982. Soil structure and its management. Review of Soil Research (Part-1). *Proc.12th Indian Cong. Soil Sci.* 61-76.

Gupta, V.V.S.R. and Germida, J.J. 1988. Distribution of microbial biomass and its activity in different soil aggregate size classes as affected by cultivation. *Soil Biol. Biochem.* **20**:777-786.

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

Jackson, M. L. 1956. *Soil Chemical Analysis*. Advanced course, privately published, Madison, WI, 991 pp.

Middleton, H.E. 1930. Properties of Soils which influence soil erosion. USDA Technical Bulletin. United State Department of Agriculture, USA.

Piper, C.S. 1950. Soil and plant analysis. The Academic Press, N.Y. U.S.A.

Ray, R., Mukhopadhyay, K. and Biswas, P. 2006. Soil aggregation and its relationship with physico-chemical properties under various land use systems. *Indian J. Soil Cons.* **34**(1): 28-32.

Richards, L.A. 1948. Porous plate apparatus for measuring moisture retention and transmission by soil. *Soil Sci*. **66**: 105-110

Saha, R., Mishra, V.K. and Khan, S.K. 2011. Soil erodibility characteristics under modified land-use systems as against shifting cultivation in hilly ecosystems of Meghalaya, India. *J. Sustain. Forest* **30**: 301-312.

Sahi, B.P., Singh, S.N., Sinha, A.C. and Acharya, B. 1977. Erosion Index - A new index of soil erodibility. *J. Indian Soc. Soil Sci.* **25**(1): 7-10.

Sharma, V. and Arora, Sanjay 2015. Land degradation processes and factors affecting crop production in Foothills of Jammu Shivaliks. *Journal of the Soil and Water Conservation* **14**(4): 294-299.

Singh, D.V. and Rathore, T.R. 2003. Soil strength and its relation with exchangeable cations, organic carbon and finer soil fractions. *Indian Journal of Agricultural Research* **37**(1): 17-22

Sparling, G.P., Shepherd, G. and Kettles, H.A. 1992. Change in soil organic carbon, microbial carbon and aggregate stability under continuous maize and cereal cropping, and after restoration to pasture in soils from Manawata region, New Zealand. *Soil and Tillage Research* **24**: 225-241.

Tan, Z.X., Lal, R., Smeck, N.E. and Calhoun, F.G. 2004. Relationships between surface soil organic carbon pool and site variables. *Geoderma* **121:** 187–195.

Tisdall, J.M. and Oades, J.M. 1979. Stabilization of soil aggregates by the root systems of ryegrass. *Aust. J. Soil Res.* **17**:429-441**.**

Tisdall, J.M. and Oades, J.M. 1982. Organic matter and water-stable aggregates in soils. *J. Soil Sci.* **33**: 141-163.

Van Bavel, C.H.M. 1949. Mean weight diameter of soil aggregates as a statistical index of aggregation. *Soil Sci. Am. Proc.* **14**: 20-23.

Walkley, A. and Black, I. A. 1934. An examination of digestion method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.* **37**: 29-37.

Yodder, R.E. 1936. A direct method of aggregate analysis and study of physical nature of erosion losses. *J. American Soc. Agron.* **28**: 337-351.

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Determination of erodibility under different land uses in the vicinity of Nirjuli, Arunachal Pradesh

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ABSTRACT

In the vicinity of Nirjuli (study area), five types of land uses are prominent and this study is aimed to find the erosive nature of the study area. Soil samples were collected from two depths i.e. 0-15, 15-30 cm from 5 land uses in the vicinity of Nirjuli. Various erodibility indices, i.e. erosion ratio, dispersion ratio, clay/moisture equivalent ratio, moisture equivalent were worked out. Correlation and regression equations were developed among erodibility indices. Mechanical composition of the soils of the experimental site reveals that in all land uses, soils were found to be coarser in texture. Results suggested that all soils (top surface and sub-surface) were found to be highly erodible as the value of dispersion and erosion ratio was more than 15 and 10, respectively in all land uses. The correlation between erosion ratio and dispersion ratio was found to be highly significant and positive. The dispersion ratio which is much easier to determine and therefore is recommended for determining the erodibility behaviour of the soils in the study area.

Key words: soil erodibility, dispersion ratio, erosion ratio

INTRODUCTION

Soil erosion is a process of detachment and transportation of soil materials from its original position by the action of wind, water, etc. In this process, the most fertile portion of the land, i.e., top soil which is rich in plant nutrients, organic matter and soil micro-organisms are physically removed from its position, and decreasing the soil fertility and productivity of the soil.

Soil erosion is greatly influenced by erosivity and erodibility. Erosivity depends on rainfall and erodibility broadly depends on physical features, topographic features and land crop management (Hadda *et al*., 2007; Upadhayay *et al*., 2013). Long term automatic rain gauge data can be used for computing erosivity. However, soil erodibility refers to the soil inherent susceptibility to erosion by rainwater and runoff. This is a function of a complex interaction of physical and chemical properties of soils affecting detachability, transportability and infiltration capacity. It is expressed in tonnes ha/ year/unit of rainfall erosivity index.

The assessment of erosion hazard can be quantified (i) by soil erodibility factor 'K' of USLE from the runoff plot which is quite expensive, time consuming and is not feasible at all places (ii) By using a simple nomograph developed by Wiscmeier *et al.* (1971) to find the value of 'K' and (iii) by different erosion indices of soil such as erosion ratio, dispersion ratio etc. as described by Middleton (1930) and correlating these with organic carbon(%), pH, ESP, ME(%) etc. (Dabral *et al.*, 2001).

The erodibility status in the hilly part of Dikrong river basin of Arunachal Pradesh (India) under different land uses were determined (Dabral *et al.*, 2001). Ravinder Kaur *et al.* (2003) have reviewed the development and use of various soil erodibility indices during the last thirty years on varied Indian soil types developed from different parent materials and exposed to varying land uses. Singh *et al.* (2006) determined the soil characteristics and erodibility indices of three soil depths *viz.*, 0-5, 5-15 and 15-30 cm under five different land uses, namely under *Leucaena*, *Prosopis,* rain-fed agriculture, grasses and open gullies lands for their management and sustained production in southeast Rajasthan (India). Das *et al*. (2007) evaluated soil erodibility factor 'K' and its relationship with some soil properties of Marmring-Patle micro-watershed in Darjeeling (India). Singh and Kundu *et al.* (2008) determined the erosion index for surface as well as subsurface layers of 26 soil sub groups of eastern Indian soil.

In the vicinity of Nirjuli, Arunachal Pradesh, five types of land uses are prominent i.e land under tea plantation, paddy cultivation kitchen

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garden, barren land and under river bed. Since, limited information is available on the erodibility status under these land uses at Nirjuli. Therefore, it was planned to determine erosive nature of the soil by estimating the erosion ratio and the dispersion ratio under different land uses and to find out the the correlation of erosion ratio with dispersion ratio, organic carbon (%), pH, bulk density and EC.

MATERIALS AND METHODS

Soil sampling of experimental site

In the vicinity of Nirjuli (Arunachal Pradesh), there are five land uses, existing prominently i.e. i) land under tea plantation, ii) land under paddy cultivation iii) land under kitchen garden, iv) barren land and v) land under river bed. Soil samples were taken with the help of tubular auger at three depths, i.e., 0-15, 15-30 cm from these five land uses. Soil samples were dried and were analyzed for various soil properties in Soil and Water Conservation Engineering Laboratory of the Department of Agricultural Engineering, NERIST, Nirjuli (Itanagar), Arunachal Pradesh.

Mechanical analysis of soil by hydrometer method

Determination of soil texture (sand, silt and clay precentage) of different land uses was determined using hydrometer method. Detail of the hydrometer method is described in the work of Pandey *et al.* (2009). For determining the dispersion ratio, R_1 (hydrometer reading at 4 min) and R_2 (hydrometer reading at 2 hours) were taken without using sodium hexametaphosphate in soil solution during the study.

Determination of bulk density, pH and organic carbon and electrical conductivity of soil

The bulk density of soil was measured by the method suggested by Punamia (1988), pH by by using glass electrode, organic carbon by Walkely and Black's oxidation method (Piper, 1950). EC of soil solution was determined with the help of Systronics S.C.D Meter 311 .

Determination of dispersion ratio

Dispersion ratio of the soil was calculated by the formula suggested by Middleton (1930) as given below:

$$\text{Dispersion ratio} = \frac{100 \text{ x water dispersible silt + clay}}{\text{Total dispersible silt + clay}} \quad ....(1)$$

Determination of moisture equivalent

Moisture equivalent is generally determined by Briggs McLane centrifuge. Since this equipment was not available, it was determined by indirect method suggested by De (1962) as given below.

$$\text{Moisture Equivalent (\%)} = 0.02 \text{ Sand (\%)} + 0.22 \text{ Silt (\%)} + 1.05 \text{ clay (\%)} \quad .....(2)$$

Determination of erosion ratio

Erosion ratio was calculated by the formula suggested by Middleton (1930) as given below:

$$\text{Erosion ratio} = \frac{\text{Dispersion ratio}}{\text{(Clay \textbackslash\ ME ratio)}} \quad .....(3)$$

Determination of correlation coefficient

The simple correlation coefficient was determined among erosion ratio, dispersion ratio, clay/ ME ratio, moisture equivalent, organic carbon (%), bulk density, EC and pH. Microsoft excel software was used for this purpose. Significance of correlation coefficient was determined at probability level of 1% using t-test as given below.

$$t = \frac{r\sqrt{(n-2)}}{\sqrt{1-r^2}} \quad ....(4)$$

Where, t= calculated value of t-test, r= correlation coefficient and n= no. of observations.

RESULTS AND DISCUSSION

Physico -chemical properties of soils under different land uses

Organic carbon (%) in the soils of tea cultivation, paddy cultivation, kitchen garden, river bed and barren land at the top surface (0-15 cm) was found to be 2.56, 0.76, 1.51, 2.68 and 1.87 per cent, respectively. Higher percentage of organic carbon (2.56 %) in the soil of tea cultivation was due to the fact that during plantation, a lot of organic matter is added to the soil through various mulch materials. Lower percentage of organic carbon (0.76) was present in soil under paddy cultivation (Table 1).

Organic carbon in the soils of tea cultivation, paddy cultivation, kitchen garden, river bed and barren land at the top surface (15-30 cm) was found to be 0.2, 0.33, 0.58, 1.61 and 2.83 %, respectively. Higher percentage of organic carbon (2.83 %) was found in the soil of barren soils. Lower percentage of organic carbon (0.20%) was present in the soil under tea cultivation (Table 1).

The low bulk density was found to be in the surface in the range of 1.23 to 1.58 g cm^{-3} in the soils of all land uses. In subsurface soil the range of bulk density was found to be 1.24 to 1.94 g cm^{-3} in soil of all land uses. In general, value of bulk density was low in all soils due to more percentage of sand content (Table 1).

The value of electrical conductivity was observed to be in surface soils in the range of 220 to 275 $\times 10^{-6}$

Table 1. Physico-chemical properties of different land uses in study site

Land use	Soil depth (cm)	Organic carbon(%)	Bulk density (g cm^{-3})	EC (10^{-6} mhos cm^{-1})	pH
Tea cultivation	0-15 15-30	2.56 0.20	1.58 1.94	275 260	4.45 4.31
Paddy cultivation	0-15 15-30	0.76 0.33	1.48 1.43	256 360	5.29 5.67
Kitchen garden	0-15 15-30	1.51 0.58	1.54 1.36	220 120	6.56 6.99
River bed	0-15 15-30	2.68 1.61	1.32 1.24	220 200	6.77 6.76
Barren land	0-15 15-30	1.87 2.83	1.23 1.79	260 270	5.30 5.44

mhos cm^{-1} and 120 to 360x10^{-6} mhos cm^{-1} in the subsurface soil in all land uses (Table 1).

The pH value was observed to be in the range of 4.45 to 6.77 in the surface soils in all land uses. In subsurface soil, pH was found to be in the range of 4.31 to 6.99 in all land uses. Soils were found to be acidic in nature in all the land uses (Table 1).

Mechanical composition of the experimental site

Mechanical composition of the soils of experimental site reveals that in all land uses, soils were found to be coarse in texture. The percentage of sand, silt and clay varied in all the soils of all land uses. In general percentage of silt was quite low in top soil surface (0-15) than subsurface soil (15-30) in all land uses (Table 2).

Erodibility status of soil in different land uses

According to the criteria of Middleton (1930), the soils having dispersion ratio value above 15 and the erosion ratio above 10 are erosive in nature. Results suggested that all soils (surface and subsurface) were found to be highly erodible as the value of dispersion and erosion ratio are more than 15 and 10, respectively in all land uses (Table 2).

The high value of erosion ratio in surface layer is more conducive to sheet erosion while high value in lower depths indicates its higher susceptibility to gully erosion; once the top layers are eroded (Bhola and Mohan, 1982). Therefore, from the study it is advisable to go for extensive soil conservation measures and proper maintenance of soils in the study area.

Correlation of erosion ratio with various indices of erodibility and soil properties

Erosion ratio has been widely accepted as a reliable index of soil erodibility. Therefore, its correlation was worked out with various indices of erodibility. Dispersion ratio was found to be directly proportional to erosion ratio. The correlation between erosion ratio and dispersion ratio was found to be highly significant and positive (0.8455), substantiating the earlier findings (Sharma *et al*., 1987; Dabral *et al*., 2001: Agnihotri *et al*., 2007; Hadda *et al*., 2008; Gupta *et al*., 2010). As the dispersion ratio increased, the erosion ratio also increased, indicating the erodibility of soils. The dispersion ratio is much easier to determine may, therefore, be recommended for determining the erodibility of soil under study (Table 3).

Clay/Moisture equivalent ratio was found to be inversely proportional to erosion ratio. This supports the finding of Middleton (1930). Moisture equivalent (%) was found to be inversely proportional to erosion ratio and both were found

Table 2. Mechanical composition, physical constant, dispersion ratio and erosion index of soils in different land uses of study site

Land Use	Depth (cm)	Mechanical Composition (%)			Silt+ clay dispersible in water (%)	Moisture Equivalent (%)	Clay/ Moisture equivalent ratio	Dispersion ratio	Erosion ratio
		Sand	Silt	Clay					
Tea cultivation	0-15 15-30	98.397 98.401	0.009 0.005	1.594 1.594	1.601 1.596	3.644 3.643	0.437 0.438	99.88 99.81	228.3 228.1
Paddy cultivation	0-15 15-30	98.866 98.396	0.019 0.008	1.115 1.596	1.143 1.595	3.152 3.645	0.354 0.438	100.79 99.44	285.0 227.1
Kitchen garden	0-15 15-30	98.405 98.400	0.003 0.006	1.592 1.594	1.594 1.590	3.640 3.643	0.437 0.438	99.94 99.38	228.5 227.1
River bed	0-15 15-30	98.409 98.409	0.001 0.001	1.590 1.590	1.582 1.590	3.638 3.638	0.437 0.437	99.43 99.94	227.5 228.7
Barren land	0-15 15-30	98.392 98.395	0.013 0.013	1.595 1.592	1.596 1.598	3.645 3.642	0.438 0.437	99.25 99.56	226.8 227.8

Table 3. Correlation between erosion ratio(Y) and soil properties(X)

Soil Property(X)	Coefficient of correlation with Erosion ratio(Y)	Regression equation
Dispersion ratio	0.8455 **	Y=-3181.7+34.241X, R^2=0.715
Clay/ ME ratio	-0.9995**	Y=526.71-638.47X, R^2=0.999
ME ratio	0.845**	Y=652.95-116.74X, R^2=0.999
Organic carbon(%)	-0.253NS	
Bulk density	-0.003NS	
Electrical conductivity	-0.130NS	
pH	-0.170NS	

*** Significant at 1 % level, NS= not significant*

to be highly significant negatively correlated (-0.9995) (Table 3).

In fact, the moisture equivalent (%) determination needs sophisticated equipment, i.e., Briggs Mclane Centrifuge which is rarely available in all soil and water laboratory. In the present study, due to non-availability of equipment, it was determined by indirect method suggested by De (1962). Therefore, clay / moisture equivalent ratio and moisture equivalent (%) indices may face problem in its determination and cannot be advised for determining the erodibility of the soil in the study.

Correlation of erosion ratio with organic carbon (%), bulk density, electrical conductivity and pH was found to be non-significant. The linear regression equations relating the important properties (Dispersion ratio, Clay/ME ratio and ME ratio) are described in Table 3 to estimate the erosion ratio in the study area and similar soils.

CONCLUSION

From the study it was observed that all soils (surface and subsurface) in different land uses were found to be highly erodible as the value of dispersion and erosion ratio was more than 15 and 10, respectively in all land uses. The correlation between erosion ratio and dispersion ratio was found to be highly significant and positive. The dispersion ratio which is much easier to determine, so may be recommended for determining soil erodibility behaviour of the soils in the study area.

REFERENCES

Agnihotri, R. C., Yadav, R. C. and Jha, P. 2007. Erodibility characterstics of Entisol soils of riparian zone of the Yamuna river in Agra: Impacts of land form and land uses. *Indian J. Soil Cons*. **35**(3):226-229.

Bhola, S.N. and Mohan, S.R. 1982.Soil erodibility of black soils of Bellary district. *Indian J. Soil Cons*. **10** (2-3):39-45.

Dabral, P.P., Murry, R. L. and Lollen, P. 2001. Erodibilty status under different land uses in Dikrong river basin of Arunachal Pradesh. *Indian J. Soil Cons.* **29**(3): 280-282.

Das, K., Dipak Sarkar, Mukhopadhyay, K. and Singh, Ratan 2007. Evaluation of soil erodibility factor 'K' with its relationship with some soil properties of Marmring-Patle micro-watershed in Darjeeling. *Indian J. Soil Cons*. **35**(2):125-128.

De, S.K. 1962. *Methods of soil analysis.* Naryan Publishing House, 629, University Road, Allahabad, p 24-25.

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

Hadda, M.S., Arora, Sanjay and Bhardwaj, D.D. 2007. Assessment of erosion risk of a catchment using soil and rainfall information in foothills of Punjab. *Indian Journal of Dryland Agricultural Research and Development* **22**(2): 70-74.

Hadda, M.S., Arora, Sanjay and Bhardwaj, D.D. 2008 Erosion risk assessment through soil erodibility, rainfall erosivity and catchment characteristics in submontaneous tract of Northwest India. *J. of Soil and Water Cons*. **7**(2): 17-22.

Middleton, H.R.1930. Properties which influence soil erosion. Tech. Bull. No. 178, USDA.

Pandey, P.K., Dabral, P.P., Ashish and Nikhil Kumar 2009. Determination of physical, water retention and transmission properties of paddy fields in the vicinity of Nirjuli (Arunachal Pradesh). *J. Soil and Water Cons.* **8**(4):3-10.

Piper, C. S.1950. Soil and Plant Analysis. Academic Press, New York, USA.

Punamia, B. C. 1988. Soil mechanics and foundations (12th edn.). A Saurabh and Co.(P) Ltd.,37-A, Motilal street, T. Nagar, Madras.

Ravindra Kaur, Singh, O. and Gurung, H.P. 2003. Soil erodibility indices- their development, use and efficiency testing on Indian soils: A review. *Indian J. Soil Cons*. **31**(3):234-242.

Sharma, I.P., Kanwar, B.S. and Gupta, M.P. 1987. Physico–chemical properties of Kangra soils in relation to their erodibility. *Indian J. Soil Cons.* **15**(1):43-47.

Singh, R. and Kundu, D. K .2008. Erodibility of major soil sub-groups of eastern region of India. *Indian J. Soil and Water Cons.* **36**(3):172-178.

Singh, R., Singh, K.D. and Parandiyal, A.K. 2006. Characterisation and erodibility of soils under different land uses for their management and sustained production. *Indian J. Soil. Cons.* **34**(3):226-228.

Upadhayay, V.K., Gupta, R.D. and Arora, Sanjay 2013. Land capability classification in relation to soil properties representing bio-sequences in foothills of North India. *J. Soil and Water Cons.* **12**(1): 3-8.

Wischmeir, W.H, Johnson, C.G. and Gross, V.V. 1971. Soil erodibility nomoglaph for farm land and construction sites. *J. Soil and Water Cons.* **10**(5): 189-193.

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Soil properties and available sulphur variability under irrigated and rainfed cotton in Bara tract of Bharuch, Gujarat

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ABSTRACT

Soil properties and available sulphur status of soils under irrigated and rainfed cotton system were investigated from Bara tract comprising Amod, Vagra and Jambusar talukas of Bharuch district, South Gujarat. In surface layer, soil pH, EC, CEC and organic C ranged from 7.1-8.9, 0.12-2.70 $dS\ m^{-1}$, 33.6-59.6 cmol $(p^+)\ kg^{-1}$ and 0.18-0.86 per cent, respectively in irrigated soils, while similarly for rainfed soils corresponding values were 6.7-9.0, 0.16-1.61 $dS\ m^{-1}$, 34.6-56.1 cmol $(p^+)\ kg^{-1}$ and 0.08-0.65 per cent, respectively. Results revealed that surface layer of irrigated (20.0 %) and rainfed (37.5 %) soils exhibited 'low' status of available S in three talukas. Surface layer had higher values of organic C and available S than sub-surface layer in both systems, while irrigated soils had higher values than rainfed soils. To overcome 'low' S status in soils by use of inorganic/ organic sources or manures like sulphonated compost/bio-composts would be beneficial for higher cotton production under both systems.

Key words: soil properties, irrigated, rainfed, canal system, sulphur

INTRODUCTION

The nature has provided the mankind with four basic resources of climate, water, soil and biodiversity to meet the survival needs. Rational use of these natural resources to meet the needs will determine the longevity of civilizations. During the last four decades, these resources have been stretched and over exploited to meet food, fibre and shelter requirements of burgeoning human and livestock populations. Over exploitation of water, soil and biodiversity has resulted in their degradation in terms of quality and availability which ultimately resulted in reduction in yield of different crops.

Cotton is most important fibre crop which plays very important role in economic and social affairs of people, especially in India. Sulphur is an essential component of two amino acids, methionine and cysteine.

These amino acids are key building blocks needed for protein formation in the cotton plant. Sulphur is recognized, as fourth important plant nutrient after N, P and K and is gaining considerable importance in quality crop production. Sulphur is an essential nutrient for plants but is required in much lower amount than N, P and K. Sulphur availability in black soils is generally sufficient. In a survey conducted on black soil regions of MP indicated that 20 to 40 per cent soils tested were found to be deficient in sulphur based on critical limit 8 ppm (Patil *et al.*, 1989). Sulphur deficiency in crops is gradually becoming widespread in different soils of the country due to high analysis sulphur-free fertilizers coupled with intensive cropping, higher crop yields and higher sulphur removals (Kour *et al.*, 2014). The deficiency of sulphur in soils and plants is being reported from several parts of the country and also from Gujarat state. Soil available S is generally low in the cotton belt region due to the hot and humid climate and high possibility of sulphate leaching. The extent of S deficiency was 37 per cent in Gujarat soils (Meisheri and Patel, 1996). Research studies indicate that high-yielding cotton will take up nearly 40 pounds of S during the growing season (Anonymous, 2016). That's about the same amount as magnesium (Mg) and about two-thirds of the phosphorus (P) needed for developing cotton roots, stems, leaves and bolls. A shortage of S can also trigger inefficient plant use of nitrogen (N), since both are required for protein development. Because of its involvement in vital function in the plant

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metabolism, sulphur deficiency would lead to adverse effect on growth and yield of many crops. S deficient cotton plants usually produced fewer bolls per plant, with a greater proportion of bolls at the first-position fruiting sites (Yin *et al*., 2012).

Approximately 65 per cent of India's cotton is produced under rainfed situations. In general, cotton is grown under rainfed condition with sporadic application of saline ground water as supplemental irrigation due to lack of availability of good quality water for less rainfall and erratic monsoon in the study areas. However, groundwater in the area is saline (SSNNL, 2009). In irrigated part of this tract, irrigation is done from Sardar Sarovar Canal for intensification of agriculture. As productivity of both rainfed and irrigated crops largely depends on the soil-site characteristics of the area under a specific set of climatic and ignorance of soil-site requirement of a particular crop leads to the sub-optimal yield or complete failure of the crop. Due to continuous cotton cultivation, soils under irrigated and rainfed system may differ/ or affect soil properties which may modify nutrients content and their availability to crops, so analysis of soil properties may have significant importance (Rao *et al*., 2016). In irrigated areas under intensive cropping, soils exhausted more with reserve S rather than with available S. Cultivation of high yielding hybrids crop cultivars and hybrids and diversification towards P and S demanding crops will place even more strain on S budget of the soil. Ultimately, declining soil fertility, fertilizer use efficiency, which increases cost of production whereas, restricts water use efficiency. Scanty of information is available on status of S under both systems in Bharuch district of Gujarat. Systematic and periodic identification of areas of S status in relation to crop yields is a prerequisite for improving and sustaining the fertility status of soil and for better management which ultimately results in getting higher yields grown. Under these contexts, an attempt has been made to generate information on soil properties and sulphur nutrient status in irrigated and rainfed situations in Bara tract of Bharuch district.

MATERIALS AND METHODS

Representative surface (0-22.5 cm) and sub-surface (22.5-45.0 cm) soil samples from two hundred nineteen (total) locations were collected based on GPS, covering major irrigated (115 fields) and rainfed (104 fields) from cotton growing areas of *Vertisols* of "Bara tract" *i.e.* Amod (21^0 59′ 39.26′′ N; 72^0 52′ 09.30′′ E), Vagra (21^0 50′ 41.84′′ N; 72^0 50′ 40.95′′ E) and Jambusar (21^0 03′ 10.78′′ N; 72^0 48′ 04.30′′ E) talukas of Bharuch district in order to characterize these samples for physico-chemically during 2015 and map of area is depicted in Fig 1. Taluka-wise representative soil samples collected

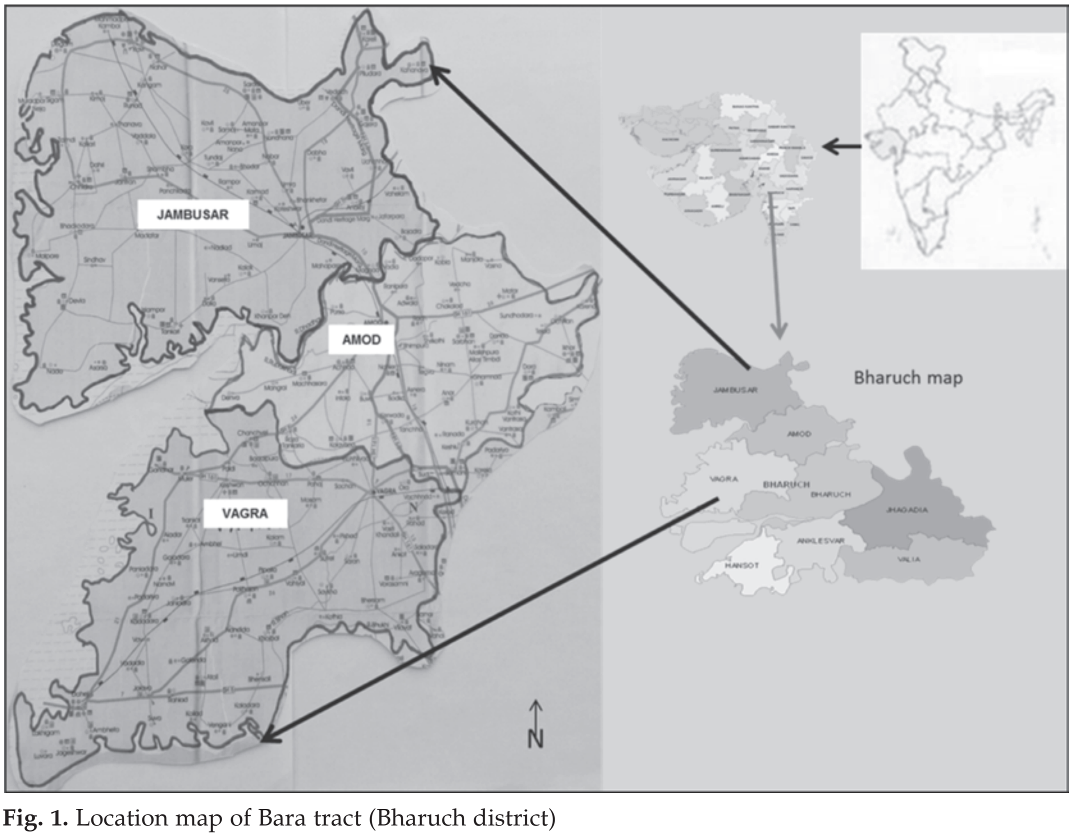

Fig. 1. Location map of Bara tract (Bharuch district)

from different villages under irrigated area were as follows: Amod: 61, Vagra: 29 and Jambusar: 25, whereas numbers of samples collected from different villages under rainfed situation from the above talukas were as follows: 7, 38 and 59 in chronological order. The collected soil samples were processed and analyzed for pH, EC, organic carbon and CEC following standard methods (Jackson, 1973). Available S was determined by using by using 0.15 per cent $CaCl_2$ solution (Willams and Steinbergs, 1959).

RESULTS AND DISCUSSION

Soil properties

In irrigated soils, overall pH, EC and CEC ranged from 7.1 to 8.9, 0.12 to 2.7 dS m^{-1} and 33.6 to 59.6 cmol (p+) kg^{-1}, respectively in surface layer, while for sub-surface layer the corresponding values were 6.9 to 9.0, 0.06 to 2.10 dS m^{-1} and 32.9 to 62.6 cmol (p+) kg^{-1}, respectively (Table 1). In case of rainfed soils, surface soils the above soil parameters in chronological order 6.7 to 9.0, 0.16 to 1.61 dS m^{-1} and 34.6 to 56.1 cmol (p+) kg^{-1}, respectively, while for sub-surface soils the order were 6.7 to 9.2, 0.09 to 1.24 dS m^{-1} and 37.6 to 60.2 cmol (p+) kg^{-1}, respectively. Overall mean soil pH of irrigated soils was lower in surface (7.9) and sub-surface (8.1) layer as compared to those of rainfed surface (8.4) and sub-surface (8.6) layer, respectively (Table 1). The reason might be due to higher organic matter in irrigated soils as compared to rainfed soils. Results were supported by Padekar *et al.* (2014) and Paramasivan and Jawahar (2014) for cotton growing areas. Overall mean soil salinity (EC) of irrigated soils was higher in surface (0.66 dS m^{-1}) and sub-surface (0.48 dS m^{-1}) layer as compared to that of rainfed surface (0.38 dS m^{-1}) and sub-surface (0.43 dS m^{-1}) layer, this was possibly due to irrigation and high evapotranspiration in irrigated soils as compared to rainfed soils which built up salinity. Results on soil salinity for cotton growing areas were supported by Padekar *et al.* (2014). Mean CEC of all irrigated soils, it was observed that surface layer of irrigated soils was higher as compared to those of all rainfed surface layer perhaps due to higher addition of OM by the farmers and variation in clay mineralogical make up. The variation of CEC from place to place under study area might be ascribed to presence of varying quantity and type of clay/ silt+clay and quantum of organic matters present in farmers field due to application difference of these manures / biocomposts from farmers to farmers. Results were supported by Padekar *et al.* (2014), Paramasivan and Jawahar (2014) and Negash and Mohammed (2014) for cotton growing areas.

Soil organic carbon (SOC)

In surface layer, SOC ranged from 0.18 to 0.86 and 0.08 to 0.65 per cent, respectively in irrigated

Table 1. Categorization of soil pH, EC and CEC in irrigated and rainfed area of Bharuch

Taluka	Depth (cm)	No. of samples	pH		EC (dS/m)		CEC (cmol/kg)	
			Range	Mean	Range	Mean	Range	Mean
	Irrigated soils							
Amod	0-22.5	61	7.1-8.6	7.9	0.15-2.70	0.97	33.6-57.8	44.9
	22.5-45.0	61	7.5-8.7	8.1	0.13-2.10	0.66	32.9-57.1	45.9
Vagra	0-22.5	29	7.5-8.9	8.2	0.17-2.10	0.37	35.7-59.6	45.8
	22.5-45.0	29	7.4-9.0	8.4	0.14-2.00	0.37	37.8-62.6	47.9
Jambusar	0-22.5	25	6.8-8.4	7.7	0.12-0.41	0.22	34.1-44.5	38.0
	22.5-45.0	25	6.9-8.8	7.9	0.06-0.42	0.17	37.6-45.7	41.0
Overall	0-22.5	115	7.1-8.9	7.93	0.12-2.70	0.66	33.6-59.6	43.6
	22.5-45.0	115	6.9-9.0	8.13	0.06-2.10	0.48	32.9-62.6	45.3
	Rainfed soils							
Amod	0-22.5	7	8.0-8.8	8.3	0.20-0.94	0.37	36.5-40.9	38.8
	22.5-45.0	7	8.1-8.9	8.6	0.18-0.86	0.44	40.2-43.4	41.8
Vagra	0-22.5	38	7.9-8.8	8.5	0.27-1.61	0.47	35.9-56.1	42.6
	22.5-45.0	38	8.2-9.1	8.7	0.37-1.24	0.50	37.9-60.2	44.5
Jambusar	0-22.5	59	6.7-9.0	8.4	0.16-1.38	0.33	34.1-43.3	38.6
	22.5-45.0	59	6.7-9.2	8.7	0.09-1.11	0.36	37.1-44.4	41.0
Overall	0-22.5	104	6.7-9.0	8.4	0.16-1.61	0.38	34.6-56.1	40.1
	22.5-45.0	104	6.7-9.2	8.6	0.09-1.24	0.42	376-60.2	42.3

and rainfed soils, while in sub-surface layer their magnitude were lower for both system (Table 2). Overall mean SOC of irrigated soils was higher in surface (0.53%) and sub-surface (0.40%) layer as compared to those of rainfed surface (0.40%) and sub-surface (0.35%) layer (Table 2) and this was observed possibly due to higher addition of organic matter/ manures/ compost *etc.* in irrigated soils. Similar results were corroborated by Padekar *et al.* (2014), Negash and Mohammed (2014) and Paramasivan and Jawahar (2014). In both irrigated and rainfed situations of three talukas (Table 2) came under 'low' category (SOC < 0.50 %) (55 and 75 villages, respectively in irrigated and rainfed surface soils, and 82 and 90 villages, respectively in irrigated and rainfed sub-surface soils). Coming to 'medium' SOC category, about 40 per cent irrigated surface soils (46 villages) and 27 per cent sub-surface soils (31 villages) belong to this category. Again about 28 per cent rainfed surface soils (29 villages) and 13 per cent sub-surface soils (14 villages) belong to 'medium' SOC category. The results were supported by Dhamak *et al.* (2014) and Prabhavati *et al.* (2015). Singh and Mishra (2012) also found that soil OC content ranged from 0.30 to 0.75 per cent (average 0.45 %) and 70 per cent of soil samples was low and remaining 30 per cent were medium. All soils with 'low' OC category and soils with 'medium' OC category indicated that productivity potential for soils of those areas were low and would pose constraints in relation to nutritional availability. Thus, addition of more organic matter/ manures/ bio-compost/ compost/ vermi-compost/ wastes *etc.* in these soils would be highly needed.

In irrigated situation, in Amod taluka, 36.1 per cent surface (22 villages) and 67.2 per cent sub-surface samples (41 villages), in Vagra taluka 89.7 per cent surface (26 villages) and 100% sub-surface samples (29 villages), and in Jambusar taluka 28% surface (7 villages) and 48% sub-surface samples (12 villages) came under 'low' SOC category (Table 2). In case of rainfed soils, in Amod taluka 57.1% surface (4 villages) and 85.7 per cent sub-surface samples (6 villages), in Vagra taluka 92.1% surface (35 villages) and 97.4% sub-surface samples (37 villages), and in Jambusar taluka 61 per cent surface (36 villages) and 79.7% sub-surface samples (47 villages) belong to 'low' SOC status. Similar results along with almost same reasons for low carbon and low productivity was put forwarded by Jatav and Mishra (2012) from Chattisgarh region. Low SOC would reflect low productivity and pose constraints in relation to nutritional availability and thus addition of organic matter/ manures/ bio-compost/ compost/vermi-compost/ wastes *etc.* in these soils would be highly needed in irrigated as well as rainfed village as the case may be. Thus, for obtaining sustained yield of cotton, addition of more organic matter/manures would be of

Table 2. Categorization of SOC in surface and sub-surface irrigated and rainfed soils of Bharuch district

Taluka	Depth (cm)	No. of samples	SOC (%)			
			Range	Low (<0.5)	Medium (0.50-0.75)	High (>0.75)
			Irrigated soils			
Amod	0-22.5	61	0.21-0.86 (0.57)	22(36.1)	28(45.9)	11(18.0)
	22.5-45.0	61	0.15-0.78 (0.44)	41(67.2)	18(29.5)	02(3.3)
Vagra	0-22.5	29	0.18-0.69 (0.38)	26(89.7)	03 (10.3)	0(0)
	22.5-45.0	29	0.12-0.48 (0.30)	29(100)	0(0)	0(0)
Jambusar	0-22.5	25	0.31-0.80 (0.59)	7(28.0)	15 (60.0)	03(12.0)
	22.5-45.0	25	0.27-0.69 (0.40)	12 (48.0)	13 (52.0)	0(0)
Overall	0-22.5	115	0.18-0.86 (0.53)	55(47.9)	46 (40.0)	14(12.1)
	22.5-45.0	115	0.12-0.78 (0.40)	82(71.3)	31(27.0)	02 (1.7)
			Rainfed soils			
Amod	0-22.5	7	0.36-0.57 (0.47)	04(57.1)	03(42.9)	0(0)
	22.5-45.0	7	0.20-0.50 (0.35)	06(85.7)	01(14.3)	0(0)
Vagra	0-22.5	38	0.08-0.59 (0.33)	35(92.1)	03(7.9)	0(0)
	22.5-45.0	38	0.05-0.53 (0.28)	37(97.4)	01(2.6)	0(0)
Jambusar	0-22.5	59	0.24-0.65 (0.45)	36(61.0)	23(39.0)	0(0)
	22.5-45.0	59	0.18-0.62 (0.39)	47(79.7)	12(20.3)	0(0)
Overall	0-22.5	104	0.08-0.65 (0.40)	75(72.1)	29(27.9)	0(0)
	22.5-45.0	104	0.05-0.62 (0.35)	90(86.6)	14(13.4)	0(0)

*Values in low, medium and high index column as number of samples and values in parenthesis ( ) expressed per cent soils immense need, particularly in low carbon to medium carbon status soil of these talukas. Conservation practices also might play an alternative role for achieving higher status of SOC.

Available sulphur

In surface layer, available sulphur *i.e.* 'low to high' status and it ranged from 3.8 to 74.8 and 4.5 to 26.2 ppm, respectively in irrigated and rainfed soils, while in sub-surface layer their magnitude were lower for both system (Table 3). In case of irrigated soils, in surface and sub-surface layer 20.0 (23 villages) and 37.4% (43 villages), respectively and in rainfed situation 37.5 (39 villages) and 60.6% (63 villages), respectively in both layers, exhibited 'low' status of available S in three talukas (Table 3). However, 47.9% surface (55 villages) and 46.1% sub-surface (23 villages) from irrigated situation and 56.7 per cent surface (59 villages) and 38.5% sub-surface (40 villages) from rainfed situation belong to 'medium' available S category in three talukas. However, rest of the surface and sub-surface soils of three talukas under both the situation came under 'high' status of available S. Overall mean available S of irrigated soils was higher in both surface (20.2 ppm) and sub-surface (13.7 ppm) layers as compared to that of rainfed surface (11.6 ppm) and sub-surface (9.1 ppm) layers (Table 3). Similar results were observed elsewhere by Kour *et al*. (2010), Bhaskaran *et al.* (2012), Singh and Mishra (2012) and Singh *et al.* (2014). Such wide range of available sulphur in these cotton soils might be attributed to variation in soil properties like pH, SOC, cation exchange capacity, microbial population, addition of varying quantum of organics and variation in agronomic practices. The reason might be the higher organic matter in irrigated soils as compared to rainfed soils. Thus, soils having sulphur status below <10 ppm (critical level) are required to be replenished / improved to meet the demand of S in cotton crop. To overcome such problem S-management through addition inorganic/ organic sources or manures like sulphonated compost/bio-composts would be needed. S-solubilising microbes and in high pH soil application of gypsum would be worth in order improve available status of S thereby to sustain soil quality and yield of cotton. At taluka level, Amod taluka, in irrigated surface and sub-surface soils 13.1 and 36.1 per cent came under 'low' available S category, respectively, while, for Vagra taluka, the corresponding values were 41.4 and 44.8%, respectively. In case of Jambusar taluka, the corresponding values were 12 and 32%, respectively (Table 3). Under rainfed situation, in surface and sub-surface soils of Amod, 57.1 and 57.1% samples came under 'low' available S category, respectively, while, for Vagra taluka, the corresponding values were 47.4 and 65.8 per cent, respectively. In case of Jambusar taluka, the corresponding values were 28.8 and 57.6%, respectively. Depending upon low or medium

Table 3. Categorization of available S in surface and sub-surface irrigated and rainfed soils of Bharuch district

Taluka	Depth (cm)	No. of samples	Available S (ppm)*			
			Range	Low (< 10)	Medium (10-20)	High (> 20)
Irrigated soils						
Amod	0-22.5	61	3.8-74.8 (24.5)	08 (13.1)	27(44.3)	26 (42.6)
	22.5-45.0	61	2.3-63.9 (16.1)	22 (36.1)	23(37.7)	16 (26.2)
Vagra	0-22.5	29	3.8-42.9 (13.3)	12 (41.4)	14(48.3)	03 (10.3)
	22.5-45.0	29	3.7-33.8 (10.5)	13 (44.8)	14(48.3)	02 (6.9)
Jambusar	0-22.5	25	7.4-33.1 (17.7)	03 (12.0)	14(56.0)	08 (32.0)
	22.5-45.0	25	3.0-31.5 (11.5)	08 (32.0)	16(64.0)	01 (4.0)
Overall	0-22.5	115	3.8-74.8 (20.2)	23 (20.0)	55(47.9)	37 (32.1)
	22.5-45.0	115	2.3-63.9 (13.7)	43 (37.4)	53(46.1)	19 (16.5)
Rainfed soils						
Amod	0-22.5	7	4.5-20.8 (11.3)	04 (57.1)	02(28.6)	01 (14.3)
	22.5-45.0	7	2.3-16.2 (8.1)	04 (57.1)	03(42.9)	0 (0)
Vagra	0-22.5	38	5.2-22.6 (11.4)	18 (47.4)	16(42.1)	04 (10.5)
	22.5-45.0	38	3.5-19.7 (8.9)	25 (65.8)	13(34.2)	0(0)
Jambusar	0-22.5	59	4.5-26.2 (11.7)	17 (28.8)	41(69.5)	01 (1.7)
	22.5-45.0	59	3.0-20.4 (9.4)	34 (57.6)	24(40.7)	01 (1.7)
Overall	0-22.5	104	4.5-26.2 (11.6)	39 (37.5)	59(56.7)	06 (5.8)
	22.5-45.0	104	2.3-20.4(9.1)	63 (60.6)	40(38.5)	01 (1.0)

*Values in low, medium and high index column as number of samples and values in parenthesis ( ) expressed per cent soils available S status at taluka and village level necessary steps to be taken to overcome S problem as stated above.

CONCLUSION

Results indicated that surface layer of irrigated and rainfed soils, 20.0 and 37.5%, respectively, exhibited 'low' status (below <10 ppm) of available S in three talukas. To overcome low productivity problem S-management through addition inorganic/ organic sources or manures like sulphonated compost/bio-composts would be needed. S-solubilising microbes would be worth in order improve available status of S thereby to sustain soil quality and yield of cotton. Low and aberrant rain fall situation (rainfed), cotton crop production would be maximize by adopting techniques like rainwater harvesting and recycling, micro-irrigation and field bunding to arrest maximum rainwater.

REFERENCES

Anonymous, 2016. http://www.cropnutrition.com/sulfur-nutrition-of-cotton.

Bhaskaran, A., Rakkiyappan, P. and Palaniswami, C. 2012. Sulphur status of sugarcane growing soils of Tamilnadu. *Journal of Sugarcane Research* **2**(2): 58-65.

Dhamak, A.L., Meshram, N.A. and Waikar, S.L. 2014. Identification of major soil nutritional constraints in Vertisol, Inceptisol and Entisol from Ambajogai tahsil of Beed district. *Journal Research in Agriculture & Animal Science* **2**(10): 35-39.

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

Jatav, G. K. and Mishra, V. N. 2012. Evaluation of soil fertility status of available N, P and K in Inceptisol of Baloda block Janjgir district of Chhattisgarh. *Asian Journal of Soil Science* **7**(1): 62-65.

Kour, S., Arora, Sanjay, Jalali, V.K. and Mondal, A.K. 2010. Soil Sulphur forms in relation to physical and chemical properties of mid-hill soils of North India. *Communications in Soil Science and Plant Analysis* **41**(3): 277-289.

Kour, S., Gupta, M. and Arora, Sanjay 2014. Soil sulphur status and response of crops in foothill region of J&K. *Journal of Soil and Water Conservation* **13**(3): 292-296.

Meisheri, M.B. and Patel V.R. 1996. Sulphur Research in Gujarat. A Compendium on Soil Research in Gujarat, B.A. College of Agriculture, GAU, Anand, pp 53-64.

Negash, H. and Mohammed, M. 2014. Soil fertility in Koka nagawo area of Lumme district in East shoa zone of Oromia region, Ethiopia. *East African Journal of Science* **8**(1): 1-12.

Padekar, D.G., Bhattacharyya, T., Deshmukh, P.D., Ray, S.K., Chandran, P. and Tiwary, P. 2014. Is irrigation water causing degradation in black soils? *Current Science* **106** (11): 1487-1489.

Paramasivan, M. and Jawahar, D. 2014. Characterization, classification and crop suitability of some black cotton soils of southern Tamil Nadu. *Agropedology* **24**(1): 111-118.

Patil, S.G, Sarma, V.A.K. and Vanloon, G.W. 1989. Acid rain, cation distribution and sulphate retention in three tropical soils. *European Journal of Soil Science* **40**(1): 85-93.

Prabhavati, K., Dasog, G.S., Patil, P.L., Sahrawat, K.L. and Wani, S.P. 2015. Soil fertility mapping using GIS in three agro-climatic zones of Belgaum district, Karnataka. *Journal of the Indian Society of Soil Science* **63**(2): 173-180.

Rao, G.G., Arora, Sanjay, Nikam, V.R. and Sharma, D.K. 2016. Prospects and impact of cultivating salt tolerant varieties of cotton and wheat in coastal saline soils of Gujarat. *Indian J. Soil Conservation* **44**(3): 308-313.

Singh, R.P. and Mishra, S.K. 2012. Available macro nutrients (N, P, K and S) in the soils of Chiraigaon block of district Varanasi (U.P.) in relation to soil characteristics. *Indian Journal Science Research* **3**(1): 97-100.

Singh, Y.P., Raghubanshi, B.P.S., Tomar, R.S., Verma, S.K. and Dubey, S.K. 2014. Soil fertility status and correlation of available macro and micronutrients in Chambal region of Madhya Pradesh. *Journal of the Indian Society of Soil Science* **62** (4): 369-375.

SSNNL (Sardar Sarovar Narmada Nigam Limited) 2009. Report of the committee for finalization of policy for constructing minors and sub-minors in Bara Tract Area under Phase-I, New Sachivalaya Complex, Gandhinagar, Gujarat, India.

Williams, C.H. and Steinbergs, A. 1959. Soil sulphur fractions as chemical indices of available sulphur in some Australian soils. *Australian Journal of Agricultural Research* **10**: 340-352.

Yin, X.H., Gwathmey, C.O. and Main, C.L. 2012. Sulfur effects on cotton yield components. *Better Crops* **96**(1): 27-28.

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Bio-remediation of saline and sodic soils through halophilic bacteria to enhance agricultural production

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ABSTRACT

Bio-remediation is one of the cheap and eco-friendly approaches for remediation of salt affected lands as the traditional physical and chemical techniques are becoming costly. The possibility of application of halophilic bacteria in saline/sodic soil recovery and the importance of microbial diversity in soil is important in order to realistically access their future application in the rehabilitation of degraded lands. The plant growth promoting halophilic bacteria helps in bio-remediation of salt affected soils and thereby improves the agricultural crop yields. Bio-inoculation of seeds of wheat with plant growth promoting halophilic bacteria resulted in increase of 18.1 and 24.2 per cent in grain and straw yield, respectively under sodic conditions. Also, soil pH of sodic soil reduced from 9.4 to 8.6 when consorita of halophilic bacteria was applied. Soil bio-chemical properties improved and there was increase of microbial biomass C upto 137 μg/g as compared to 82 μg/g in control.

Key words: bacteria, salt tolerance, bio-remediation, saline, sodic soil

INTRODUCTION

Salt-affected soils occupy an estimated 952.2 million ha of land in the world that constitutes to nearly 7% of the total land area and nearly 33% of the area of potential arable land. In India, the salt affected soils account for 6.727 million ha i.e. 2.1 % of geographical area of the country. A build-up of soluble salts in the soil may influence its behaviour for crop production through changes in the proportions of exchangeable cations, soil reaction, physical properties and the effects of osmotic and specific ion toxicity (Singh *et al.*, 2016). The influence of the high salt concentrations masks other soil forming processes or soil properties and environmental conditions, often altering them. Microorganisms play an important role in the maintenance and sustainability of any ecosystem as they are more capable of rapid adjustment towards environmental changes and deterioration. Microorganisms are considered to be the first life forms to have evolved; they are versatile and adaptive to various challenging environmental conditions like salt stress.

The applications of halophilic bacteria include recovery of salt affected soil by directly supporting the growth of vegetation thus indirectly increasing crop yields in salt stress. The biotic approach 'plant-microbe interaction' to overcome salinity/sodicity problems has recently received a considerable attention from many workers throughout the world. Halophilic bacteria provide a high potential for biotechnological applications for at least two reasons: (1) their activities in natural environments with regard to their participation in biogeochemical processes of C, N, S, and P, the formation and dissolution of carbonates, the immobilization of phosphate, and the production of growth factors and nutrients (Rodriguez-Valera, 1993); and (2) their nutritional requirements are simple.

The use of halophilic bacteria in the recovery of saline soils is covered by the following hypotheses. The first hypothesis is that microbial activities in saline soil may favor the growth of plants resistant to soil salinity. The second hypothesis is based on the utilization of these bacteria as bio-indicators in saline wells. Indicator microorganisms can be selected by their abilities to grow at different salt concentrations. Halophilic microbes are also found to remove salt from saline soils (Arora *et al.*, 2013; Bhuva *et al.*, 2013). There are reports that potential salt tolerant bacteria isolated from soil or plant tissues and having plant growth promotion trait, helps to alleviate salt stress by promoting seedling growth and increased biomass of crop plants grown under salinity stress (Arora *et al.*, 2014a,b). Both physical and chemical methods of their

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reclamation are not cost-effective and also the availability of mineral gypsum or other chemical amendments is a problem. The applications of halophilic bacteria include recovery of salt affected soils by directly supporting the growth of vegetation thus indirectly increasing crop yields in salt affected soils.

MATERIALS AND METHODS

With the objective to use bio-remediation approach for reclamation and management of saline and sodic soils, the present study was conducted. Halophilic bacteria were isolated from saline soil from coastal Gujarat and sodic soil from Indo-Gangetic plains of Uttar Pradesh. The bacterial isolates were characterized and screened for salt tolerance and plant growth promoting traits as per standard proptocol. Salt removal efficeiny of the strains were tested in the liquid media.

The efficient strains were mass cultured for their performance in crop production in saline as well as sodic soils. A pot experiment was conducted with maize and the seeds were inoculated and sown. The pots were irrigated with saline waters (5% NaCl) as and when required. Plant growth parameters were recorded to ascertain the effect of halophilic strains. A field experiment was conducted in sodic soil (pH 9.4) to adjudge the effect of halohilic bacteria and their consortia in remediation of alkali soil and performance of wheat. The grain and straw yield of wheat was monitored and after harvest soil was analysed for changes in soil bio-chemical properties as per the standard procedures.

RESULTS AND DISCUSSION

Plant-microbe interactions are beneficial associations between plants and microorganisms and also a more efficient method for reclamation of saline soils. Two promising halophilic bacterial strains that showed positive for plant growth promotion were selected and tested for salt removal efficiency. Halophilic bacteria strain (CSSRO2) was more efficient in reducing sodium concentration from 1,12,230 ppm in supernatant to 1,00,190 ppm at 24 hour while strain CSSRY1 reduced Na concentration to 92,730 ppm at 48 hours in halophilic broth with 15% NaCl. This shows that inoculation of strains in liquid media resulted in removal of 12040 and 19500 ppm of Na by halophilic bacterial strains CSSRO2 and CSSRY1 respectively (Fig 1). The halophilic bacteria strains CSSRY1 and CSSRO2 were also shown to have high potential for removal of sodium ions from soil. CSSRY1 efficiently removed sodium at higher (6%, 8%, 10% NaCl) salt concentration in comparison of CSSRO2 and association of both organisms (CSSRY1 and CSSRO2). This was also confirmed by reduction of electrical conductivity or total dissolved salts (TDS). It is hypothesized that once the sodium ion concentration is reduced in rhizosphere, plants are able to resume nutrient and water uptake.

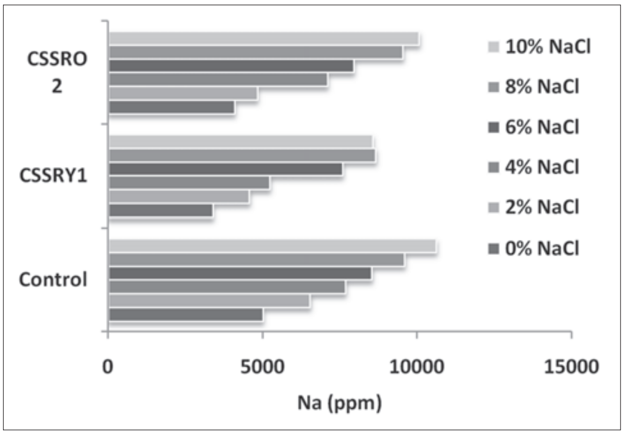

Fig. 1. Sodium removal by halophilic bacterial inoculates in saline soil

To confirm about the sodium removal efficacy of these halophilic bacterial strains from soil, CSSRY1 and CSSRO2 were inoculated in sterile soil to test their efficacy for sodium removal from the soil containing different concentrations of NaCl (0% to 10% NaCl). It was observed that inoculation of strain CSSRY1 decreased soluble sodium content up to 31% at 4% NaCl concentration while at 10% NaCl concentration, it reduced only 19% sodium from soil. These selected cultures were further studied in greenhouse pot experiments for plant growth promotion. Results showed that in the 5% NaCl treated soil, the growth of *Zea mays* was observed. Plants inoculated with a consortium of halophilic bacteria also showed growth at 10% NaCl, whereas inoculation with single isolates did not promote plant growth at this salt concentration. The maximum fresh weight, dry weight, shoot length and root length of plant were found in the case of "Consortium 5% NaCl" treated pot, 194.5% increase in fresh weight, 98.97% increase in dry weight, 15.37 cm increase in shoot length and 7.4 cm increase in root length as compared to the uninoculated control plants (Table 1). The results show that inoculation with these bacterial isolates can promote the growth of plants in salt affected soils due to production of hormone auxin and thus enhanced root growth. Another very likely mechanism may be alleviation of salinity stress via plant growth promoting rhizobacteria that express ACC deaminase activity (Govindasamy *et al*., 2008).

Table 1. Maize performance under 5% salinity as influenced by halophilic bacteria inoculation

Treatment	Fresh weight (g/pot)	Dry weight (g/pot)	Shoot length (cm)	Root length (cm)
HB1	1.94	0.660	14.50	12.00
HB2	2.92	0.505	25.00	16.80
HB3	2.90	0.665	18.36	17.16
HB4	2.82	0.855	11.15	13.80
Consortia	5.59	0.975	27.07	17.80
Control	1.90	0.490	11.70	10.40

HB: halophilic bacterial inoculation

This enzyme removes stress ethylene from the rhizosphere. Also, the halophilic/ halotolerant bacteria remove sodium from the surrounding soil and thus useful in plant growth promotion in salt affected soils. Salt-tolerant plant growth promoting strains promotes the growth and yield of wheat cultivated in saline soil (Rajput *et al*., 2013). Also, Vivekanandan *et al*. (2015) also reported improvement in crop productivity in saline soils through application of saline-tolerant rhizosphere bacteria. Ealier, Barassi *et al*. (2006) also reported seed inoculation with *Azospirillum* helps in mitigating salinity effect.

Various plant growth promoting rhizo bacteria including *Rhizobium*, *Pseudomonas*, *Acetobacter*, *Bacillus*, and *Flavobacterium* and several *Azospirillum* can maintain their plant growth promotion ability even at high saline conditions. Halophilic bacteria strain (CSSRO2 *Planococcus maritimus*) and CSSRY1 (*Nesterenkonia alba*) having plant growth promotion properties were isolated from rhizosphere of dominant halophytes from coastal ecosystem (Arora *et al*., 2012). Salt tolerant rhizobium species were isolated from coastal saline soils (Trivedi and Arora, 2013) and were found to alleviate salt stress.

The isolated halophilic plant growth promoting bacterial isolates were tested for plant growth promotion in sodic soil in field (pH 9.4) experiment. It was observed that grain yield of wheat (*T. aestivum*) in field increased from 3497 kg ha^{-1} to 4129 kg ha^{-1} when consortia of halophilic N-fixers and P-solublizers where inoculated in seed (Table 2). Similarly straw yield also increased from 5.03 to 6.24 t ha^{-1} with inoculation of these halophilic isolates. Researchers have demonstrated the feasibility of *Azospirillum* inoculation to mitigate negative effects of NaCl on plant growth parameters. This beneficial effect of *Azospirillum* and halophilic N-fizers inoculation was observed in wheat seeds, where a mitigating effect of salt stress was also evident (Creus *et al*., 1997; (Arora et al., 2015). *Azospirillum* inoculated wheat seedlings subjected to osmotic stress developed significant higher coleoptiles, with higher fresh weight and better water status than non-inoculated seedlings (Alvarez *et al*., 1996; Creus *et al*., 1998).

Table 2. Effect of inoculation of halophilic bacterial strains on wheat

Treatment	Grain yield (kg ha^{-1})	Straw Yield (kg ha^{-1})
Control (FYM)	3497	5028
FYM+HB1	3742	5645
FYM+HB2	4011	6112
FYM+HB3	3996	5872
FYM+Consortia	4129	6245
CD(5%)	112.7	169.1

Initial soil pH = 9.4; Org. C= 0.21%; Plot size: 30m^2

Effect of incoluation on soil sodicity in terms of Na content was also monitored and it was found that Na content decreased with inoculation in surface soil layers indicative remediation potential of these strains. Further, improvement in soil bio-chemical properties with increase of microbial biomass C upto 137 µg/g in surface soil was found as compared to 82 µg/g in control (Table 3). Inoculation of halophilic plant growth promoting isolates resulted in improved soil bio-chemical properties. It was observed that in surface soils, Na content substantially reduced and microbial biomass C, enzyme activities as well as available N and P content got enhanced. Surface soil pH got

Table 3. Effect of inoculation of halophilic bacterial strains on soil properties

Treatment	pH	Na content (mg/kg)	Av. K (mg/kg)	Av. P (mg/kg)	Microbial biomass C (µg/g)	Dehydrogenase activity (µg TPF/g/h)
Control (FYM)	9.3	323.8	28.70	9.9	82	12.45
FYM+HB1	8.9	269.7	29.95	14.6	116	19.65
FYM+HB2	8.7	226.4	24.00	11.8	137	15.88
FYM+HB3	8.8	240.0	25.95	15.6	104	13.16
FYM+Consortia	8.6	197.4	20.40	12.9	129	16.80

FYM: farm yard manure; HB: habophilic bacteria inoculation reduced substantially in consortia inoculation in field experiment. Maximum reduction in Na content was noted in plots where consortia of halophilic N-fixer and phosphate solubuilizers were inoculated where it was found to be 197.4 mg/kg compared to surface soil from control plot where it was 323.8 mg/kg. Improvement in soil bio-chemical properties on introduction of microbial inoculation has been elaborated (Rao and Patra, 2009; Majeed *et al*., 2015).

Halophilic microbes were found to have the ability to remediate the saline and sodic soils and can be use for glycophytes/crop plants for optimum growth under salt stress condition.

CONCLUSION

Halophilic bacteria having plant growth promotion potential helps in bio-remediation of salt affected soils. Incoulation of seeds with cultures of halophilic bacteria helps in alleviation of stress and enhances crop productivity vis-à-vis health of the degraded soils.

REFERENCES

Alvarez, M.I., Sueldo, R.J. and Barassi, C.A. 1996. Effect of *Azospirillum* on coleoptiles growth in wheat seedlings under water stress. *Cereal Res.Commun.* **24**: 101–107.

Arora, Sanjay, Patel, P., Vanza, M. and Rao, G.G. 2014a. Isolation and Characterization of endophytic bacteria colonizing halophyte and other salt tolerant plant species from Coastal Gujarat. *Afr. J. Microbiol. Res*. **8**(17): 1779-1788.

Arora, Sanjay, Singh, Y.P., Mishra, V.K., Singh, A.K. and Sharma, D.K. 2015. Integrated effect of pressmud, chemical amendments and microbial bio-inoculant on sodic soil reclamation and productivity of rice-wheat. In: Bhan, S. and Arora, Sanjay (eds.) *Advances in soil and water resource management for food and livelihood security in Changing Climate*, SCSI, New Delhi, pp.519-528.

Arora, Sanjay, Trivedi, R. and Rao, G.G. 2013. Bioremediation of coastal and inland salt affected soils using halophyte plants and halophilic soil microbes. CSSRI Annual Report 2012-13, CSSRI, Karnal, India, pp.94-100.

Arora, Sanjay, Trivedi, R. and Rao, G.G. 2012. Bioremediation of coastal and inland salt affected soils using halophilic soil microbes. *Salinity News* **18**(2): 3.

Arora, Sanjay, Vanza, M., Mehta, R., Bhuva, C. and Patel, P. 2014b. Halophilic microbes for bio-remediation of salt affected soils. *Afr. J. Microbiol. Res*. **8**(33): 3070-3078.

Barassi, C.A., Ayrault, G., Creus, C.M., Sueldo, R.J. and Sobrero, M.T. 2006. Seed inoculation with *Azospirillum* mitigates NaCl effects on lettuce. *Scientia Horti*. **109**(1):8–14.

Bhuva, C., Arora, Sanjay and Rao, G.G. 2013. Efficacy of halophilic microbes for salt removal from coastal saline soils. National Seminar with the theme "Microbes and Human Welfare", Bharathidasan University, Tiruchirappalli, India.

Creus, C.M., Sueldo, R.J. and Barassi, C.A. 1997. Shoot growth and water status in *Azospirillum*-inoculated wheat seedlings grown under osmotic and salt stresses. *Plant Physiology and Biochem.* **35**: 939–944.

Creus, C.M., Sueldo, R.J. and Barassi, C.A. 1998. Water relations in *Azospirillum* inoculated wheat seedlings under osmotic stress. *Canadian J. Bot*. **76**: 238–244

Govindasamy, V., Senthilkumar, M., Gaikwad, K. and Annapurna, K. 2008. Isolation and characterization of ACC deaminase gene from two plant growth-promoting rhizobacteria. *Curr. Microbiol*. **57**(4): 312–317.

Majeed, A., Abbasi, M.K., Hameed, S., Imran, A. and Rahim, N. 2015. Isolation and characterization of plant growth-promoting rhizobacteria from wheat rhizosphere and their effect on plant growth promotion. *Front. Microbiol*. **6**: 198.

Rajput, L., Imran, A, Mubeen, F. and Hafeez, Y. 2013. Salt-tolerant PGPR strain *Planococcus rifietoensis* promotes the growth and yield of wheat (*Triticum aestivum* L.) cultivated in saline soil. *Pak. J. Bot*. 45(6): 1955-1962.

Rao, D.L.N. and Patra, A.K. 2009. Soil microbial diversity and sustainable agriculture. *J. Indian Soc. Soil Sci*. **57**(4): 513-530.

Rodriguez-Valera, F 1988. Characteristics and microbial ecology of hypersaline environments. In: Rodriguez-Valera F (ed) *Halophilic Bacteria*, vol. 1: CRC Press, Boca Raton, Fla, pp 3–30.

Singh, Y.P., Mishra, V.K., Sharma, D.K., Singh, G., Arora, Sanjay, Dixit, H. and Cerda, A. 2016. Harnessing productivity potential and rehabilitation of degraded sodic lands through Jatropha based intercropping systems. *Agri. Ecosys. Env*. **233**: 121-129.

Trivedi, R. and Arora, Sanjay 2013. Characterization of acid and salt tolerant *Rhizobium* sp. isolated from saline soils of Gujarat. *Int. Res. J. Chem*. **3**(3): 8-13.

Vivekanandan, M., Karthik, R. and Leela, A. 2015. Improvement of crop productivity in saline soils through application of saline-tolerant rhizosphere bacteria - Current Perspective. *Int. J. Adv. Res*. **3**(7):

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Probability analysis of rainfall at Shivri for crop planning

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ABSTRACT

Probability analysis of rainfall offers a better scope for predicting the minimum assured rainfall to help in crop planning. An attempt has been made to evaluate rainfall distribution patterns i.e. weekly, seasonal, and annual rainfall, based on 13 years (2000-2012) data of Shivri, Lucknow, Uttar Pradesh. Expected weekly, monthly, seasonal, and annual rainfall values at different probability levels were determined by using Blom plotting function. The analysis reflects that the observed rainfall based on 13 years annual average was 829.35 mm emerging from an average rainy days of 40.7. The predicted annual rainfall at 75% probability level is 636.5 mm. Similarly, at 75% probability level, the highest weekly rainfall of 42.0 mm predicted in 37th week followed by 38.6 mm in 27th standard week, and lowest rainfall of 0.0 mm in 40th week. Whereas, analysis of monthly rainfall at 70, 75 and 80% probability levels shows that July, August, and September are the three important wet months having chances of receiving a monthly rainfall between 100 to 150 mm. The predicted value of seasonal rainfall shows 600 mm during kharif season at 70% probability level, whereas the same was 12.6 mm in case of rabi and 4.2 mm in case of zaid cropping seasons.

Key words: rainfall, probability analysis, crop planning

INTRODUCTION

Rainfall is one of the prime meteorological factors that have direct impact on soil water balance. Its amount falling on the soil surface, time of occurrence and spatial variability controls the crop planning and crop calendar for a particular agro-climatic zone. Agricultural calendar have direct link with the onset and withdrawal of the rainfall which in turn have, direct impact on agricultural productivity. This necessitates understanding the trend based on the historic data to enable future predictions. Studies on rainfall probability and its occurrence have been carried out by many researchers. Frequency analysis of rainfall data has been attempted for different places in India (Muniyappa and Aruchamy, 2010; Jeevrathnam and Jaykumar, 1979; Prakash and Rao, 1986; Aggarwal *et al.*, 1988; Bhatt *et al.*, 1996; Rizvi *et al.*, 2001).

Based on historic data of rainfall and its analysis, researchers have attempted the expected future rainfall trends. Based on 38 years rainfall data analysis, Baweja (2011) reported the stable rainfall period of Solan, Himachal Pradesh, India to be spreading over 24th to 37th standard meteorological week. Barman *et al.* (2012) quotes that probability analysis of rainfall data of Barrackpore (WB) India, reveals that onset of monsoon is on 23rd week. Fisher (1924) studied the influence of rainfall on the yield of wheat in Rothamasted. He showed that it is the distribution of rainfall during a season rather than its total amount, which influence the crop yield. Khandelwal *et al*. (2013) reported temporal rainfall distribution affecting crops and its analysis for harvesting. Yengoh (2010) states that there is a significant increase in mean rainfall per rainy day, he also analyzed that there is significant decrease in number of rainy days and probability of dry spells of up to seven to eleven days in the first four weeks of the planting season while analyzing the rainfall data of Northern Ghana.

Analyzing the frequency and intensity of rainfall extremes over India from 1951-2003, Krishnamurthy *et al.* (2009) reports that the north and central sections of Indian Subcontinent have experienced generally decreasing trend in

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frequency and intensity of extremes while coastal regions in peninsular and region immediately west of Bangladesh have experienced increasing trends. Rajeevan *et al*. (2008) while analyzing trends of extreme rainfall events in the country using 104 years data observed significant increase in the frequency of VHR (very high rainfall) events after mid 1970s. This suggests that knowledge of total rainfall and its distribution pattern round the year of a place is very important for better crop planning, determining irrigation and drainage requirement of crops, design and construction of soil and water conservation structures. Probability and frequency analysis of rainfall data facilitates to determine the expected rainfall at various percent chances. It is the most reliable method to predict occurrence of future rainfall events based on past behavior of rainfall.

The analysis of rainfall data for computation of expected rainfall of a given frequency is commonly done by utilizing different probability distributions. Subudhi *et al.* (2012) conducted a study on probability analysis of rainfall for crop planning in Kandhmal district of Orissa. They found that the available rainwater for crop is assured at 75% probability levels. This suggests importance of studying the localized pattern of rainfall based on the local rainfall data also. Keeping this in view, probability analysis of rainfall has been attempted for weekly, monthly, seasonally, and annually, by collecting the 13 years data of Shivri experimental farm of ICAR-CSSRI Regional Research Station, Lucknow (Uttar Pradesh).

METHODOLOGY

The daily rainfall data for the last 13 years (2000-2012) was observed at meteorological observatory of CSSRI-RRS, Research farm, Shivri, Lucknow situated at 26^0 47′ 45'' N to 26^0 48′ 13'' N on latitude and 80^0 46′ 7'' E to 80^0 46′ 32'' E on longitude at 120 m above mean sea level. Weekly monthly, seasonal, and annual rainfall patterns are examined and analyzed. Whole year is divided in to three seasons to study the seasonal pattern namely summer, kharif and rabi. Standard Week no. 17^{th} to 19^{th} (from 23^{rd} April to 13^{th} May) is considered for summer season (Zaid), standard week no. 20^{th} to 44^{th} (14^{th} May to 4^{th} Nov.) is considered for kharif season (Monsoon) and standard week no. 45^{th} to 16^{th} (5^{th} Nov. to 22^{nd} April) is considered for rabi season (Winter). In case of monthly rainfall, the daily rainfall data has been clubbed starting from beginning and end of the month for all the 12 months. The data were made to fit in appropriate probability distribution in order to draw inference on probable future behavior of such events. Probability of rainfall at different level was computed by using Blom plotting function (Blom, 1958) to determine the expected amount of rainfall at different probability levels. The equation used to compute the normal probability density function from the mean and standard deviation is as below:

$$P(\%) = (\frac{m - 0.375}{N + 0.25}) * 100$$

Where, P = Probability, m = Order number, N = Number of years of record

This relationship was used to estimate the expected amounts of rainfall at different probabilities of exceedence. Further, probability (P%) were plotted (semi log scale) with respect to weekly, monthly, seasonal and annual time intervals and power equation of second degree was fitted to predict expected rainfall at different probability levels.

RESULTS AND DISCUSSION

Rainfall trend

Annual rainfall

The 13 years annual rainfall and rainy days trends are presented in Fig 1. Studying the annual pattern of rainfall from 2000-2012, it is observed that the lowest amount of rainfall received in a year was 491.06 mm during the year 2007 resulting from 25 rainy days; this was closely followed by the year 2003 in which the total annual rainfall was 499.24 mm resulting from 34 rainy days. The highest total annual rainfall observed was 1435.2 mm resulting from 45 rainy days, received in the year 2008. The 13 years annual average rainfall observed was 829.35 mm received from the average rainy days of 40.7.

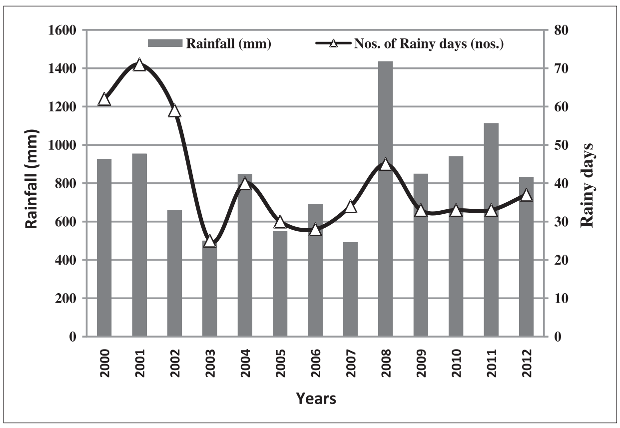

Fig. 1. Annual Rainfall and Rainy days Variability at Shivri Farm

Mean monthly rainfall

The 13 years average monthly rainfall and rainy day is depicted from Fig. 2. It shows the rainfall in this region is mainly concentrated during June, July, August, and September months of the year, which initiate from May as pre-monsoon rains. The similar trends were also observed for average monthly rainy days. The rainfall trend indicates that the mean monthly rainfall of May, June, July, August, and September is 23.83 mm, 111.11 mm, 237.62 mm, 223.62 and 185.64 mm, respectively. In respect to this, the mean monthly rainy days for May, June, July, August and September were 2.46, 6.08, 10.15, 9.23 and 7.92, respectively. The withdrawal of monsoon starts from October, which shows 13 years mean rainfall of 7.59 mm with an average rainy day period limiting to 0.23 days. On other hand, there are evidences of winter rains but comparatively the rainfall depth received during winter is very less mostly confined to December to February months of the year.

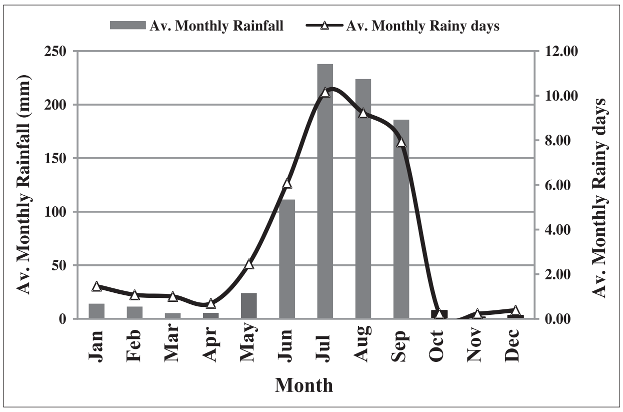

Fig. 2. Average monthly rainfall and rainy day for 13 years

Considering 13 years annual average rainfall of 829.35 mm, it was observed that, approximately 95% of the rainfall is received between May to October months whereas, the monsoon months namely June, July, August and September contributes 91% of the total annual average rainfall.

Mean weekly rainfall

The 13 years weekly average rainfall trend is presented through Fig. 3. The average rainfall trend shows barring pre-monsoon rains between 16th to 21st standard weeks, the monsoon rains sometimes arrives between 23rd to 25th standard weeks (4th June to 24th June). The withdrawal of monsoon takes place between 38th to 40th standard weeks (17th Sept to 7th Oct.).

Based on 13 years average, it can be understood that major wet period is between 25th to 37th standard weeks (18th June to 16th September) of the year. This period shows highest probability of receiving an average weekly rainfall depth between 50 mm to 100 mm.

Rainfall Probability Estimation

Weekly rainfall probability estimation

The past 13 years rainfall data have been analyzed and its weekly probability of occurrence was predicted and is presented in Table 1. This prediction helps to optimize choice of crops, sowing date and irrigation scheduling of different crops to be cultivated and efficient use of rainwater for getting maximum production. In weekly rainfall probability estimation, we mainly considered the monsoon season weeks (22nd to 40th) as depicted in Table 1.

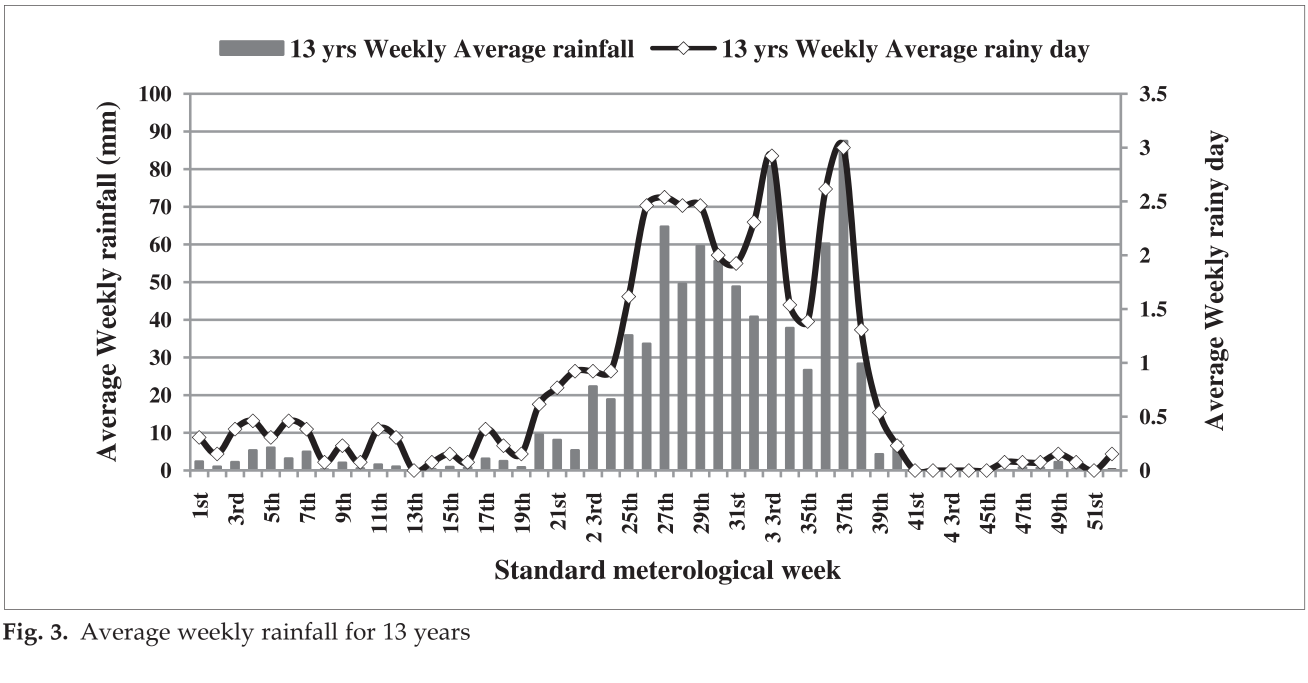

Fig. 3. Average weekly rainfall for 13 years

Table 1. Prediction of weekly rainfall (mm) at different probability level

SMW	Probability level									
	10%	20%	30%	40%	50%	60%	70%	75%	80%	90%
22	20.1	14.1	10.6	8.1	6.1	4.6	3.2	2.6	2.1	1.0
23	104.9	71.2	51.5	37.6	26.7	17.9	10.4	7.0	3.9	0.0
24	92.3	62.4	44.9	32.5	22.8	14.9	8.3	5.3	2.5	0.0
25	148.7	102.8	75.9	56.9	42.1	30.0	19.8	15.3	11.0	3.2
26	107.1	73.0	53.1	39.0	28.0	19.0	11.4	8.0	4.9	0.0
27	128.2	97.3	79.2	66.4	56.4	48.3	41.4	38.4	35.5	30.2
28	132.2	93.9	71.5	55.5	43.2	33.1	24.6	20.8	17.2	10.7
29	170.5	119.0	88.9	67.6	51.0	37.4	26.0	20.9	16.1	7.3
30	157.0	110.0	82.5	63.0	47.8	35.5	25.0	20.3	15.9	7.9
31	170.2	118.7	88.6	67.2	50.6	37.1	25.6	20.5	15.7	7.0
32	166.0	112.9	81.8	59.8	42.7	28.7	16.9	11.6	6.7	0.0
33	224.4	157.8	118.8	91.1	69.7	52.1	37.3	30.7	24.5	13.1
34	142.2	99.7	74.8	57.1	43.4	32.2	22.8	18.6	14.6	7.4
35	113.7	75.2	52.6	36.6	24.2	14.0	5.4	1.6	0.0	0.0
36	166.0	117.0	88.4	68.0	52.3	39.4	28.5	23.6	19.1	10.7
37	217.9	157.4	122.0	96.9	77.4	61.5	48.0	42.0	36.4	26.1
38	123.1	82.6	59.0	42.2	29.1	18.5	9.5	5.5	1.7	0.0
39	44.5	30.0	21.5	15.5	10.9	7.1	3.8	2.4	1.0	0.0
40	204.2	132.6	90.7	61.0	38.0	19.1	3.2	0.0	0.0	0.0

SMW: Standard monthly weeks

The predicted values of rainfall reflect that the value of rainfall decreases with increase in probability level of particular week. Many researchers have suggested that rainfall amount predicted at 75 per cent probability of exceedence can be taken as minimum assured value for crop planning. The predicted rainfall values at 70 to 90 percent probability level are depicted graphically in Fig. 4. It reflects that the 90 percent probability received lowest rainfall whereas, 70 percent is on the top followed by the curve of higher probabilities. At 75 percent probability level, the highest rainfall of 42.0 mm received by 37th week followed by 38.6 mm in 27th standard week. The lowest rainfall of 0.0 mm observed in 40th week. Similarly, for 70, 80 and 90 percent probability the highest observed rainfall values were 48.0 mm (37th week), 36.4 mm (37th week) and 30.2 mm (26th week), whereas, lowest rainfall values observed were 3.2 mm (22nd and 40th standard week), 0.0 mm (35th and 40th standard week) and 0.0 mm (23rd, 24th, 26th, 32nd, 35th, 38th, 39th and 40th standard weeks), respectively.

The graphical trend reflects three peaks between 26th to 28th, 32nd to 35th and 35th to 38th standard weeks. This reflects greater chances of rainwater availability between 26th to 38th standard weeks and during other period need based irrigation can be provided through available irrigation sources.

The predicted weekly rainfall values of rabi (winter) season for 70% to 90% probability level are depicted through Fig. 5. It reflects that for *rabi* season, major wetting period is between 2nd to 8th standard weeks. However, amount of rainfall

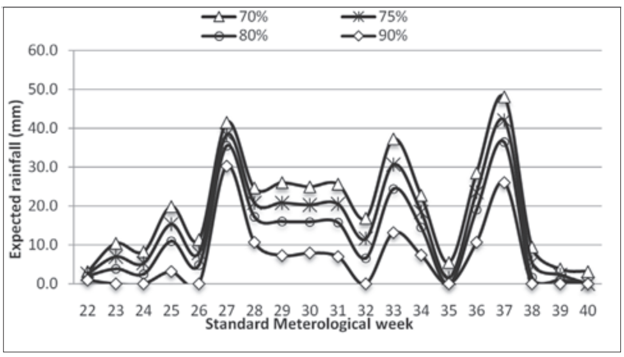

Fig. 4. Predicted weekly rainfall at different probability level of monsoon weeks (kharif)

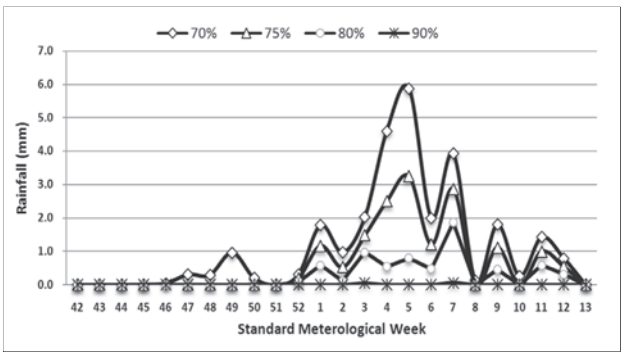

Fig. 5. Predicted weekly rainfall at different probability level

received is not sufficient. Hence, during rabi season support of irrigation facilities will be mandatory to avoid crop failure especially in case of wheat crop.

Monthly rainfall probability estimation

The month-wise rainfall variations at different probabilities are presented in Table 2 and Fig. 6. Observing the predicted values it reflects that July, August, and September are the three important wet months having chances of receiving a monthly rainfall between 100 to 150 mm at 70, 75 and 80 percent probability levels.

Hence, during this period strategies for collection of surface runoff for efficient use of harvested rainwater during the subsequent dry period can be thought of Dhingre *et al*. (2004) and Tomar (2006) suggested that rainfall at 70 percent probability could be safely taken as assured rainfall while 50 percent probability is upper most limits for taking risk. The expected rainfall amount at 70 percent probability ranged between 120 to 140 mm in the months of July, August and September. Considering the predicted rainfall from the table, it is observed that the three wet months namely July, August and September contributes approximately 29, 26 and 25 percent rainfall out of the total annual rainfall at 70 percent probability leading to overall contribution of 80 percent of total annual rainfall. Hence, transplanting of rice should be planned accordingly, as the major water requirement stages of rice falls during July to September.

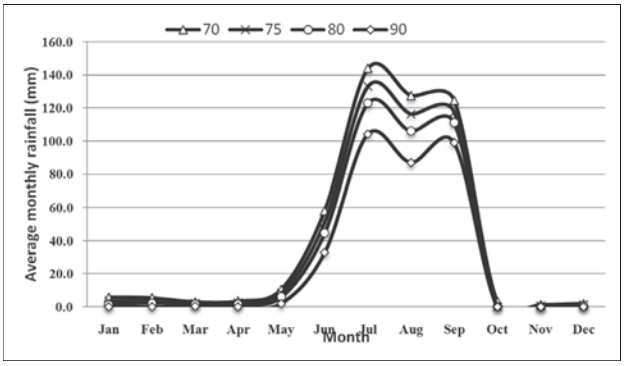

Fig. 6. Predicted monthly rainfall at different probability level

Cropping season rainfall probability estimation

The cropping season probability values are presented in Table 3 and Fig. 7.

The rainfall trend of seasonal analysis of rainfall at various probability levels also reflects that the value of rainfall decreases with increase in probability level. The 70 percent probability level considered safer for seasonal agricultural planning.

The predicted value of seasonal rainfall shows 600 mm rainfall annually during kharif season at 70 percent probability level, which is higher than the other two seasons. This trend gives an

Table 2. Prediction of monthly rainfall (mm) at different probability level

Months	Probability level									
	10%	20%	30%	40%	50%	60%	70%	75%	80%	90%
Jan	69.5	46.8	33.6	24.2	16.9	10.9	5.9	3.6	1.5	0.0
Feb	50.3	34.4	25.0	18.4	13.2	9.0	5.5	3.9	2.4	0.0
Mar	24.4	16.8	12.4	9.2	6.8	4.8	3.1	2.4	1.7	0.4
Apr	29.9	20.5	15.0	11.2	8.1	5.7	3.6	2.7	1.8	0.2
May	77.6	53.8	39.8	30.0	22.3	16.0	10.7	8.3	6.1	2.1
Jun	254.8	184.8	143.8	114.8	92.3	73.8	58.3	51.3	44.8	32.9
Jul	450.6	341.4	277.5	232.1	197.0	168.2	143.9	133.1	122.9	104.3
Aug	441.8	329.9	264.4	217.9	181.9	152.5	127.6	116.4	106.0	87.0
Sept	323.8	252.9	211.4	182.0	159.2	140.5	124.8	117.7	111.1	99.0
Oct	204.2	132.6	90.7	61.0	38.0	19.1	3.2	0.0	0.0	0.0
Nov	25.6	17.0	12.0	8.4	5.7	3.4	1.5	0.6	0.0	0.0
Dec	26.6	17.9	12.8	9.2	6.4	4.1	2.2	1.3	0.5	0.0

Table 3. Prediction of seasonal rainfall (mm) at different probability level

Months	Probability level									
	10%	20%	30%	40%	50%	60%	70%	75%	80%	90%
Zaid	41.2	28.0	20.3	14.8	10.6	7.1	4.2	2.8	1.6	0.0
Kharif	1209.3	992.2	865.3	775.2	705.3	648.3	600.0	578.4	558.2	521.3
Rabi	91.8	63.6	47.0	35.3	26.3	18.8	12.6	9.7	7.1	2.3

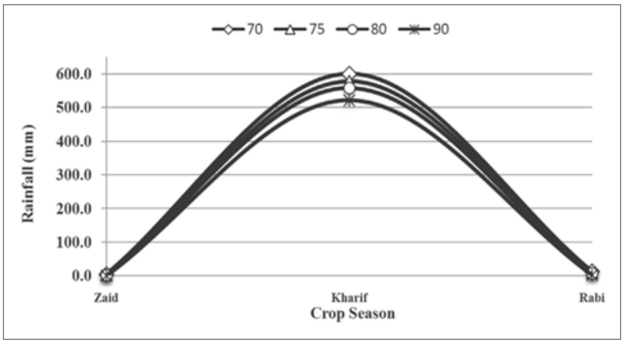

Fig. 7. Estimation of rainfall at different probability level on the basis of crop season

opportunity that the excess rainfall during the *Kharif* season may be planned to harvest and can be recycled as life saving irrigation at critical stages of crop growth during dry periods. At 70 percent probability level the predicted rainfall in case of rabi is around 12.6 mm which reflects that barring pulses there is need of assured irrigation facility to raise other crops such as wheat and oilseeds.

Annual rainfall probability estimation

Probability distribution of annual rainfall is important to predict the relative frequency of occurrence of a given amount of annual rainfall with reasonable accuracy and depicted through Fig. 8.

It is clear from the Fig. 8 that the value of rainfall reduces with increase in probability level. The values of rainfall estimated to be 583.5, 617.7, 636.5, 56.5, 701.3, 754.3, 819.1, 902.7, 1020.4, and 1221.8mm at 90, 80, 75, 70, 60, 40, 30, 20, and 10 percent probability levels respectively. As per, IMD an area/region is considered to be drought affected if it receives seasonal/yearly total rainfall less than 75 percent of its normal value (AppaRao, 1986). Considering the 13 years annual rainfall three years i.e. 2002, 2003, 2005 and 2007 received rainfall less than 636.5 mm, predicted at 75 percent probability level.

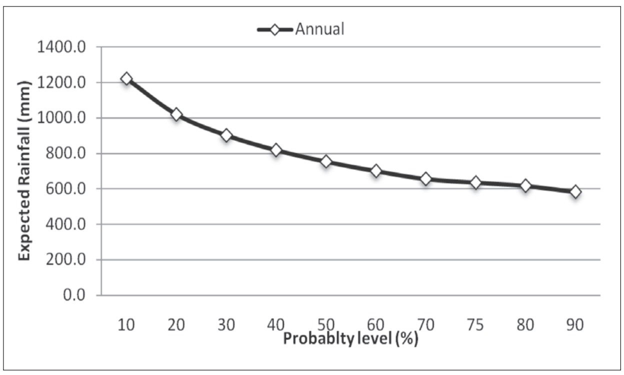

Fig. 8. Annual expected rainfall at different probability level

CONCLUSIONS

The trend of rainfall indicates that June, July, August and September are the wet months receiving a 13 years mean monthly rainfall of 111.11 mm, 237.62 mm, 223.62 and 185.64 mm respectively. Considering 13 years annual average rainfall of 829.35 mm, the rainfall trend shows that approximately 95 % of the rainfall is received between May to October months whereas, the monsoon months namely June, July, August and September alone contributes 91percent of the total annual average rainfall. Analysis of weekly rainfall data reflects that the monsoon rain arrives sometimes between 23rd to 25th standard weeks (4th June to 24th June). The withdrawal of monsoon takes place between 38th to 40th standard weeks (17th Sept to 7th Oct.). Based on 13 years average it can be said that major wet period is between 25th to 37th standard weeks (18th June to 16th September) of the year. This period shows highest probability of receiving an average weekly rainfall depth between 50 mm to 100 mm. This suggest that activities in kharif season can be initiated between 22ndto 23rd standard week and in case of rabi season around 43th to 44th standard week to harness maximum rainfall use.

REFERENCES

Aggarwal, M.C., Katiyar, V.S. and Ram Babu. 1988. Probability analysis of annual maximum daily rainfall of U.P. Himalayas. *Indian J. of Soil Cons.* **16**(1): 35-42.

AppaRao, G. 1986. Drought climatology, Jal Vigyan Samiksha, National Institute of Hydrology, Roorkee.

Barman D., Shaha A. R., Kundu D. K. and Mahapatra B. S. 2012. Rainfall characteristics analysis for jute based cropping system at Barrackpore, West Bengal, India. *Journal of Agricultural Physics* **12**(1): 23-28.

Baweja, Parminder Kaur. 2011. Rainfall variability and probability for crop planning in Solan, Himachal Pradesh. *Journal of Farm Sciences* **1**(1):75-88.

Bhatt, V.K., Tewari, A.K. and Sharma, A.K. 1996. Probability models for prediction of annual maximum daily rainfall of Datia. *Indian J. of Soil Cons*. **24**(1): 25-27.

Blom, G. (1958). *Statistical estimates and transformed beta variables*. John Wiley and Sons, New York.

Dhingre, S., Shahi, N.C. and Khan, A. A. 2004. Predicting precipitation characteristics of Srinagar region of Kashmir valley. *Journal of Water Management* **12**(2): 71-74.

Fisher, R.A. 1924. The influence of the rainfall on the yield of wheat at Rothamsted. *Philosophical transaction of the Royal Society of London*. Series B, Vol. **213**: 89-142.

Ishappa, Muniyappa and Aruchamy, S. 2010. Spatial analysis of rainfall variation in Coimbatore district

Tamil Nadu using GIS. *International Journal of Geomatics and Geosciences* **1**(2): 106-118.

Jeevrathnam, K. and Jay Kumar, K. 1979. Probability analysis of maximum daily rainfall for Ootacamud. *Indian J. of Soil Cons.* **7**(1): 10-16.

Khandelwal, M.K., Arora, Sanjay and Raju, K.C.B. 2013. Spatial and temporal variations in rainfall and rainwater harvesting potential for Kutch district, Gujarat. *Journal of Soil and Water Conservation* **12**(2): 117-122.

Krishnamurthy, Chandra Kiran, LallUpmanu and Kwon, Hyun-Han 2009. Changing frequency and intensity of rainfall extremes over India from 1951 to 2003. *Journal of Climate* **22**: 4737-4746.

Prakash, C. and Rao, D.H. 1986. Frequency analysis of rain data for crop planning, Kota. *Indian J. of Soil Cons.* **14**(2): 23-26.

Rajeevan, M., Bhate, Jyoti and Jaswal, A. K. 2008. Analysis of variability and trends of extreme rainfall events over India using 104 years of gridded daily rainfall data. *Geophysical Research Letters* **35**: L18707.

Rizvi, R.H., Singh, R., Yadav, R.S. Tewari, R.K., Dadhwal, K.S. and Solanki, K.R. 2001. Probability analysis of annual maximum daily rainfall for bundelkhand region of Uttar Pradesh. *Indian J. of Soil Cons.* **29**(3): 259-262.

Subudhi, C. R., Sahoo, M. and Senapati, S. C. 2012. Rainfall probability analysis for crop planning in Kandhamal district of Orissa. *Indian J. of Soil Cons.* **40**(3): 247-251.

Tomar, A. S. 2006. Rainfall analysis for ensuring soil moisture availability at dryland area of semi-arid Indore region of Madhya Pradesh. *Indian J. of Soil Cons.* **5**(1): 1-5.

Yengoh, Genesis Tambang 2010. Trends in agriculturally-relevant rainfall characteristics for small-scale agriculture in Northern Ghana. *Journal of Agriculture Science* **2**(3): 3-16.

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Mulching in fruit and vegetable crop production under rainfed conditions: A review

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ABSTRACT

In water deficit area (rainfed area), judicious use of water is essential for increasing area under fruit and vegetables crop production with limited water supply. Use of moisture conservation measures is essential under rainfed situation. Mulching has been advocated as an effective means for conserving soil moisture. Mulching is a soil and water conservation technique in which the use of organic materials like plant residues, straw, leaves, peat, etc. and synthetic materials like paper, polyethylene, wax coated papers, steel foils and asphalt spray emulsions etc. for the purpose of increasing soil productivity is involved. This practice is very useful in protecting the roots of the plants from heat, cold or drought or to keep fruit clean. It checks evaporation and conserves the soil moisture, prevents weed growth and enhances the soil structure in which a plant is growing. This may include temperature moderation, salinity and weed control. It exerts decisive effects on earliness, yield and quality of the crop. Mulching is also applicable to most field crops. However, it is preferred in fruit orchard, flower and vegetable production, nurseries and forest where frequent cultivation is not required for raising the crops. Most commonly used agricultural mulch is black plastic. Weed control beneath the mulch is a deterrent to its use. White or aluminum reflective mulch is used where soil cooling is desired, such as establishing fall crops during the heat of summer. The present review deals with the discussion of every aspect of mulching and how it has beneficiary effect.

Key words: soil moisture, mulching, crop residue, organic matter, improvement of soil structure

INTRODUCTION

Any material used or spread at surface or vertically in soil to assist soil and water conservation and soil productivity is called mulch. The word mulch has been probably derived from the German word "molsch" means soft to decay, which apparently referred to the use of straw and leaves by gardeners as a spread over the ground as mulch. The practice of applying mulches to soil is possibly as old as agriculture itself. Mulches are used for various reasons but water conservation and erosion control are the most important objective for its use in agriculture in dry regions. Conservation of soil moisture by application of mulches becomes essential for profitable cultivation of the crop under rainfed condition of semi-arid ecosystem. In spite of no assured irrigation in these regions, the moisture conservation technique is not in practice. Mulches not only conserve soil moisture but also impart manifold beneficial effects, like suppression of extreme fluctuation of soil temperature and reduction of water loss through evaporation, resulting is more stored soil moisture (Shirugure *et al*., 2003; Arora *et al*., 2008), maintenance of soil fertility (Slathia and Paul, 2012), suppression of weed growth (Ramakrishna *et al*., 2006), improvement in growth and yield (Ban *et al*., 2009). The requirement of water through mulch can further be reduced by using locally available organic materials as mulches which not only save irrigation water but also conserves soil moisture. Various studies have indicated that in fruit crops like apple, sapota and acid lime, mulching improves soil moisture status, growth, yield and quality of these fruits, besides reducing weed growth (Abouziena *et al*., 2008). Other reason for high mulching use includes soil temperature modification, soil conservation, nutrient addition, improvement in soil structure, weed control and crop quality control. Mulching reduces the deterioration of soil by way of preventing the runoff and soil loss, minimizes the weed infestation and checks the water evaporation. Thus, it facilitates more retention of soil moisture and helps in control of temperature fluctuations, improves

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physical, chemical and biological properties of soil, as it adds nutrients to the soil and ultimately enhances the growth and yield of crops. Mulches are either organic or inorganic.

Organic mulches are those derived from plant and animal materials. Those most frequently used include plant residues such as straw, hay, peanut hulls, leaf mold and compost, wood products such as sawdust, wood chips and shavings and animal manures. Organic mulch properly utilized can perform all the benefits of any mulch with the possible exception of early season soil warming. However, natural mulch materials are often not available in adequate quantities for commercial operations or must be transported to the place of use. Natural materials cannot be easily spread on growing crops and require considerable hand labour. Expense and logistical problems have generally restricted use of organic mulch in crop production and gardening of fruit plants with only limited use on a large commercial scale.

Inorganic mulch includes plastic mulch and accounts for the greatest volume of mulch used in commercial crop production. The plastic materials used as mulch are poly vinyl chloride or polyethylene films. Owing to its greater permeability to long wave radiation it can increase temperature around the plants during night in winter. Hence, polyethylene film mulch is preferred as mulching material for crop production. Now a day application of black plastic mulch film is becoming popular and very good results have been achieved particularly in rainfed agriculture. Use of polyethylene mulch has been reported to conserve soil moisture appreciably. Hence, under prevailing drought and water scarcity conditions, conservation of soil moisture and to ensure availability of soil moisture to crop is of much importance. The black polyethylene mulch also checks all types of weeds in addition to soil moisture conservation. Moreover, mulching with plastic polyethylene is found effective in conserving the soil moisture and increasing the growth, yield and quality in different citrus cultivars (Shirugure *et al.*, 2005).

Effect of mulches on soil and plants

Conserve soil moisture

Conservation of soil moisture through mulching is one of the important purposes. The microclimatic conditions are favorably affected by optimum degree of soil moisture. When soil surface is covered with mulch, it helps to prevent weed growth, reduce evaporation and increase infiltration of rain water during growing season. Plastic mulch helps prevent soil water loss during dry years and sheds excessive water away from the crop root zone during periods of excessive rain fall. This can reduce irrigation frequency and amount of water. It may help reduce the incidence of moisture related physiological disorders on fruit cracking in lime and pomegranate. Research has shown that mulch provides many benefits to crop production through soil and water conservation, enhanced soil biological activity and improved chemical and physical properties of the soil. Muhammad *et al*. (2009) stated that mulching improves the ecological environment of the soil and increases soil water contents. Singh *et al*. (2008) observed that the higher soil moisture in black polyethylene at 0-15 cm and 15-30 cm depth after 170 days of mulching at both depths. The higher soil moisture content below the mulches in various mulching treatments may be owing to reduction of water erosion, reduction in soil surface evaporation, suppression in extreme fluctuation of soil temperature, resulting more stored soil moisture (Pande *et al*., 2005). Cao *et al*. (2012) reported that both wheat straw mulching and film mulching increased soil water contents and helped the soil water move to the deep soil. Mishra *et al*. (2010) reported that black plastic mulch was higher soil moisture content (23%) than the over control treatment in turmeric.

Reduce infiltration rate

Mulching increase the total intake of water due to formation of loose soil surface. The rain drops on mulched soil do not seal the particles as they do on unmulched soil. This sealing effect of rain drops results in more loss of water through erosion. The water infiltrated in soil can be utilized by crops there-by crop yields are increased. Mulches obstruct the solar radiation reaching to soil. Infiltration and soil evaporation are among the key processes that determine soil water availability to crops in semi arid agriculture. The presence of crop residue mulch at the soil-atmosphere interface has a direct influence on infiltration of rainwater into the soil and evaporation from the soil. Straw mulch conserved higher soil moisture to an extent of 55 per cent more compared to control (Rajput and Singh, 1970). (Abu- Awwad, 1999) observed that covering of soil surface reduced the amount of irrigation water required by the pepper and onion crop by about 14 to 29 and 70 per cent respectively. Singh *et al*. (2008), found that black polyethylene, subabool lopping, maize straw, paddy straw, rice husk and grasses as mulch in Aonla conserved more moisture compared to control. The higher soil moisture content below the mulches in various mulching treatments may be owing to reduction of water erosion, reduction in soil surface evaporation, suppression in extreme fluctuation of soil temperature, resulting more stored soil moisture (Pande *et al*., 2005).

Minimum weed growth

Mulching materials reduce the weed growth, germination and nourishments of many weeds. If somehow weeds are growing they become pale and ultimately die. Mulching materials such as wheat straw, maize straw, bajra straw, subabool lopping, paddy straw, rice husk, dry grasses, saw dust and black polyethylene are good in this respect. Covering or mulching the soil surface can prevent weed seed germination or physically suppress seedling emergence. White and green covering had little effect on weeds, whereas brown, black, blue or white on black (double color) films prevented weeds emergence (Bond and Grundy, 2001). Ossom *et al.* (2001) also observed significant differences in weed control between mulched and unmulched plots of eggplant, cowpea and sweet potato.

Minimum evaporation and maintain of soil temperature

Mulching reduces soil temperature in summer and raises it in winter. It prevents the extremes of temperatures. During summer, mulching conserves the soil moisture due to reduced evaporation. The cooling effect of soil promotes root development. In general, the effect of mulching on the temperature regime of the soil varies according to the capacity of the mulching material to reflect and transmit solar energy. Mulches results in greater water content and lower the evaporation.

However, effects on soil temperature are highly variable. White mulches decrease soil temperature while clear plastic mulches increase soil temperature. Plastic mulching has many advantages for agriculture including maintaining soil temperature and humidity, preventing soil borne diseases and attack by soil pests and speeding up growth. At night, condensation on the mulch absorbs the longwave radiation emitted by the soil thereby slowing cooling the soil (Lamont, 2005). The ability of clear mulches to produce soil temperatures high enough to control weeds, plant pathogens and nematodes forms the basis for the soil solarization process (Stapleton *et al*., 2005). The dry soil is heated more easily than a wet soil because the specific heat of water is nearly five times than that of dry soil. The high specific heat of water prevents the sudden changes in temperature of irrigated soil during winter. Mulches reduce water evaporation from soil and help maintain stable soil temperature (Kar and Kumar, 2007). Cao *et al*. (2012) reported that in the growing season soil temperature in the farmland mulched by wheat straw was lower than under the control condition by 22.5^0C.Soil temperature in the farmland mulched by film was higher at both daytime and night-time than the control. While the growing season accumulated soil temperature in the farmland mulched by film was higher than under the control condition by 159.5^0C.

Enhance plant growth and development

The effect of mulches on plants is operative through the effects of mulches on soil water, soil temperature structure and erosion. Reduced evaporation is major reason for the growth of the plants and there by high crop production due to mulch. Mulching provides a favourable environment for growth. A combination of the above, and perhaps other factors, results in more vigourous, healthier plants which may be more resistant to pest injury. Therefore, mulched plants usually grow and mature more uniformally than unmulched plants. Barman *et al.* (2005) recorded significant improvement in number of days taken to first floret opening, spike length and rachis length with the application of paddy straw mulch in gladiolus.

Improving the quality and yield

Mulch helps keep fruits such as tomato from contacting the ground. This reduced soil rot and helps keep the product clean. Fruit cracking and blossom end rot are reduced in many cases. Fruits tend to be smoother with fewer scars. Properly installed plastic mulch helps keep soil from splashing in to the plants during rainfall, which can reduce grading time. The yield and chemical composition to tomatoes, cucumber, muskmelons, eggplant, Aonla etc, .were found to be improved. The yield and keeping quality of early potatoes, cabbage and other vegetables may be improved by straw mulch. This is probably due to better plant growth which is governed by soil temperatures with minimum fluctuations, and soil moisture as well. Plastic (polyethylene) mulches have the potential to alter soil temperatures, reduce crop water use, improve crop quality and control weeds, thereby improving crop development and increasing yields (Ngouajio *et al*., 2005). Black mulch warms the soil by absorbing light then transferring heat by conduction to the underlying soil, provided that the mulch is in close contact with the soil (Lamont *et al*., 2005). Gandhi and Bains (2006) observed that mulches modified the microclimate by modifying soil temperature, soil moisture and evaporation and the modified microclimate affected the yield contributing characters of tomato. Crop under straw mulch produced higher number of branches (8.7), fruit weight (28.08 g) and total yield (496.3 q ha^{-1}) as compared to no mulch (8.1, 27.86 g and 478.5 q ha^{-1}, respectively). Singh *et al*. (2008) Observed that the higher crop yield in black polyethylene mulch then the organic mulch viz. maize straw, paddy straw, rice husk, grasses and subabool loppings after the decomposition of mulching at both 2004 and 2005 years in Aonla. Khurshid *et al*. (2006) pointed out that maize grew taller under greater mulch levels, because of availability of more soil moisture contents for plant growth. Shashidhar *et al*. (2009) reported that the total leaf yield of mulberry was found maximum in paddy straw mulched plots (15201.36 kg ha^{-1}) as compared to control plots (11785.32 kg ha^{-1}). Besides beneficial effect on earliness, polyethylene film as a mulch can enhance plant growth and development, increase yield, decrease soil evaporation and nutrient leaching, reduce incidence of pests and weeds, and improve fruit cleanliness and quality (Hutton *et al*., 2007). The yield increase in squash has been found to the tune of 30 per cent (Annda *et al*., 2008).

Rapid earlier harvest

Mulch can be used effectively to modify soil temperature. Black or clear mulch intercept sunlight which warms the soil. Black mulch applied to the planting bed prior to planting will warm the soil and promote faster growth in early season, which generally leads to earlier harvest. First harvest acceleration of 7 to 14 days is not uncommon, depending on weather conditions. Clear mulch warms the soil more than black and usually provides even earlier harvest. Warm season vegetable, such as cucumbers, muskmelons, watermelons, eggplant, peppers, usually respond well to mulching in terms of early maturity and more yields. An earlier maturity is probably due to maintenance of favourable temperatures during growing season. Applications of polyethylene films as mulch have shortened growing season and enhanced earliness and yield (McCann *et al*., 2007). Beneficial effect of polyethylene mulch on the increase of the early yield was also found for watermelon (Romic *et al*., 2003), tomato (Hutton *et al*., 2007) and pepper (Hutton *et al*., 2007). Mulching helps to maintain an even soil temperature, induce early flowering and better blooms (Anonymous, 2003).

Minimum fertilizer leaching

As excessive rainfall is shed from the root zone, fertilizer loss due to leaching is reduced. This is particularly true in sandy soils. This allows the grower to place more pre plant fertilizer in the row prior to planting the crop. Liu *et al*. (2009) concluded that mulch increases soil moisture and nutrients availability to plant roots, in turn, leading to higher grain yield. Annual legumes, grasses and *Brassica* species are mostly recommended for mulching purpose and used in the practice (Hooks *et al*., 2003). They are also efficient in reduction of nitrates leaching and contamination of surface and ground waters by these compounds. The influence of plants left as a mulch has many positive aspects: mulches improve soil physical properties, prevent erosion, supply organic matter, regulate temperature and water retention, improve nitrogen balance, take part in nutrient cycle as well as increase the biological activity (Muhammad *et al*., 2009).

Addition of organic matter

Organic mulches return organic matter and plant nutrients to the soil and improve the physical, chemical and biological properties of the soil after decomposition, which in turn increases crop yield. Soil under the mulch remains loose and friable. Aeration and soil microbial activity are enhanced. Mulching increased soil moisture, organic matter contents leading to suitable environment for root penetration. The soil organic matter increased due decomposition of applied mulch. Applications of crop residue mulches increase soil organic carbon contents (Saroa and Lal, 2003). Khurshid *et al*. (2006) concluded that organic matter was significantly higher when more mulch was applied. Muhammad *et al*. (2009) observed that mulched treatments show significantly greater total uptake of nitrogen, phosphorus and potassium than corresponding unmulched ones. Higher organic carbon content of soil recorded with sunhemp mulch (0.71%) followed by silkworm bed waste (0.68%) and paddy straw (0.66%) mulched plots. Least organic carbon content was recorded in no mulched plot (0.48%) (Shashidhar *et al*., 2009).

REFERENCES

Abu- Awwad, A.M. 1999. Irrigation water management for efficiency water use in mulched onion. *Journal of Agronomy and Crop Science* **183**: 55-59.

Anonymous 2003. *Commercial flowers* Vol-II, 2nd revised addition, Naya Prokashan Calcutta, pp. 351.

Abouziena, H. F., Hafez, O. M., El-Metwally, I. M., Sharma, S. D. and Singh, M. 2008. Comparison of weed suppression and mandarin fruit yield and quality obtained with organic mulches, synthetic mulches, cultivation, and glyphosate. *Hort. Science* **43**(3): 795-799.

Annda, A., Venkatesha, M.M., Kiran Kumar K.C., Krishnamurthy, N. and Bhanu Prakash V.H. 2008. Mulching: an ideal approach for soil and water conservation in dry lands. *Rashtriya Krishi* **3**(2): 128-129.

Arora, Sanjay, Hadda, M.S. and Bhatt, R. 2008. Tillage and Mulching in relation to soil moisture storage and maize yield in foothill region. *Journal of Soil and Water Cons.* **7**(2): 51-56.

Bond, W., Grundy, A. C. 2001. Non-chemical weed management in organic farming systems. *Weed Research* **41**: 383-405.

Barman, D., Rajni, K. , Rampal, Upadhyay, R.C. 2005. Effect of mulching on cut flower production and corm multiplication in gladiolus. *Journal of Ornamental Horticulture* **8**: 152-154.

Ban, D., Zanic, K., Dumicic, G., Culjak, T. G. and Ban, S. G. 2009. The type of polyethylene mulch impacts vegetative growth, yield, and aphid populations in watermelon production. *Journal of Food Agriculture and Environment* **7**: 543-550.

Cao, J., Zhou, X., Zhang, W., Liu, C., and Liu, Z. 2012. Effects of mulching on soil temperature and moisture in the rain-fed farmland of summer corn in the Taihang Mountain of China. *Journal of food, Agriculture & Environment* **10**(1): 519-523.

Gandhi, N. and Bains, G. S. 2006. Effect of mulching and date of transplanting on yield contributing characters of tomato. *Journal Research Punjab Agriculture University* **43**: 6-9.

Hooks, C. R. R. and Johnson, M. W. 2003. Impact of agricultural diversification on the insect community of cruciferous crops. *Crop Protection* **22**: 223-238.

Hutton, M. G. and Handley, D. T. 2007. Effects of silver reflective mulch, white inter-row mulch, and plant density on yields of pepper in Maine. *Hort. Technology* **17**:214-219.

Kamble, T., Rao, B.K. and Sharma, R. 2016. Mulch farming techniques for improving resource conservation, carbon sequestration and crop production in rainfed regions- A review. *Journal of Soil and Water Cons.* **15**(1): 14-21.

Khurshid, K., Iqbal M., Arif, M. S. and Nawaz, A. 2006. Effect of tillage and mulch on soil physical properties and growth of maize. *International Journal of Agriculture & Biology* **8**: 593–596.

Kar, G. and Kumar, A. 2007. Effects of irrigation and straw mulch on water use and tuber yield of potato in eastern India. *J. Agricultl. Water Manag.* **94**: 109- 116.

Lamont, Jr., W. J., Plastics 2005. Modifying the microclimate for the production of vegetable crops. *Hort. Technology* **15**: 477-481.

Liu, J., Xu, S. A., Zhou, G. Y. and Lu, H. H. 2009. Effects of transplanting multi-cropping spring maize with plastic film mulching on the ecological effect, plant growth and grain yield. *Journal Hubei Agriculture Coll.* **2**: 100–102.

McCann, I., Kee, E., Adkins, J., Ernest, E. and Ernest, J. 2007. Effect of irrigation rate on yield of drip-irrigated seedless watermelon in humid region. *Science Horticulture* **113**:155-161.

Muhammad, A. P., Muhammad, I., Khuram, S. and Anwar-Ul-Hassan 2009. Effect of mulch on soil physical properties and NPK concentration in Maize (*Zea mays*) shoots under two tillage system. *International J. of Agriculture & Biology* **11**:120-124.

Mishra, J.N., Paul, J.C. and Pradhan, P.C. 2010. Effect of mulching on in situ soil moisture, growth, yield and economics of turmeric under rainfed condition in Orissa. *J. of Soil and Water Conservation* **9**(2): 123-126.

Ngouajio, M. and Ernest, J. 2005. Changes in the physical, optical, and thermal properties of polyethylene mulches during double cropping. *Hort. Science* **40**: 94-97.

Ossom, E. M., Pace, P. F., Rhykerd, R. L. and Rhykerd, C. L. 2001. Effect of mulch on weed infestation, soil temperature, nutrient concentration, and tuber yield in *Ipomoea batatus* (L.) Lam. In Papua New Guinea. *Trop. Agric*. (Trinidad) **78**: 144–151.

Pande, K.K., Dimn, D.C. and Kamboj, Prashant 2005. Effect of various mulches on growth, yield and quality of apple. *Indian J. of Horticulture* **62**: 145-147.

Rajput R.K. and Singh M. 1970. Efficiency of different mulches on conserving soil moisture in cotton. *Indian Journal of Agronomy* **15**: 41-45.

Romiæ, D., Borošiæ, J., Poljak, M. and Romiæ, M. 2003. Polyethylene mulches and drip irrigation increase growth and yield in watermelon (*Citrullus lanatus* L.). *European J. of Horticultural Science* **68**: 192-198.

Ramakrishna, A., Tam, H. M., Wani, S. P. and Long, T. D. 2006. Effect of mulch on soil temperature, moisture, weeds infestation and yield of groundnut in northern Vietnam. *Field Crops Research* **95**(2): 115-125.

Saroa, G. S. and Lal, R. 2003. Soil restorative effects of mulching on aggregation and carbon sequestration in a Miamian soil in Central Ohio. *Land Degrad. Development* **14**: 481-493.

Shirugure, P. S., Sonkar, R.K., Singh, S. and Panighrah, P. 2003. Effect of different mulches on soil moisture, weed reduction, growth and yield of drip irrigated Nagpur mandarin (*Citrus reticulata*). *Indian Journal of Agricultural Sciences* **73**:148-52.

Shirugure, P.S., Singh, S., Panighrah, P. and Sonkar, R.K. 2005. Evaluation of mulches for improving bearing acid lime. *Indian Journal of Soil Conservation* **33**(1):62-66.

Stapleton, J. J., Molinar, R. H., Lynn-Patterson, K., Mc Feeters, S. K. and Shrestha, A. 2005. Soil solarization provides weed control for resource and organic growers in warmer climates. *California Agriculture* **59**: 84-89.

Singh, A.K., Singh, S., Apparao, V.V. and Meshram, D.T. 2008. Effect of mulching on soil properties, growth and yield of 'NA-7' aonla (*Emblica officinalies*) in semi arid ecosystem. *Indian Journal of Agricultural Sciences* **78**(3):193-197.

Shashidhar, K. R., Bhaskar, R. N., Priyadharshini, P. and Chandrakumar, H. L., 2009. Effect of different organic mulches on pH, organic carbon content and microbial status of soil and its influence on leaf yield of M-5 mulberry (*Morus indica* L.) under rainfed condition. *Current Biotica* **2**: 405-412.

Slathia, P.S. and Paul, N., 2012 Traditional practices for sustainable livelihood in Kandi belt of Jammu. *Indian Journal of Traditional Knowledge* **11**(3): 548—552.

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Morphometric analysis of Chanavada – II watershed in Aravalli hills of southern Rajasthan using geospatial technique

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ABSTRACT

Watershed management has gained importance in management of natural resources, such as soil, water their conservation and improvement in the livelihood of the peoples in the region. Morphometric analysis has been commonly applied to prioritization of watersheds arresting the loss of soil and water. In the present study an attempt has been made to study the morphometric characteristics of Chanavada micro watershed using remote sensing and GIS technique. The Chanavada micro-watershed is part of Jhakham, Gomti catchment covering an area of 1475 ha in Girwa block of Udaipur district in southern Rajasthan. The morphometric analysis of the watershed reveals that the watershed is 4th order, elongated in shape having mixed drainage pattern. The value of mean stream length (Lsm) varies from 0.59 to 8.67 may be due to variation in slope and topography. The stream length ratio showed an increasing trend in the length ratio from lower order to higher order indicating their mature geomorphic stage. The high value of bifurcation ratio indicates the strong structural control on the drainage development. The drainage density of the watershed is 4.16 which could be the result of impermeable sub-surface material, sparse vegetation and mountainous relief and drainage texture of the watershed lie between 2 and 4 which is related to coarse texture. The low Rf value (0.23) indicated elongated shape of watershed and suggesting flatter peak flow for longer duration. The value of elongation ratio (Re) is associated with high relief and steep slope showing elongated shape of watershed. The present study demonstrates the utility of remote sensing and GIS technique in studying morphometric analysis of hilly watershed.

Key words: Watershed, remote sensing, GIS, drainage morphometry

INTRODUCTION

The concept of watershed Management recognizes the inter relationship between land use, soil and water and the linkage between upland and downstream areas (Tideman, 1996). Soil and water conservation are key issues in watershed management in India behind demarcating the priority watershed. In developing countries watershed projects which focus on water harvesting and soil conservation typically state three objectives, firstly, to conserve and strengthen the natural resource base; secondly, to make natural resource based activities like agriculture more productive and finally to support rural livelihood to alleviate poverty (Chauhan, 2010; Gupta and Arora, 2010; Arora and Gupta, 2014).

Morphometric analysis provides quantitative description of the basin geometry to understand initial slope or in equalities in the rock hardness, structural controls, recent diastrophism, geological and geomorphic history of drainage basin (Strahler, 1964). It covers measurement of linear, aerial and relief aspect of watershed. It helps to assess and evaluate erosion risk, soil and water conservation strategies, ground water potential and other environmental factors. The role of rock types and geologic structures in the development of stream network can be better understood by studying the nature and type of drainage pattern and by a quantitative morphometric analysis. Remote sensing is a science of acquiring information about an object or surface at a distance and it has the ability to provide synoptic view of large area therefore through the satellite images of finer resolution it is very useful in analyzing drainage morphometry. In addition to this image interpretation technique is less time consuming than the ground surveys. Many workers studied

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morphometric analysis of watersheds in West Bengal, Punjab and southern India using remote sensing (Nag, 1998; Srinivasa, 2004; Chopra *et al*., 2005) and found the influence of rock types and structure in the development of drainage network in the hard rock area. Thus the information relating to this hilly terrain of Aravalli system in Udaipur District of Rajasthan is scanty. Hence the effort has been made to understand and evaluate the influence of topography, lithology and geologic structure in development of drainage network of Chanavada watershed through deriving morphometric characteristic using remote sensing and GIS.

MATERIALS AND METHODS

Study area

Chanavada watershed is located in Girwa tehsil of Udaipur district of southern Rajasthan state (Fig. 1) and lies between 24^{o} 15' to 24^{o} 16' N latitude and 73^{o} 35' to 73^{o} 40' E longitude and falls in Survey of India toposheet 45H/11 (1:50000). The study area forms part of Aravalli range hence has high relief and steep slopes covering an area of 1475 ha. The climate of the study area is tropical semi-arid characterized by hot summer and intense winter with maximum temperature in the month of June and minimum in the month of December and January. The average rainfall is 650 mm and the mean annual temperature is 24^{0}C while the minimum and maximum temperature varies between 10^{0} to 40^{0}C. As a part of Aravalli landscape, geologically Aravalli system is derived from argillaceous deposits composed of slates, phyllites and mica schist's along with granite and quartzite. The natural vegetation of the study area is tropical dry deciduous type forest. The elevation of the area ranges from 439 to 642 M above MSL.

While characterizing watershed the first step is delineation of watershed. First of all the toposheet was georeferenced in Arc GIS (Ver. 10) GIS software using minimum four GCP. Then boundary of watershed is delineated following drainage divide. Simultaneously the drainage lines were digitized with the help of same software. Latter on these drainages were updated with the help of geo-coded satellite data of IRS P6 LISS-IV of Oct. 2007 and March 2008. Then the updated drainages were used for morphometric analysis. The morphometric parameters such as stream length, mean stream length, stream length ratio, drainage density, stream frequency, drainage texture, form factor, circulatory ratio, elongation ratio, and relief ratio were computed using standard methods and formulae of different worker given in Table. 1.

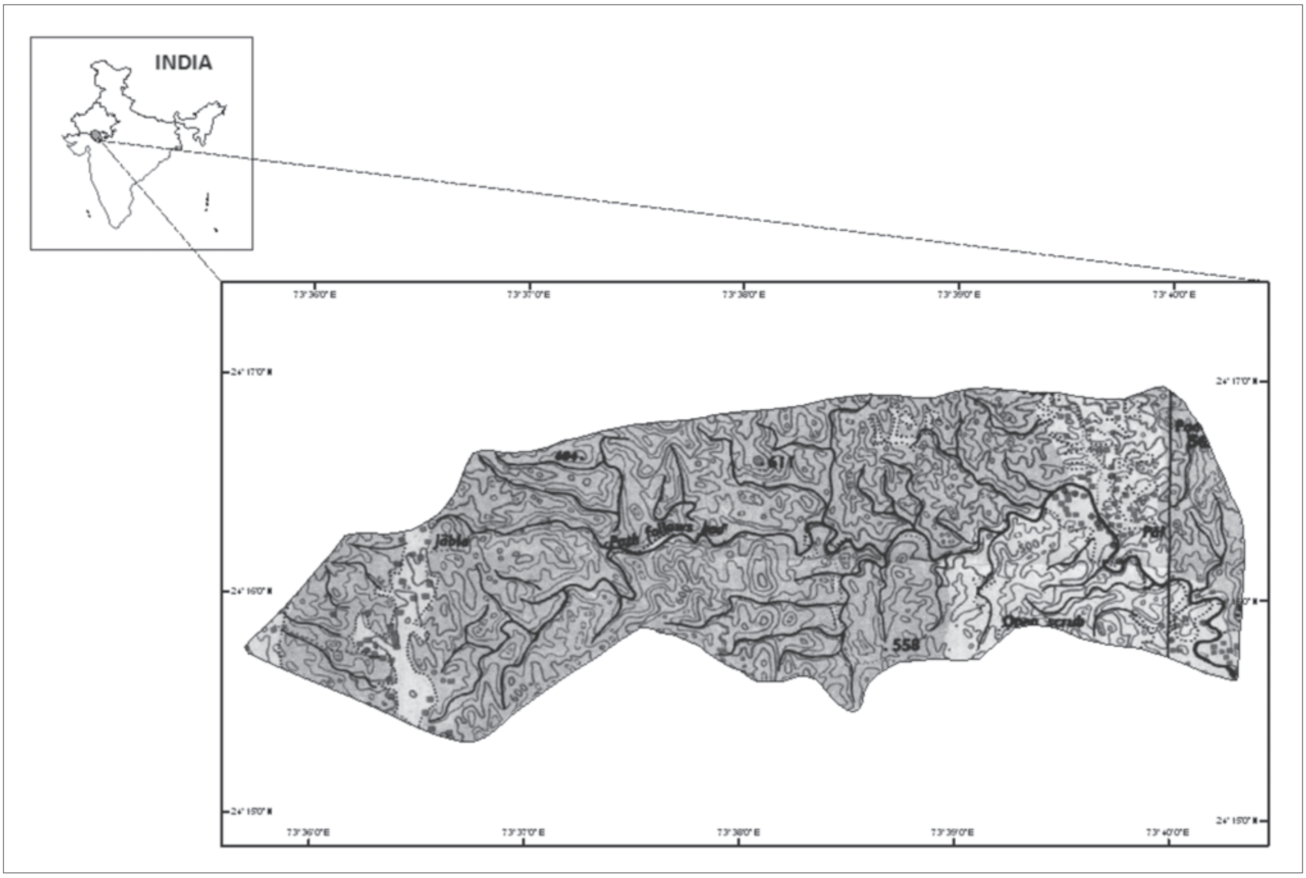

Fig 1. Location map of Chanavada watershed

Table1. Methodology adopted for computation of morphometric parameters

S. No.	Morphometric Parameters	Formula	Reference
1.	Stream Order	Hierarchical rank	Strahler (1964)
2.	Stream Length (Lu)	Length of the stream	Horton (1945)
3.	Mean Stream Length (Lsm)	Lsm = Lu/Nu Where, Lsm = Mean Stream Length Lu = Total stream length of order 'u' Nu = Total no. of stream segments of order 'u'	Strahler (1964)
4.	Stream Length Ratio (RL)	RL = Lu/Lu-1 Where, RL = Stream length ratio Lu = Total stream length of order 'u' Lu-1 = The total stream length of its next lower order	Horton (1945)
5.	Bifurcation Ratio (Rb)	Rb = Nu/Nu+1 Where, Rb = Bifurcation ratio Nu = Total no. of stream segments of order 'u' Nu+1 = Number of stream segments of the next higher order	Schumn (1956)
6.	Drainage Density (D)	D = Lu/A Where, D = Drainage Density Lu = Total stream length of all orders A = Area of the basin (Km^2)	Horton (1932)
7.	Stream Frequency (Fs)	Fs = Nu/AWhere, Fs = Stream Frequency Nu = Total no. of stream segments of order 'u' A = Area of the basin (Km^2)	Horton (1932)
8.	Drainage Texture (Rt)	Rt=Nu/PWhere, Rt = Drainage Texture Nu = Total no. of streams of all orders P = Perimeter (Km)	Horton (1945)
9.	Form Factor (Rf)	Rf=A/Lb^2 Where, Rf = Form Factor A = Area of the basin (Km^2) Lb^2 = Square of basin length	Horton (1932)
10.	Circulatory Ratio (Rc)	Rc=4*Pi*A/P^2 Where, Rc = Circulatory Ratio Pi = 'Pi' value i.e., 3.14 A = Area of the basin (Km^2) P^2 = Square of the perimeter (Km)	Miller (1953)
11.	Elongation Ratio (Re)	Re=2"(A/Pi) / Lb Where, Re = Elongation ratio A = Area of the basin (Km^2) Pi = 'Pi' value i.e., 3.14 Lb = Basin length	Schumn (1956)
12.	Relief Ratio (Rh)	Rh=H/Lb Where, Rh = Relief Ratio H = Total relief (Relative relief) of the basin (Km) Lb = Basin length	Schumn (1956)

RESULTS AND DISCUSSION

Delineation of drainage network/Drainage pattern

The drainage network of the watershed is derived initially from the survey of India topographical sheet which is prepared during 1977. The stream lines were digitized in the Arc GIS (Ver, 10) GIS software. Then these drainages were updated using geo-coded satellite data of IRS P6 LISS-IV (March 2008). It is found that the new drainages have come up. The watershed exhibit mixed drainage pattern (Fig. 2). In the upper reaches of high hills it is parallel drainage network which is peculiar pattern of hilly ranges and in the valley region it is dendritic drainage pattern. Overall the entire watershed possess good network of small and medium drains throughout.

Morphometric analysis

Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimensions of the landforms (Clarke, 1966).

Linear aspects

Stream orders, stream length, mean stream length, stream length ratio and bifurcation ratio are linear aspects that were determined and results have been given in Table 2.

Stream Orders

The designation of stream orders is the first step in the drainage basin analysis and it is based on hierarchic ranking of streams (Strahler, 1964). The first order streams have no tributaries. The second order stream possesses only first order streams as tributaries. The third order streams have first and second order streams as tributaries. The data presented in table 2 shows that Chanavada watershed is 4^{th} order watershed and the number of streams decreases with increase in stream order (Fig. 2).

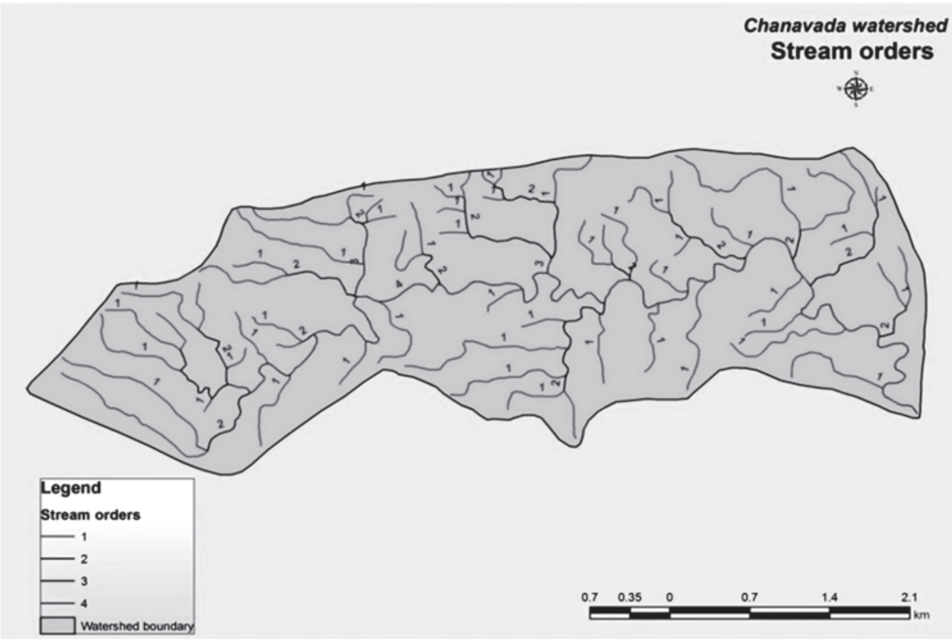

Fig 2. Stream orders of Chanavada watershed

Stream Length

It is the total length of streams in a particular order. The number of streams of various orders in a watershed was counted and their length from the mouth to drainage divide is measured with the help of Arc GIS (Ver. 10.0) software. Generally, the total length of stream segments is maximum in first order streams and decreases as the stream order increases. The data presented in Table 2 shows some deviation from the trend. This may be due to flowing of streams from high altitude and steep slopes.

Mean Stream Length

Mean stream length (Lsm) of a channel is a dimensional property and reveals the characteristics size of drainage network components and its contributing surface (Strahler, 1964). The mean stream length has been calculated by dividing the total stream length of order 'u' by the number of stream segments of order 'n'. The value of Lsm varies from 0.59 to 8.67 (Table

Table 2. Morphometric characteristics of Chanavada watershed

Area (Km^2)	Perimeter (Km)	Basin length (Km)	Stream Order	Number of streams (Nu) Km	Stream length (Lu)	Mean Stream length (Lsm) Km	Stream length ratio (RL)	Bifurcation ratio (Rb)	Drainage density (D) (Km/ Km^2)	Stream frequency (Fs)	Drainage texture (Rt)	Form factor (Rf)	Circulatory ratio (Rt)	Elongation ratio (Re)	Relief ratio (Rh)
14.75	21.84	7.97	I	60	39.27	0.65	-	3.53	4.16	5.49	3.70	0.23	0.38	0.27	0.024
			II	17	10.09	0.59	0.26	5.66							
			III	3	3.36	1.12	0.33	3.0							
			IV	1	8.67	8.67	2.58	-							

2). Generally, the value of Lsm of any order is greater than that of lower order and less than that of its next higher order but here picture is different which might be due to variation in slope and topography.

Stream Length Ratio

Stream length ratio (RL) is the ratio of the mean length of one order to the next lower order of the stream segment. Table 2 shows an increasing trend in the length ratio from lower order to higher order indicating their mature geomorphic stage.

Bifurcation Ratio

Horton (1945) considered bifurcation ratio as an index of relief and dissections. Bifurcation ratio may be defined as the ratio of number of stream segments of given order to the number of segments of the next higher order (Schumn, 1956). Strahler (1957) demonstrated that bifurcation ratio shows a small range of variation for different regions or for different environment except where the powerful geological control dominates. Table 2 shows high value of bifurcation ratio which indicates the strong structural control on the drainage development. Similar results were reported earlier by Srinivasa *et al*. (2004) while studying morphometric characteristics of sub watershed in the Pavgada area of Karnataka.

Aerial Aspects

The aerial aspects include different morphometric parameters like drainage density, drainage texture, stream frequency, form factor, circulatory ratio and elongation ratio. The values of these parameters presented in Table 2 and discussed here under.

Drainage Density

Drainage density (D) expresses the closeness of spacing of channels. It is the measure of the total length of the stream segments of all orders per unit area. Density factor is related to climate, type of rocks, relief, infiltration capacity, vegetation cover, surface roughness and runoff intensity index. Of these only surface roughness has no significant correlation with drainage density. The amount and type of precipitation influences directly the quantity and character of surface runoff. According to Nag (1998) low drainage density generally results in the areas of highly resistant or permeable sub soil material, dense vegetation and low relief. High drainage density is the result of weak or impermeable subsurface material, sparse vegetation and mountainous relief. The drainage density of Chanavada watershed is 4.16 which could be the result of impermeable sub surface material, sparse vegetation and mountainous relief.

Stream Frequency

Horton (1932) introduced the term stream frequency which means total number of stream segments of all orders per unit area. Hypothetically, it is possible to have the basins of same drainage density differing stream frequency and basins of the same stream frequency differing in drainage density. In the present study the value of stream frequency (Table 2) is positively correlated with drainage density suggesting increase in stream population with respect to increase in drainage density.

Drainage Texture

Drainage texture (Rt) is the total number of stream segments of all orders per perimeter of that area (Horton, 1945). It is one of the important concept of geomorphology which means that the relative spacing of drainage lines. Horton (1945) recognized infiltration capacity as the single important factor which influences Rt and considered drainage texture which includes drainage density and stream frequency. Amount of vegetation and rainfall absorption capacity of soils which influences the rate of surface runoff affects the drainage texture of an area. Smith (1950) has classified drainage density into five different textures that means very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). In the present study drainage texture of thw watershed lie between 2 and 4 which is related to coarse texture.

Form Factor

According to Horton (1932) form factor (Rf) may be defined as the ratio of basin area to square of the basin length. The value of form factor would always be less than 0.7854 for a perfectly circular basin. Smaller the value of form factor more elongated will be the basin. The basin with high form factors have high peak flows of shorter duration, where as elongated watershed with low form factor have lower peak flows of longer duration (Chopra *et al*., 2005). Table 2 shows low Rf value (0.23) indicating elongated shape of watershed and suggesting flatter peak flow for longer duration.

Circulatory Ratio

The circulatory ratio (Rc) is mainly concerned with the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin. It is the ratio of the area of the basin to the area of circle having the same circumference as the perimeter of the basin (Miller, 1953). The value of the Rc is 0.38 which is less than 0.5 indicating the elongated shape of watershed.

Elongation Ratio

Schumn (1956) defined elongation ratio (Re) as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. Singh and Singh (1997) reported that a circular basin is more efficient in the discharge of runoff than an elongated basin. The values of Re generally vary from 0.6 to 1.0 over a wide variety of climatic and geologic types. Values close to 1.0 are typical of regions of very low relief; where as values in the range of 0.6 to 0.8 are usually associated with high relief and steep ground slope (Strahler, 1964). In the present case value of Re (0.27) is associated with high relief and steep slope showing elongated shape of watershed.

Relief Aspects

Relief is the elevation difference between the highest and lowest point on the valley floor of the region. The relief measurements like relief ratio, basin length and total relief are presented in Table 2.

Relief Ratio

The maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line is termed as relief ratio (Schumn, 1956). It measures the overall steepness of a drainage basin and is an indicator of the intensity of erosion processes operating on the slopes of basin. Relief ratio has direct relationship between the relief and channel gradient. The relief ratio normally increases with decreasing drainage area and size of the watershed of a given drainage basin (Gottschalk, 1964). In the present study value of relief ratio is 0.024, which indicate steep slope and high relief (461m).

CONCLUSIONS

The present study demonstrates the utility of remote sensing and GIS technique in studying morphometric analysis of hilly watershed. The satellite remote sensing has the ability to provide synoptic view of large area and is very useful in analyzing drainage morphometry. It served as an efficient tool in drainage delineation and updating. In the present study these updated drainage have been used for morphometric analysis. The morphometric analysis was carried out through measurement of linear, aerial and relief aspects of the basin. Chanavada watershed is elongated in shape with mixed drainage pattern that mean dendritic and parallel with coarse texture. The variation in stream length and mean stream length may be due to flowing of stream from high altitude, steep slope and lithological variation. The increasing trend of stream length ratio from lower order to higher order indicates the mature geomorphic stage of streams. The bifurcation ratio shows strong structural control over the drainage development and high value of drainage density is the result of weak or impermeable sub surface material, sparse vegetation and mountainous relief.

REFERENCES

Arora, Sanjay and Gupta, R.D. 2014. Soil related constraints in crop production and their management options in North Western Himalayas. *Journal of Soil and Water Conservation* **13**(4): 305-312.

Chauhan, Malavika 2010. A perspective on watershed development in the Central Himalayan state of Uttarakhand, India. *International Journal of Ecology and Environmental Sciences* **36**(4): 253-259.

Chopra, Rajiv, Dhiman, Raman Deep and Sharma, P.K. 2005. Morphometric analysis of sub-watersheds in Gurdaspur District, Punjab using Remote Sensing and GIS techniques. *J. Indian Soc. Remote Sensing* **33**(4): 531-539.

Clarke, J. I. 1966. *Morphometry from Maps*. Essays in Geomorphology. Elsevier Publ. Co. New York, pp. 235-274.

Gottschalk, L. C. 1964. Reservoir Sedimentation. In: V. T. Chow (ed), *Handbook of Applied Hydrology*. McGraw Hill Book Company, New York, Section 7-I.

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

Horton, R. E. 1932. Drainage Basin Characteristics. *Trans. Am. Geophys. Union* **13**:350-361.

Horton, R. E. 1945. Erosional Development of Streams and their Drainage Basins; Hydrological Approach to Quantitative Morphology. *Geol. Soc. Am. Bull*. **56**:275-370

Miller, V. C. 1953. A quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee. Proj. NR 389-402, Tech Rep 3, Columbia University, Department of Geology, ONR, New York.

Nag, S. K. 1998. Morphometric analysis using remote sensing techniques in the Chaka sub-basin, Purulia district, West Bengal. *J. Indian Soc. Remote Sensing* **26**(1&2): 69-76

Schumn, S. A. 1956. Evolution of Drainage Systems and Slopes in Badlands at Perth Amboy, New Jersey. *Geol. Soc. Am. Bull*. **67**:597-646.

Singh, S. and Singh, M. C. 1997. Morphometric analysis of Kanhar River Basin. *National Geographical J. of India* **43**(1): 31-43.

Smith, K. G. 1950. Standards for grading textures of erosional topography. *Am. Jour. Sci.* **248**:655-668.

Srinivasa, V. S., Govindaiah, S. and Honne Gowda, H. 2004. Morphometric analysis of sub-watershed in the Pavagada area of Tumkur district, South India using remote sensing and GIS techniques. *J. Indian Soc. Remote Sensing* **32**(4): 351-362.

Strahler, A. N. 1957. Quantitative analysis of watershed geomorphology. *Trans. Am. Geophys. Union* **38**:913-920.

Strahler, A. N. 1964. Quantitative Geomorphology of drainage basins and channel networks, In: VT Chow (ed), Handbook of Applied Hydrology. McGraw Hill Book Company, New York, Section 4-11.

Tideman, E. M. 1996. *Watershed Management, Guidelines for Indian Conditions*. Omega Scientific Publishers, New Delhi, pp. 372.

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Geo-informatics based groundwater plan preparation of Kichna nala watershed of Odisha

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ABSTRACT

Remote sensing and geographical information system (GIS) technique have been applied for the investigation of groundwater potentiality of the Kichna nala watershed in Bamara block of Sambalpur District (Odisha), where ground water resources have not been fully exploited. The role of various parameters namely drainage, lineament, land cover, geomorphology have been emphasized for delineation of ground water potential zones. IRS-ID LISS-III FCC merged satellite images on 1:50,000 scale and toposheet map number 73 C/05 together with field verification have been used as the data source. Different thematic maps like, geomorphology, drainage and surface water body, land use/ land cover, etc. were prepared by various integration and finally all these map were analysed in GIS to prepare an integrated ground water potential map of the study area with five different ground water potential zones. Analysing the lineament intersection points and ground verification in the watershed, 18 sites have been selected and suggested for tube well construction with their latitude and longitude.

Key words: Kichna nala watershed, land use/land cover, hydrogeomorphology, groundwater, remote sensing, GIS

INTRODUCTION

Groundwater, the largest source of fresh water on this planet excluding the polar ice caps and glaciers, is a dynamic and replenishable natural resource. Its availability in hard rock terrain is of limited extent and its occurrence is essentially confined to fractured and weathered zones (Saraf and Choudhury, 1998). The identification and location of groundwater resources using remote sensing data is based on an indirect analysis of some directly observable terrain features like geology, lithology, structure, geomorphic units and the hydrologic characteristics.

Remote sensing method provides the mapping of natural resources economically than these of the conventional methods and yields better results. In recent years the increasing use of satellite remote sensing data has made it easier to define the spatial distribution of different groundwater prospect zones on the basis of geomorphology and other associated parameters (Sinha *et al.*, 1990; Prakash and Mishra, 1991; Tiwari and Rai, 1996; Ravindran and Jeyram, 1997; Kumar *et al.*, 2014). Geographical Information System (GIS) provided a medium to develop, store, analyse and visualize spatially distributed data. The possibility of rapidly combining data of different types in a Geographical Information System has led to significant increase in its use in hydrological applications (Sashi Kumar and Jayanthi, 2006; Farooq *et al.*, 2008; Dhabale *et al.*, 2014; Srivastava *et al.*, 2014). Land use pattern of watersheds of Siang river of Arunachal Pradesh has using remote sensing and GIS has been studied by Dutta *et al.* (2015). Satellite Imagery data from 2005 to 2009 were used to study the land use/ land cover condition and overall biomass changes using remote sensing and GIS of North Tripura district, Tripura over a time scale as shifting cultivation is a crucial factor in the north eastern region that governs the stability of ecosystem (Das and Sarkar, 2014). Land capability classification and land resources action plan were developed for Malegaon watershed in the district of Nasik, Maharashtra; using remote sensing and GIS (Pali *et al.*, 2014). Analysis of remotely sensed data along with survey of India topographical sheets and collateral information with necessary field checks help in

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generating the base line information for ground water investigation. In this study, the Kichna nala sub-watershed in Bamara block of Sambalpur District, Odisha (India) has been selected for the investigation of ground water potential zones using remote sensing and GIS.

STUDY AREA

Kichna nala sub-watershed lies geographically between 21°48′ to 21°57′ N latitude and 84°20′ E to 84°24′E longitude at a distance of about 25 km from the block headquarter Bamara and 90 km from the district headquarter Sambalpur in the state of Odisha (Fig. 1). Total areal extent of the watershed is 48.26 sq.km. The average annual rainfall is 1499 mm and the temperature in summer goes up to 43°C whereas in winter it comes down to 5°C. The climate of the region is semi-arid. The topography of the area varies between 300 m to 600 m above mean sea level. The area is drained by Kichna nala with a number of small tributaries. Drainage pattern is mostly dentrite and sub-dentride controlled by fractures, joints and lineaments. The ground water occurs under unconfined conditions in the weathered, fractured and fissured horizons.

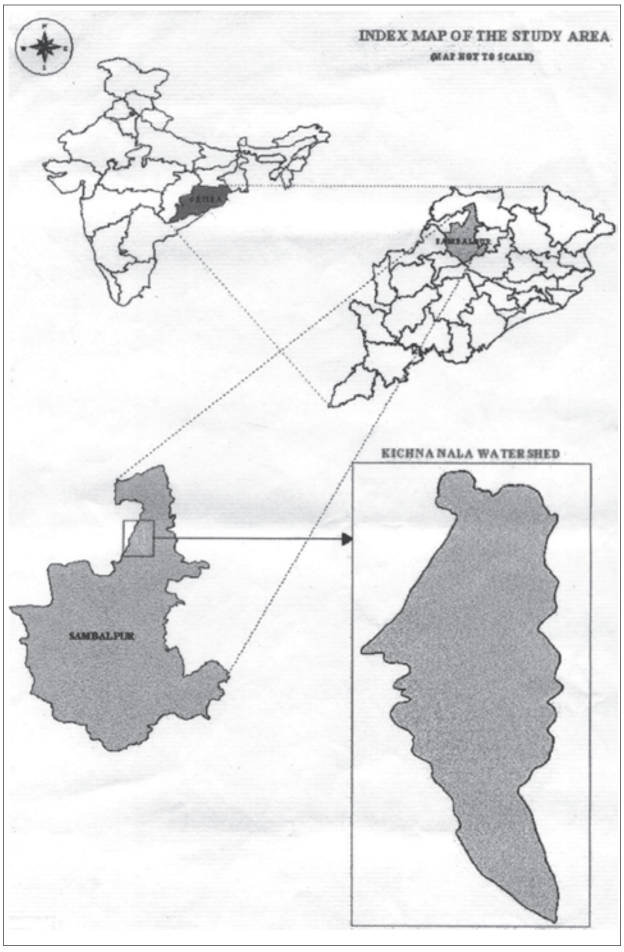

Fig. 1. Map of the study area

DATA AND METHODOLOGY

IRS-1D LISS-III false colour composite (bands– 2,3 and 4) of 3rd Feb 2001, 14th May 2001 and 14th Nov 2002 were used for the study. The survey of India toposheet no.73 C/05 has been used for the preparation of base map. The methodology includes for the study involved two major steps, first the generation of thematic information and second its analysis for ground water potentiality in the study area. The generation of thematic maps such as settlement and road network, drainage with surface water body, hydro-geomorphology, land use/land cover and lineaments of the study area were done through visual interpretation of satellite remote sensing data. The identification and delineation of various units on the thematic maps are based on the size, shape, colour, tone, texture, pattern and association characteristics of images. All the thematic maps were verified during the field checks. The thematic details thus finalised were transferred to the base maps prepared from the survey of India toposheet. Finally all the information from the thematic maps were analysed and integrated in GIS (using ARC VIEW software) and the groundwater potential map of the study area was prepared.

Preparation of groundwater potential map

First the thematic maps prepared were converted into the digital raster image by manual digitization or scanning. Then the raster image was converted to vector image. The vector co-ordinate unit from pixel value in files were transformed into the geocoded ARC/IMG unit (in GRID files) to generate a coverage having single co-ordinate system. The different thematic ARC/INFO coverage along with the attribute exported to the ARC/VIEW environment and different themes are created for different view. Different colours and symbols were given to different attributes to classify different features of a map. Then the geographical analysis was done with the following procedure to prepare the final ground water potential map of the watershed.

i) Overlaying Analysis

This may be vector overlaying or raster overlaying. In this analysis map features and associated attributes are integrated to produce a composite map. Logical operators and conditional operators are used for this purpose. The geo-hydrological map, drainage map and land use/ land cover map were overlaid with reference to the common control points to analyse the correlation among the map features and finally to generate an integrated ground water potential map of the Kitna nala sub-watershed.

ii) Proximity Analysis (Buffer operation)
It is mainly done to locate the extent of area and to know the characteristics of the area surrounding a specified location or a particular structure. The lineaments present in the study area were allocated a width in the field by this buffer operation.

iii) Tabular and Statistical Analysis
The attribute and geographic data of the integrated land use/ land cover map and ground water potential map were stored in tabular form with all available statistics.

iv) Data base Query
The data base query used the individual land use/land cover and buffer area identity to regenerate a new identity for the integrated ground water potential map.

RESULTS AND DISCUSSION

Land use/land cover of the study area

Land use refers to man's activity and various uses, which are carried out on land. Land cover refers to natural vegetation, water bodies, artificial cover and other resulting due to land transformations (Anonymous, 1994). Land use/ land cover map of Kichna nala sub-watershed was prepared through visual interpretation of satellite imageries and the spatial data in form of land use/ land cover map with its different units were classified and presented in Table 1. The information on land use/land cover status of the area is shown in Fig. 2.

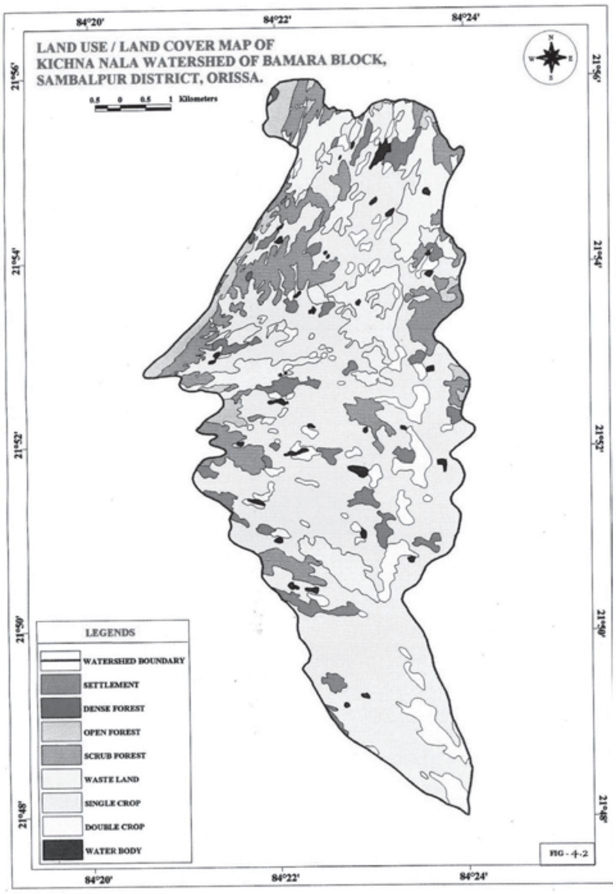

Fig. 2. Land use/land cover map

The result shows that the Kichna nala sub-watershed is a potential region for agricultural development. Agriculture alone occupies about 64.212 per cent of total watershed area but most of the agricultural land (56.487 per cent) are single cropped. So, groundwater can play a major role in converting the single cropped area into double-cropped area or agro-horticultural area.

Table 1. Land use/land cover classification of Kichna nala sub-watershed

Map unit		Land use land cover class	Area (ha)	Total area (%)
I		BUILT-UP LAND		
	1.	Settlement	250.898	5.199
II		AGRICULTURAL LAND		
	2.	Single cropped area	2726.117	56.487
	3.	Double cropped area	372.809	7.725
III		FOREST		
	4.	Dense forest	6.960	0.144
	5.	Open forest	174.926	3.625
	6	Scrub forest	602.810	12.490
IV		WASTE LAND		
	7.	Land without scrubs (culturable)	637.058	13.200
V		WATER BODIES		
	8.	Reservoir/tanks	54.525	1.130
		TOTAL	4826.103	100.00

Hydrogeomorphology

Hydrogeomorphology depicts different aspects like landform; land characterization, geological information etc. Information about different landform characteristic is a vital input for land management, soil mapping etc., whereas information about different geological aspects like lithology/ rock types is an indispensable source to identify the occurrence of ground water potential zones (Anonymous, 1995). The hydrogeomorphological units were identified and mapped through visual interpretation and GIS tools. The hydrogeomorphological map of the study area is presented in Fig. 3 and the hydrogeomorphological unit of the area is shown in Table 2.

The study area was broadly classified into three zones as runoff, infiltration and discharging zone. The residual hills and the pediments constitute the runoff zone. The buried pediments both shallow and medium, represents the infiltration zone where as the valley fills and the lineaments are the discharge zones. Different hydromorphological units representing their groundwater prospects are discussed below.

Residual Hill: Residual hills are the end product of the process of pediplannation, which reduces the original mountain masses into a series of scattered knolls standing on the pediplains. There shape is controlled by different lithological composition, distribution and spacing of joints and fractures. Residual hills are identified on the northern and western boundary of the study area spreading over an area of 163.509 ha (33.38% of total area). Here infiltration is very low and these units behave as runoff zones. Groundwater potential is very poor on these units.

Pediment: Gently slopping isolated patches of rock surrounding the residual hills and ridges, which act as run off zones, represent the pediment. Pediments are found around the residual hills and also in patches in the central part of the watershed. Such units cover an area of 2140.463 ha, which is 44.352% of the total geographical area of the watershed. Sometimes these units are transversed by fractures and joints permitting infiltration. The groundwater potential is poor to moderate in such units.

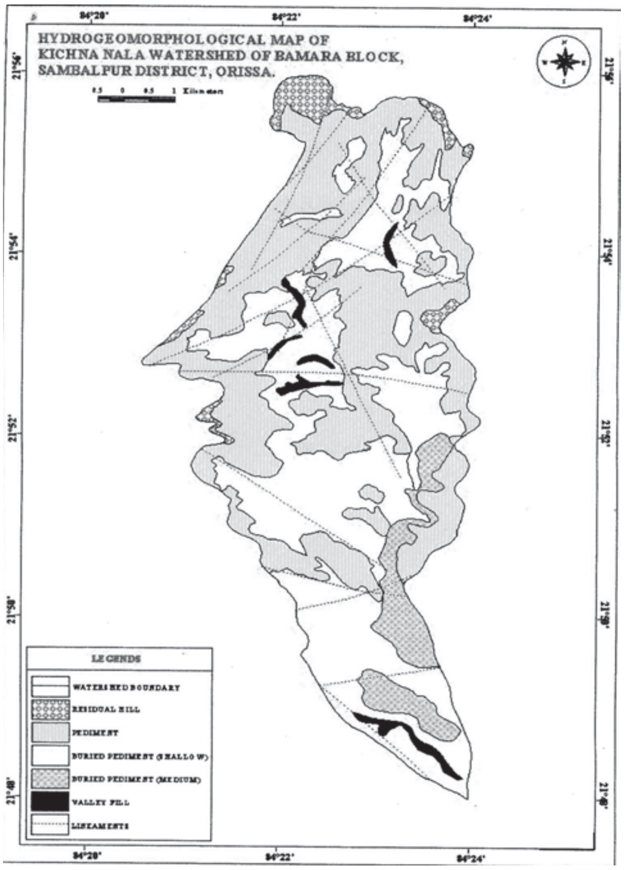

Fig. 3. Hydrogeomorphological map

Shallow weathered buried pediment: This unit is basically a pediment zone and covered by various soil types. It consists of very low to moderately weathered zone with thickness of materials varying from 5m to 15m. These units are found around the drainage lines of the study area and also in patches within the pediments with an area of 2120.523 ha (43.938 % of watershed area). Infiltration in such units is moderate and groundwater potential is moderate to poor in such units.

Table 2. Hydrogeomorphological characteristics of Kichna nala watershed

Map unit	Geomorphic unit	Groundwater prospect	Area (ha)	(%) of total area
1.	Residual hill (RH)	Poor to nil	163.509	33.88
2.	Pediment (P)	Poor to nil	2190.463	44.352
3.	Shallow weathered buried pediment (BPS)	Moderate – poor	2120.523	43.938
4.	Moderately weathered buried pediment (BPN)	Good-moderate	321.165	6.655
5.	Valley fill (VF)	Very good	80.443	1.667
6.	Lineaments (L)	Excellent	-	-

Moderately weathered buried pediment: This unit is formed due to high weathering of the hornblende biotic gneisses under semi-arid climatic condition. In this unit infiltration is moderately good. The thickness of weathered zone varies from 10m to 25 m and favours a good amount of water to circulate within this zone before reaching the deeper fracture zone. Medium buried pediments are found around the main drainage line and nearer to the watershed outlet with an area of 321.165 ha (6.655 % of watershed area). The ground water potential is good to moderate.

Valley fill: Valley fills consist of unconsolidated alluvial materials like sand, silt and gravels, pebbles etc. deposited along a valley. This unit acts as both recharging and discharging zones for groundwater. Groundwater potential is very good because of the topographical location at the bottom of hill and geological compositions consisting of highly porous materials. Sub-surface water potential is also good to excellent as the deposits harbour dense vegetation. It covers an area of 80.443 ha which is 1.667 % of total watershed area.

Lineaments: Lineaments are defined as the large-scale linear fractures, which express themselves in terms of topography of the underlaying structural features. Lineaments provide the pathway for groundwater movement and are hydrologically very important. The fracture zone forms an interlaced network of high transmissivity and serves as ground water conduits in massive rocks in inter-fracture areas. The lineaments are tending in different directions extending over a considerable length and with (50-100 m) in the sub-watershed. The lineament intersection points are the excellent ground water potential zones. In total, 16 lineaments were identified in the watershed and most of them are present in the northern part of the watershed. The length of the lineaments varies from 2 km to 5 km.

Drainage and surface water body

Drainage and surface water body map refers to different drainage lines like major river, streams, nalas etc. and the presence of different water bodies like tanks, reservoirs ponds etc. (Anonymous, 1995). The drainage and surface water body map of the area is presented in Fig. 4.

Groundwater potential zones

Groundwater potential zones have been demarcated in the study area after integrating the geological, hydrogeomorphological data, recharge conditions of the terrain, lineament analysis and well inventory data collected during the field verification. Five groundwater potential zones were identified as follows and are presented in Fig. 5.

Fig. 4. Drainage and surface water body map

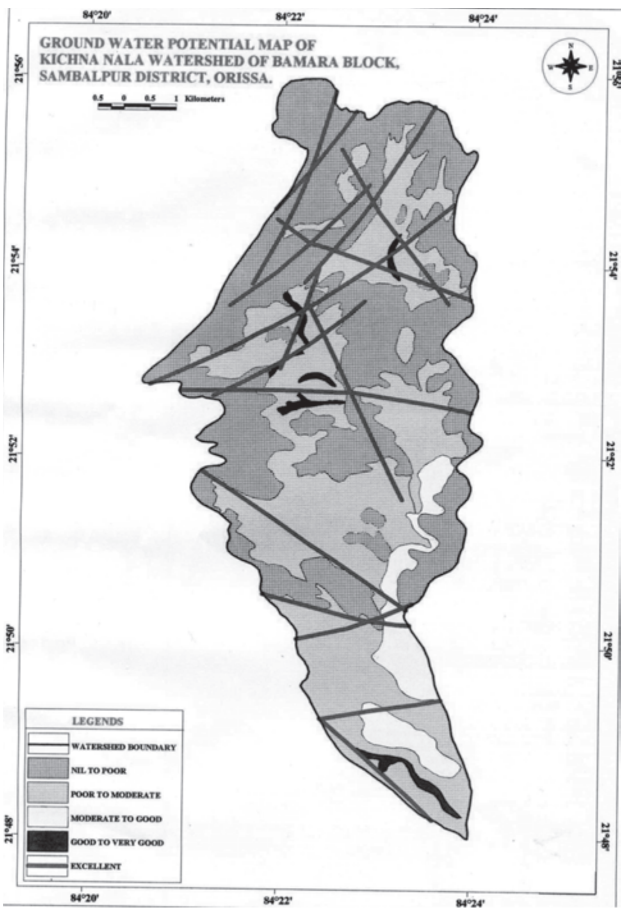

Fig. 5. Groundwater potential map

Excellent: Lineaments and intersection of lineaments are the excellent groundwater potential zones, which work as aquiducts and possess ground water abundantly. The static water level varies from 10 m to 35 m below ground level depending on the geomorphology. Yield in this zone is 200 lpm to 300 lpm.

Good to very good: The geomorphic units in this zone are alluvial plains and valley fills which are found in pockets in the study area. Quartenary sediments mostly influence this zone. The aquifer materials are loose sediment in alluvial plain and unconsolidated sand and fractured rock in valley fills. The static water level in this zone ranges between 15 to 25 m below ground level. Tube wells with a depth range of 50 m to 120 m are suggested which are expected to discharge 100-200 lpm with a high rate of homogenity and success.

Moderate to good: This zone is dominated by alluvial plains, deep and moderate buried pediments mostly developed nearer to the drainage lines. The formations are mainly confined to weathered and fractured rocks, which influence the water table. The static water level of this zone ranges between 15 to 35 m below ground level and the recharge conditions are moderate to good. Suggested depth for tube well is 70 to 120 m and a discharge of 50 to 100 lpm is expected with a high rate of success for quartenary sediments and moderate rate of success for weathered and fractured rock aquifer.

Poor to moderate: These are mainly the shallow buried pediments units come under this zone. The aquifer material varies from loose sediments for alluvial plains to weathered and fractured rocks for buried pediments. The depth of weathering is low and not uniform. Therefore, aquifers in this zone are characterized by low yield poor homogenity and low rate of success. The recharge conditions are also either limited or moderate. Under these conditions, the suggested depth of tubewells varies between 60 to 100 m, which can yield 10 to 50 lpm.

Nill to poor: The geomorphic units of this zone are the pediments and the residual hills. Due to favourable slope condition and surface characteristics, this zone is ideal for runoff generation and not suitable for groundwater exploration except the valley portion having very limited prospect. The aquifers are granite and/or quartzite formations having static water level 20 to 40 m bgl. The expected discharge is less than 10 lpm with poor recharge capacity.

Ground truthing

Basing upon the classification of groundwater potential zones and geomorphic units in the Kichna nala sub-watershed, ground truthing was done to confirm the results. Wells (dug/tube) were observed at specific locations like lineaments, intersection of lineaments, pediments, BPM, BPS, valley fills and their discharge were verified and found as per their classification.

Best sites for tube well construction

The lineaments act as aqueducts and possess groundwater abundantly. The intersection points of lineaments are the most prospecting zones for groundwater with average yield of more than 300 lpm. Therefore, these intersection points are the most suitable site for tube wells. Based upon the findings of the research work eighteen tube well sites have been proposed over the intersection points of lineaments in the watershed and are presented in Table 3 with their latitude and longitude.

Table 3. Proposed tube well sites in the watershed

Latitude (N)	Longitude (E)	Village
21º55′12"	84º22′12"	Dumermunda
21º54′36"	84º22′12"	Baladmal
21º54′00"	84º22′12"	Charmal
21º54′00"	84º22′48"	Charmal
21º54′36"	84º22′48"	Solbaga
21º54′38"	84º22′48"	Solbaga
21º54′00"	84º23′24"	Kesaibahal
21º54′00"	84º23′12"	Kesaibahal
21º53′48"	84º23′24"	Kendumal
21º53′24"	84º22′12"	Balijori
21º53′24"	84º22′12"	Balijori
21º52′48"	84º22′12"	Kabaribahal
21º53′12"	84º22′12"	Segapara
21º52′48"	84º21′36"	Bandhkani
21º52′48"	84º22′48"	Kabaribahal
21º50′24"	84º23′24"	Lasratangar
21º50′24"	84º22′48"	Arbabahal
21º49′12"	84º22′12"	Ramtileimal

CONCLUSION

The study has focussed on identification of favourable zones for groundwater exploration using remote sensing and GIS in a geologically, geomorphologically and structurally complex terrain like the Kichna nala watershed. The results show that the moderate to deep weathered pediments, lineaments and the intersection of lineaments are the most prospective zones for groundwater. The surface water bodies, lineaments, intersection of lineaments and various lithologic units are directly influencing the pattern of groundwater table. The lineaments are acting as pathways of groundwater movements, as a result the groundwater level in existing wells near the lineaments increase considerably during the monsoon periods. A good inter-relationship was found among the geomorphic units, geological characteristics and water yield of the observation wells in the study area.

REFERENCES

Anonymous. 1994. Manual of land use/ land cover mapping. National Remote Sensing Agency, Dept. of Space, Govt. of India.

Anonymous. 1995. Technical Guidelines. Integrated mission for sustainable development. National Remote Sensing Agency, Dept. of Space, Govt. of India.

Das, S. N. and Sarkar, D. C. 2014. Monitoring ecosystem of North Tripura using remote sensing techniques. *Journal of Soil and Water Conservation* **13**(2): 23-26.

Dhabale, S., Singh, P. K. and Singh, R. S. 2014. Morphometric analysis of Chanavada micro-watershed using remote sensing and GIS. *Journal of Soil and Water Conservation* **13**(1): 10-15.

Dutta, H., Goswami, D. C. and Karmakar, R. M. 2015. Land use pattern of selected sub-watersheds of the Siang river of Arunachal Pradesh using remote sensing and GIS techniques. *Journal of Soil and Water Conservation* **14**(4): 326-332.

Farooq, Md., Rashid, G. and Arora, Sanjay 2008. Spatio-Temporal change in land use and land cover of district Rajouri: A Geo-Spatial approach. *Journal of Soil and Water Conservation* **7**(4): 20-24.

Kumar, A., Tomar, S. and Prasad, L.B. 1999. Analysis of fractures inferred from DBTM and remotely sensed data for ground water development in Godavari sub-watershed. Giridih, Jharkhand. *J. Indian Soc. Remote Sensing* **26**(2): 105-114.

Kumar, S., Sharma, S. K., Satyavan, Ramprakash, Rajpaul and Sharma, R. 2014. GIS mapping of groundwater quality of Bahadurgarh block of Jhajjar district, Haryana. *Journal of Soil and Water Conservation* **13**(2): 34-39.

Pali, A. K., Suryavanshi, S., Sinha, B. L. and Sinha, J. 2014. Land capability classification and land resources planning using remote sensing and GIS. *Journal of Soil and Water Conservation* **13**(1): 3-9.

Prakash, S.R. and Mishra, D. 1999. Identification of ground water prospective zones by using remote sensing and geo-electrical methods in and around Saidnagar area, Dakar block, Jalaun district, U.P. *J. Indian Soc. Remote Sensing* **21**(4): 217-227.

Ravindran, K.V. and Jeyaram, A. 1997. Ground water prospects of Sahahbed Tehsil. Baran District. Estern Rajasthan: A remote sensing approach. *J. Indian Soc. Remote Sensing* **25**(4): 239-246.

Sankar, K. 2002. Evaluation of groundwater potential zones using remote sensing data in upper Vaigai river basin, Tamil Nadu, India. *J. Indian Soc. Remote Sensing* **30**(3): 119-129.

Sashikumar, M.C. and Jayanthi, S. 2006. Assessment of surface runoff for a watershed using GIS and SCS Curve Number techniques. *J. of Soil and Water Conservation* **5**(3): 10-15.

Saroj, A.K. and Choudhury, P. R. 1998. Integrated remote sensing and GIS for groundwater exploration and identification of artificial recharge sites. *Int. J. Remote Sensing* **19**(10): 1825-1841.

Sinha, B.K., Kumar, A., Srivastava, D. and Srivastava, S. K. 1990. Integrated approach for demarcation the fracture zone for well site location. A case study near Gumla and Lohardaga, Bihar. *J. Indian Soc. Remote Sensing* **18**(3): 1-8.

Srivastava, R. K., Sharma, H. C., Singh, J. P., Sushmita and Dadhich, H. 2014. Estimation of runoff of Western Himalayan watershed using remote sensing and GIS. *Journal of Soil and Water Conservation* **13**(2): 27-33.

Tiwari, A. and Rai, B. 1996. Hydrogeomorphological mapping for ground water prospecting using landsat NSS images – A case study of part of Dhanbad district, Bihar. *J. Indian Soc. Remote Sensing* **24**(4): 281-285.

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Climate change scenario: A study on perception, adaptation and mitigation strategies in reference to Indian farmers

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ABSTRACT

The issue of impact of climate change on agriculture has emerged in recent decades and it is necessary to evaluate its impact on agriculture. It is resulting in problems with food security and may threaten the livelihood activities upon which much of the population depends. However it may affect crop yields both positively and negatively, as well as the types of crops that can be grown in certain areas, by impacting agricultural inputs such as water for irrigation, amounts of solar radiation that affect plant growth, as well as the prevalence of pests. Keeping in mind the importance of the issue a study was conducted in two villages of Haryana state. The objective of the study was to determine the perception of farmers on issue of climate change. A sample of 300 respondents (40 %) was randomly selected from a total population of 800 farmers. Data were collected from the sampled respondents in 2013 and 2014. Most of the farmers (69.3 %) perceived that climate change started between last 5 to15 years. Almost half of the farmers (48.0%) believe that environmental factor is responsible for climate change and felt that both rainy season and cold season start late and are of shorter duration. Hot season shows opposite scenario as it starts early but is prolonged. Mean duration of hot season has significantly increased in recent past compared to last decade. Similarly, they perceived that hotness has increased (88.7%) and coldness has reduced (60.0%). Farmers observed a reduction in overall rainfall (83.3%) as well as variation in the speed and duration of strong wind. They felt that incidence of drought has increased (73.3 %). However the educational status of the farmers and access to extension services had significant association with their perceived cause towards climate change.

Key words: climate change, mitigation, adaptation, agriculture

INTRODUCTION

Agriculture is a major economic, social, and cultural activity, and it provides a wide range of ecosystem services. Importantly, agriculture in its many different forms and locations remains highly sensitive to climate variations, the dominant source of the overall interannual variability of production in many regions and a continuing source of disruption to ecosystem services. For example the El Niño Southern Oscillation phenomenon, with its associated cycles of droughts and flooding events, explains between 15 percent and 35percent of global yield variation in wheat, oilseeds, and coarse grains (Ferris, 1999).

India, being a country of diversified climatic variation and farming systems, has high dependency of agriculture on the monsoon rains and a close link exists between climate and water resources. Two thirds of the area in India is rainfed. Climate change can affect crop yields (both positively and negatively), as well as the types of crops that can be grown in certain areas, by impacting agricultural inputs such as water for irrigation, amounts of solar radiation that affect plant growth, as well as the prevalence of pests (Kumar, 2014). Agriculture represents a core part of the Indian economy and provides food and livelihood activities to much of the Indian population. It represents 35 percent of India's Gross National Product (GNP) and as such plays a crucial role in the country's development (Singh and Nautiyal, 2011). However it is greatly dependent on climatic conditions and impact of climate change on agriculture could result in problems with food security thus threatening the livelihood activities upon which much of the population depends. There will be increased frequency of floods during the monsoon and a decrease in winter precipitation with a lower number of rainy days. With a 0.68 degrees Celsius increase

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in temperature so far in India, it is expected that there will be pronounced warming in future, particularly during the post monsoon period and winter (Pathak *et al*., 2012).

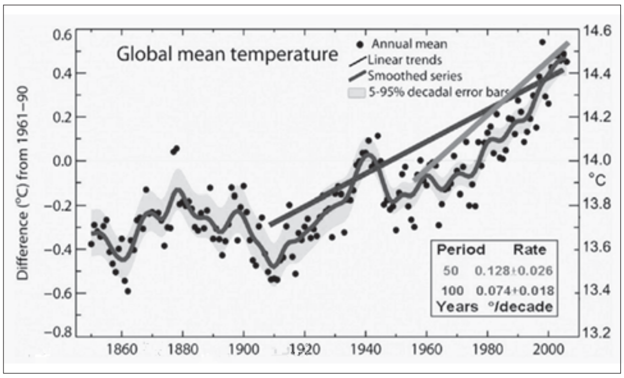

Fig. 1. Trends in global temperature over the years (*Source*: IPCC, 2007)

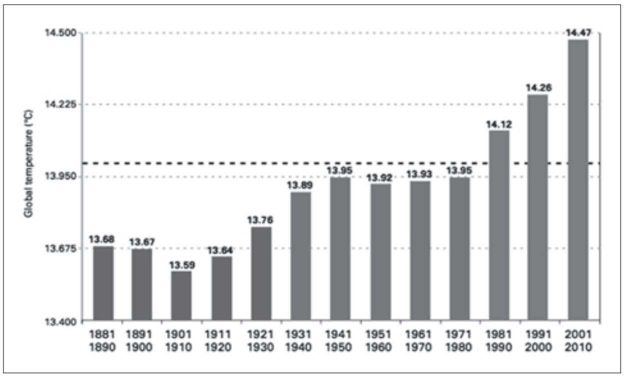

Fig. 2. Trends in global temperature over the years (*Source*: NASA, 2012)

According to Pratheep (2015), amongst the key impacts will be the faster retreat of Himalayan glaciers, frequent floods and decrease in crop yields, yield reductions in wheat and rice due to temperature rise in key growing regions The potential impacts on Indian agriculture would look like this: the productivity of most cereals would decrease due to increase in temperature and CO_2, and the decrease in water availability. There will be a projected loss of 10-40% in crop production by 2100 if no adaptation measures are taken. Global temperature shows the increasing trend (Fig 1, 2) that affects agriculture crops. Every one degree Celsius increase in temperature may reduce yields of major food crops by 3-7%. The length of the growing period in rain-fed areas is likely to decrease, especially in peninsular regions. An increase in climatic extremes such as heat and cold waves will likely to increase production variability (Hijioka *et al*., 2014). Keeping in the mind the importance of the issue in reference to cropping system and farmers it is inevitable to identify the status of agri-workers in reference to their knowledge status. A study was conducted with the objectives (a) to determine the perception of farmers on the issue of climate change, (b) to determine barriers felt by farmers in adopting climate resilient technologies and (c) to find out the Important Farm-level adaptation strategy to combat climate change.

METHODOLOGY

The present study focuses on agri-workers in the northern area of country where the climatic conditions have great variations throughout the year. The study was conducted in a survey approach through a Performa to be filled during the interaction with each worker for identifying their perception towards the issue.

For this purpose ten variables were selected and these were further categorized under four standards *viz.* confirm (positively sure with understanding the reasons behind the fact), agree (sure without knowing the reasons behind the fact), neutral and disagree with the fact. Sample size for farmers was 300 from the two villages of Faridabad namely *Badarpur Said* and *Jasana.* The selection of the respondents was done randomly however keeping in the mind the close participation of fair gender in the agriculture works; women farmers were also included in the study. The study also included identification of the barriers responsible for inhibiting the adoption of climate combat strategies in the cropping system. Some adaptation and mitigation strategies based upon the climate and cropping system of the area were advocated to the farmers for adoption. The mitigation strategies were based upon the variability in the climatic conditions since the last two decades however the cropping system of the area is replicated by the farmers in the same way as their ancestor were practicing while it is not appropriate according to current scenario.

RESULTS AND DISCUSSION

Perception of farmers towards climate change

As revealed by the Table 1, that more than two third respondents (69%) were of the opinion that change in climate has started more voraciously during last fifteen years. Another twenty five percent of the respondents have also showed the agreement with the similar views. However respondents who were of different opinion and did not coincide with the statement were only few ie less than 4 percent. Less than half (48%) had the opinion that climatic conditions are due to environmental factors which are basically causing

Table 1. Perception of farmer towards climate change under different variables (n=300)

Perception	Confirm		Agree		Uncertain/Neutral		Disagree	
	(f)	(%)	(f)	(%)	(f)	(%)	(f)	(%)
Climate change started between last 5 to15 years	207	69.0	80	26.6	03	1.0	10	3.3
Environmental factor is responsible for climate change	144	48.0	106	35.3	40	13.0	10	3.3
Rainy season and cold season are delayed and of shorter duration	185	61.0	65	21.6	35	11.6	15	5.0
Increase in temperature	266	88.0	14	4.66	20	66.0	0	0
Temperature in winters is moderate	180	60.0	20	6.66	80	26.6	20.0	6.6
Reduction in overall rainfall	249	83.0	11	3.6	25	8.3	15.0	5.0
Change in timing of rains	85	28.3	65	21.6	35	11.6	15.0	5.0
Sporadic rains	15	5.0	20	6.6	80	26.6	85.0	28.3
Water table decreasing sharply	219	73.0	40	13.3	20	6.6	11.0	3.6
Need to change cropping system	135	45.0	65	21.6	35	11.6	65.0	21.6

the change in climatic conditions. Nearly 35 percent were also having the same views but were not capable to connect the both, the environmental factors and the changing climatic scenario. However, only a few respondents expressed their opinion that both the concepts have no dependency at all.

Keeping in mind the dependency of Indian agriculture on rains, the study included different variables related to weather conditions. Nearly 61 percent respondents expressed their perception that both rainy and winter seasons are commencing delayed and also experiencing shorter duration. However, only 5 percent of the respondents did not coincide with their opinion. The study also revealed that a considerable number of respondents (11.6%) were having no idea about the change in duration and commencement of rainy and winter seasons.

The increase in temperature during the last few years was experienced by 88 percent of the respondents and more than half of the respondents experienced the similar views about the critical coldness levels in winters too. These respondents felt that critical minimum temperature was not experienced by northern Indian Plains as it was experienced a few decades ago. However a few (26%) of respondents did not perceive this change in the temperature during winters.

The survey also covered the important aspects of climate change like scanty rainfall, change in timing of rains, sporadic rains, and water table decreasing sharply. A major portion (83%) perceived that there is a considerable decrease in the rain fall during the last decade as a consequence of the changing climatic scenario. While very few also experienced that rains perceived by the land is same as it was earlier.

The study also tried to judge the mind set of respondents regarding the mitigation strategies like change in cropping system and revealed that nearly half of the respondents (45%) advocated the demand of change in cropping system from conventional to climatic savvy cropping system, while only 20 percent also agreed with statement.

Important farm-level adaptation strategy to combat climate change

The top three ranked adaptation strategies adopted by farmers were increased use of irrigation, moved to non-farm activities and practicing crop diversification was observed by 80, 65 and 40 percent. However, the important climate combat strategies like agro forestry, soil conservations techniques, zero tillage, use of drought tolerant varieties and use of salinity tolerant varieties were found completely missing from the cropping system of the area (Table 2).

The other important strategies like cultivating short duration crops, practicing intercropping and practicing crop rotation were also found in very less percent (less than 10).

Important Barriers felt by farmers to Combat Climate Change strategies

The very less adoption of climate combat strategies in the cropping system led authors to identify the barrier responsible for non-adoption of the strategies. In this reference some barriers were identified and ranked as perceived by the respondents. The top most barriers perceived by farmers are lack of information about weather, lack of Information about climate resilient varieties and lack of information about climate change. Lack of knowledge about adaptations and lack of credit or savings were also observed by the respondents as

Table 2. Adoption percentage of Important Farm-level adaptation strategy to combat climate change

S. No.	Adaptation Strategy	Percent Farmers	Rank
a.	Increased use of irrigation	80.0	I
b.	Moved to Non-farm activities	65.0	II
c.	Practicing crop diversification	40.0	III
d.	Change in crop variety	35.0	IV
e.	Integrated farming system	34.0	V
f.	Buy insurance	15.0	VI
g.	Build a water-harvesting structure	14.0	VII
h.	Crop insurance	9.0	VIII
i.	Cultivating short duration crops	9.0	IX
j.	Practicing intercropping	7.0	X
k.	Practicing crop rotation	5.0	XI
l.	Agro forestry	0	XII
m.	Soil conservations techniques	0	XIII
n.	Zero tillage	0	XIV
o.	Use of drought tolerant varieties	0	XV
p.	Use of salinity tolerant varieties	0	XVI

a major barrier in way to adoption the strategies. However, the less ranked barriers were lack of appropriate seed, adaptation not cost effective and lack of market access or transport problems were also observed by a moderate number of respondents (Table 3).

Table 3. Important barriers felt by farmers to combat climate change strategies

S. No.	Barrier	Rank
a.	Lack of information about weather	I
b.	Lack of Information about climate resilient varieties	II
c.	Lack of information about climate change	III
d.	Lack of knowledge about adaptations	IV
e.	Lack of credit or savings	V
f.	Lack of appropriate seed	VI
g.	Adaptation not cost effective	VII
h.	Lack of market access or transport problems	VIII

Adaptation and mitigation strategies

The area of north India just like other part of the world is experiencing variability in temperature which was not seen earlier so there is an urgent need to review the protocol and colander of cropping system accordingly. Since the issue of climate change is very complex to tackle by researchers any how some mitigation strategies that are must to follow in current scenario are prescribed to farmers. These are as follows.

(a) Farmers need crops and varieties that fit into new cropping systems and seasons.
(b) Researchers need to develop varieties with changed duration and varieties for high temperature, drought, inland salinity and submergence tolerance.
(c) Agri-workers need crops varieties that may tolerate coastal salinity and seawater inundation and may respond to high CO_2.
(d) Quality research is required to make germplasm climate resilient.
(e) Wild and extinct varieties have traits tolerant to high temperature, elevated CO_2 etc.
(f) Wild and extinct varieties might have been discarded in the past due to low yield potential but can be made use of today as parents for the breeding of tolerant varieties to climate change.
(g) There is a need to revisit gene banks with a view to searching for unique traits required for climate change. In this search, indigenous knowledge and farmer's wisdom have immense value.
(h) Efficient and wise management practices hold the key to adaptation and mitigation.
(i) Better water management and nutrient management.
(j) Lastly, agriculture needs varieties with high radiation use efficiency.

CONCLUSIONS

Most of the farmers (69.3%) perceived that climate change started between last 5 to15 years. Almost half of the farmers (48.0%) believe that environmental factor is responsible for climate change felt that both rainy season and cold season delays to start but ends early. Mean duration of both seasons has been significantly reduced in recent past than long time ago. Hot season shows opposite scenario as it starts early but delays to end. Mean duration of hot season has been significantly increased in recent past compared to long time ago. Similarly, they believe that hotness has increased (88.7%) and coldness has reduced (60.0 %). Farmers found a reduction in overall rainfall (83.3%) and variation in wind speed, duration of strong wind. They felt the incidence of drought has been increased (73.3%) and flood has been decreased (66%). Level of education and access to extension services had significant association with their perceived cause of climate change. Science, too, has to adapt. Multi-disciplinary problems require multi-disciplinary solutions, *i.e.* a focus on integrated rather than disciplinary science and a strengthening of the interface with decision makers. The barriers lack of information about weather, lack of Information about climate resilient varieties were ranked first and second respectively.

REFERENCES

Kumar, C.P. 2014. Impact of climate change in Agriculture. *Int. J. Engg. Manag. Res*. **1**(4): 151-156.

Ferris, J. 1999. *Am J Agric Econ* 81: 1309–1309.

Pathak, H., Aggarwal, P.K. and Singh, S.D. 2012. Climate change impact, adaptation and mitigation in agriculture: Methodology for assessment and application. IARI, New Delhi.

Pratheep, P. S. 2015. Climate change and its impact on Indian agriculture. *Int. J. Env. Rehab. Cons*. **IV**(1): 17-26.

Rao, M. Srinivasa, Rao, Ranga, G. V., and Venkateswarlu, B. 2010. Impact of Climate Change on Insect Pests, in B. Venkateswarlu et al. (eds.), Lead Papers: National Symposium on Climate Change and Rainfed Agriculture, Indian Society for Dryland Agriculture, Central Research Institute for Dryland Agriculture, Hyderabad, February 18–20, available at http://www.crida.ernet.in/conf-completed/Publications- Climatepercent20change percent20/leadpapers.pdf.

Hijioka, Y., E. Lin, J.J. Pereira, R.T. Corlett, X. Cui, G.E. Insarov, R.D. Lasco, E. Lindgren, and A. Surjan, 2014. Asia. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1327-1370.

Sikka, A.K. 2015, http://www.nicra-icar.in/nicrarevised/index.php

Sunandu Sudhakaran; S. P. Singh and D.K. Nauriyal, 2011. Sustainable Agriculture and Climate Change. *J. of Sustainable Development and Environmental Protection* 1: 18-29.

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Dynamics of hill agriculture in emergent rural economy of Kangra district, Himachal Pradesh

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ABSTRACT

The existence of human beings depends on the mountains and ecosystem services. Farming systems are facing immense difficulties owing to severe water shortage, changing climate patterns, dying traditional knowledge and increasing animal menace. Mountain ecosystem is adversely affected by the pressing population and resultant poverty. Natural resources are under huge pressure with diminishing land and water resources. The present paper examines the agriculture based livelihood security in changing socio-economic environments in district Kangra, Himachal Pradesh. Resource mapping, indexing, scoring and ranking of agro-ecosystem along with human and social capital have been used. In Kangra, about 45% of the work force is dependent on agriculture and the agricultural labourer accounted for 8% of the total work force. There is sluggish growth of employment opportunities in other sectors primarily in secondary and tertiary sectors to absorb surplus labour force from agricultural sector. The district has the largest number of cultivators i.e. 0.3 million out of 2 million cultivators in the state. The diminishing importance of the agro-ecosystem resources and their role as source of income are not sufficient in the present context of livelihood opportunities. The traditional sources of services have been decreasing in importance because of other sources of diversified income along with tourism in the hill region of Kangra. About 60 per cent of the households depend on the livestock for their additional income as well as other non-farm sources. Integrated farming system improves the livelihood situation and brings financial stability and security.

Key words: self-sustained community, integrated farming, diversification, agriculture/ ayurveda tourism

INTRODUCTION

Agriculture in India holds the key position in the economy, a way of life which permeates all sectors and spheres of life. In India, there is a high concentration of rural poor in low agricultural potential areas i.e rainfed compared to high potential areas i.e. irrigated (Fan and Hazell, 1997). The globalization processes have largely accrued to the urban sector growth leaving the rural sector behind. A large section of Himalayan people largely depends on the agriculture based livelihood (Maikhuri *et al*., 2001).

The very antiquity of Indian agriculture based livelihood has built certain peculiar characteristics such as fragmented landholdings, subsistence character, dominance of food crops with lack of modern technology, dependence on irrigation, absence of use of fertilizers and other tools, rural indebtness and hidden unemployment. The nature of unemployment is multifaceted and the hill state like Himachal is no exception. Kangra in Himachal Pradesh is a small hill district located in the western Himalaya. Ninety four percent of its 15,10075 population inhabits over 3,369 villages spread over the mountain landscape from low hills to high mountain areas. The number of persons unemployed in the rural areas of the district was 8,254 out of which 57 % are males (District Agriculture Plan, 2009). The dominant features of hill and mountain farming are small land holdings, sloping marginal farmlands and cultivation under rainfed farming. Since past decade subsistent farming was a dominating feature on the hill tracts but in recent time change is underway with diversification to high value cash crops. Crop diversification is a pungent applied concept to remove the plight of subsistence agricultural economy to ensure diversified nutrition status to the masses (Pratap, 2003). Challenges relating to

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infrastructure, transportation, uneven geography, climate change etc. are apparent. Hopper burn in rice was first reported in the Kangra valley during 2008 as an effect of climate change. Priority to ensure economic viability of fruit, vegetable and cash crop agriculture in the hill region is the need of the hour. The role of the Kangra tea cultivation cannot be neglected in the sustainable development of the valley. The future of the 150 years old industry should be analysed in the light of increasing competition in the market (Sankhian, 2007). Various research studies suggest that for better agricultural performance and improved land productivity; irrigational facilities need to be strengthened, an overall governmental programme for supporting the farmers need to be re-oriented. Other major agricultural constraints of stray animals, monkey menace, forest fire, water shortage, geographical constraints have major impact on the productivity (District Agriculture Plan, 2009). Medicinal plant sector has a vast potential for generating income for rural poor but it needs to overcome the challenges in its cultivation to develop Ayurveda tourism. The unique ecology of high hill region is suitable for quality medicinal plants and has potential to improve livelihood scenario (Kuniyal *et al*., 2006).

MATERIALS AND METHODS

The study was conducted in the Kangra district of Himachal Pradesh during 2012-2015 with a mix of qualitative and quantitative techniques. The survey was done between April and June 2012 and November and December 2013 and July and August 2014 and 2015. Four sample villages namely Dashalni, Zamanbad, Dragella and Shibnath were selected on the basis of diversified geographical and socio-economic conditions. A structured questionnaire was administered to 132 sample population. Focus group discussion and personal interviews were applied to identify the changing agricultural patterns in the region. Land use Resource mapping, indexing, scoring and ranking, human and social capital have been used in the study area. The study facilitates the understanding of the present status of cultivation of medicinal plants along with other diversified sources of income generation using both primary and secondary survey methods. For calculating the diversification of crops Simpson Diversity Index and Composite Capital Index is used to analyze its impact on the economic condition of people (Fig. 1).

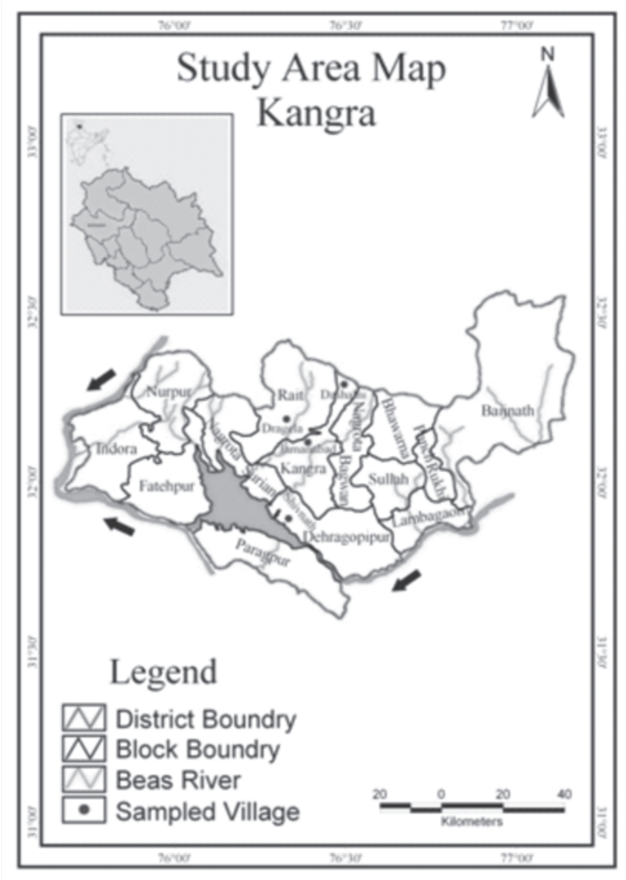

Fig.1. Location map of the sampled villages in Kangra district of H.P.

RESULTS AND DISCUSSION

Land use pattern in Kangra

The land use change in the Himalaya is significant and affects a whole range of issues including agriculture (Maikhuri *et al*., 2001). The total geographical area constitutes 5,68,759 ha from which 39% area lies under forest. The maximum area under forest was in Baijnath and the minimum was in Panchrukhi block. At the district level, more than 12% area was under grazing land as pastures. The area under other type of land use, culturable wasteland and fallow land altogether accounted for 19.20% in Fatehpur block which shows that this area can be put under cultivation provided that the irrigation facilities, critical inputs and technical knowledge are extended to the farmers of the block. The soils are shallow, black, brown and alluvial. Land sliding on account of sloppy land, over-grazing, animals and monkey and boar menace etc. were most common problems in a majority of the blocks in the district. Land use pattern is always seen adjunct to agricultural growth and development. The scope for an extension of cultivable land along with efficiency and agricultural productivity are relative terms. Land utilization in the district has remained by and large the same and maximum geographical area (55%) reported was under forest and pastures that constraints the scope for extension of cultivation. The striking feature is the increase in area under non-agricultural uses (13%). About 27.14% of the geographical area is cultivated in the district and there has been an increase in the fallow land area and area put to non-agricultural uses. The construction of roads in hinterlands, upcoming of new buildings, creation of infrastructural facilities and creation of urban and semi-urban fringes is taking place on prime agricultural lands. There is predominance of marginal and small holdings. In Kangra district, around 75.15% of the holdings are marginal (< 1ha) and 14.30% are small collectively accounting for 88 per cent of the total holdings compared to 86.35% at the state level. This clearly shows that pressure on land is much higher in Kangra. The challenge is further aggravated with continuous increase in holdings without corresponding increase in operational area. The number of marginal holding (less than 1 hectare) increased from 66.68% in 1980-81 to 75.15% in 2000-01 and 75.54% in 2005-06 (State Statistical Abstract of H. P., 2012-13). Contrary to this, number of medium and large holdings has shown sharp decrease. About 45 per cent of the work force is dependent on agriculture where 67% are women cultivators and the agricultural labourer accounted for 8% of the total work force. The percentage share of cultivators and other worker categories are nearly similar with 44.88 and 44.68, respectively. This shows sluggish growth of employment opportunities in other sectors primarily in secondary and tertiary to absorb surplus labour force from agricultural sector. Despite considerable decline of share in agriculture the district has the largest number of cultivators i.e. 0.3 million out of 2 million cultivators in the state (Table 1, 2, District Agriculture Plan, Kangra, 2009).

Table 1. Land use pattern of Kangra district (ha)

Particulars	Kangra (Area, ha)
Total geographical area	5,68,759 (100)
Forests	2,20,705 (38.80)
Productive	2,01,761
Degraded	18944
Barren land	73,289 (12.88)
Rocky	73229
Stony	60
Land put to non-agricultural uses	35,224 (6.19)
Buildings	30,365
Roads/paths/ Channels	4,859
Culturable waste	22,815 (4.01)
Weed/bush infested	16,534
Area prone to animal menace	6281
Permanent pastures and other grazing lands	35,344(6.25)
Productive	32,192
Degraded	3,432
Miscellaneous trees and grooves	10,539(1.85)
Fallow land	16,287(2.86)
Current fallow	12,318
Other fallow	3969
Total Cropped area	221830
Net sown area	115748
Net Irrigated Area	34653
Cultivated land	1,54,417 (27.14)

Source: District Agriculture Plan, Kangra (2009); Figures in Parentheses are percentage of state total

Table 2. Category of workers of Kangra

Category of Workers	Percentage
Cultivators	44.88
Agricultural Labourers	8.12
Workers in Households	2.32
Other Workers	44.68

Source: Census of India (2011)

Subsistence agriculture and shift towards rural non-farm sources

Rural livelihood security is enhanced due to diverse portfolio of activities. Rural Non-farm Employment (RNFE) contributed significantly in the rural employment and income (Reardon *et al*., 1998). Diversity promotes greater flexibility as it allows more possibilities for substitution between opportunities that are declined and those that are expanding (Venkateswarlu, 2005; Ellis, 2000). The cultivation of off seasonal vegetables in Chotta Bhangal region of Kangra district has made a perceptible impact on the livelihood of local people. Since the incidence of landlessness in these panchayats is negligible, practically every household has benefited from the cultivation of these crops. On an average, even a sub-marginal farmer having land as low as 0.2 hectare earns a net income of fifteen to twenty thousand rupees per crop season and is in a position to meet his basic needs (Human Development Report, 2009). Vegetable has been adopted as most desired option providing quick cash and livelihood security in the sampled village of *Jamanabad.* The average income (Rs. 11,400) of this village is accounted to be highest as compared to other village. Lack of irrigation and animal menace are mainly responsible for the agricultural diversification especially into non-farm activities. Currently role of livestock is significant as a resource base for the region. Share of cow and buffalo play significant role in income generation while the other animals partly contribute (Table 3). The primary survey reveals the subsistence nature of agriculture in the surveyed villages. The main staple food comprises wheat, maize and rice. Though there has been considerable increase in the cropping pattern and it is achieved as a result of efforts made by the agriculture department in the state. Medicinal plant sector has a vast importance both from the point of view of maintaining the eco-system and also for generating employment and income for rural poor which require its cultivation (Nandi, 1999). Cultivation of medicinal plants is not picking up in the region because of several bottlenecks including socio, economic and policy related issues along with market failure. Kangra district is an abode of several medicinal plant species which remain under utilized. The Ayurveda once flourished here in this ecological zone, but with passage of time, the use pattern has declined considerably and restricted to few people. But presently, the herbal products and its demand all across the world has revived considering its benefits. There has been tremendous pressure on the natural herbal resources in the Himalayan region. Considering the pressure and threat of herbal extinction, there has been growing concern among government and non- government sector. Many private sectors have emerged in this field in order to save the natural wealth and earn profit out of it. The role of Tibetans and local people of Kangra place great importance in disseminating the knowledge of the herbal wealth (Fig. 2 and 3).

Hill agriculture is difficult in the region when it has to depend on rain. Irrigation is thus one of the prerequisite for food production. As per total irrigated area, it accounts for about 10 percent of total cultivable area as per 1981 census. The major source of irrigation in district Kangra is the age old method of directing water from various streams, rivulets and springs through small rills or channels to the cultivated fields. Kuhl irrigation continues to be the most popular and suitable source of irrigation in the region accounting about 80 per cent of net irrigated area. The other sources of irrigation include the private wells (5 %) private tubewells (2 %). The remaining irrigation is done by private lift irrigation schemes (District Agriculture Plan, 2009). Another factor is cost of construction of irrigation system. Even cultivable land is available at higher places where water from streams cannot be lifted economically. Public and private agencies should construct dams/ponds across the routes of deep streams/rivers so that water could be transported via cannels/*khuls* to utilize it for an increase in productivity (Fig. 4).

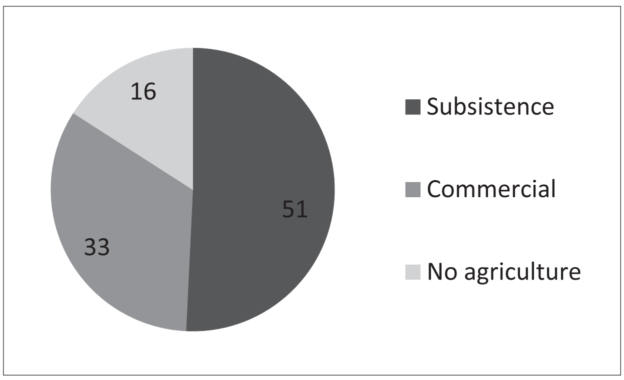

Fig. 2. Subsistence nature of agriculture in Kangra, H.P.

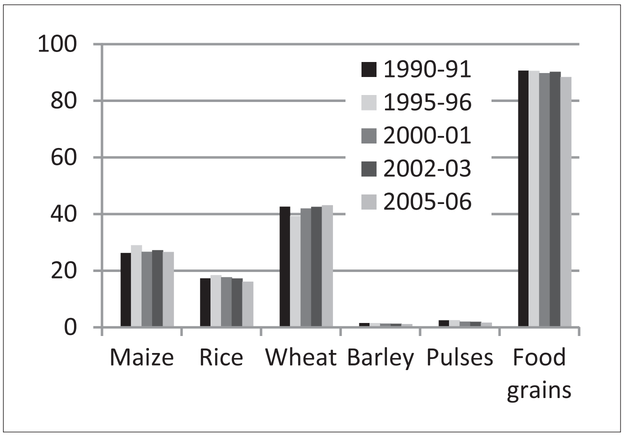

Fig. 3. Changing Cropping Pattern of Kangra, H.P.

Source: Statistical Outline, Govt. of Himachal Pradesh, Directorate of Economics and Statistics, Shimla

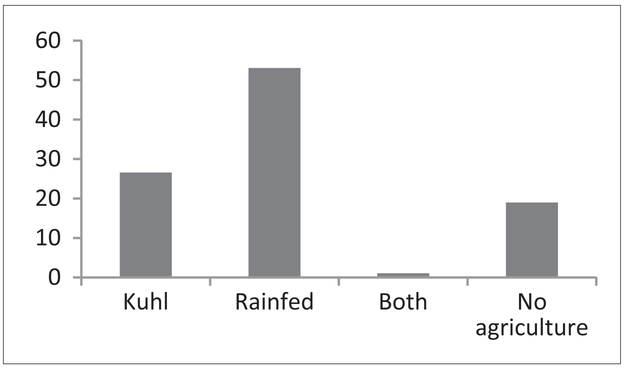

Fig. 4. Sources of Irrigation in study villages

Livestock as potential resource base in rural non-farm sector

Livestock farming has been an integral component of agriculture since times immemorial. Of late, it has emerged as a strong component of agricultural diversification with its concomitant implications for food security, employment, ecology and exports in the new economic regime. And unlike plains, it is more so for the hilly regions that have scant livelihood options. Besides milk, meat and related livestock products, in hills it provides draught power to till the land and perform other agricultural operations such as threshing and transportation. The latter become all the more important as the scope of mechanization is constrained by the hostile physiography and poor economic endowments of the hill peasantry. Livestock sector contributed around 22.0 per cent to the Gross District Domestic Product (GDDP) in Kangra in 1999-2000. However, as a proportion of domestic product originating in agriculture and allied sectors, livestock contribution was highest at 60.6 per cent (HDR, 2009 and Jayachandra and Naidu, 2006). Studies have analyzed the economics of buffalo farming in some states as highly profitable enterprise including Bihar and Jharkhand. Agriculture becomes cost effective with the livestock rearing (Kumar *et al*., 2006). The major constraints identified by the authors include non-availability of fodder (Pandey and Brijbala, 2000). From the surveyed data, about 31% believe dairy as very significant source of income improvement. 15 per cent consider it to be non-significant source of income because of high expenses on the livestock, shortage of fodder and space for rearing milch animals and lack of financial support from the government are some major reasons contributing to that. About 29% of respondents did not own milch animals and thus did not have view catering to its benefit. It is reported from the study that ownership of land and rearing of milch animals specifically are closely linked together. People having their own land can support their animal's fodder from the field itself; otherwise the fodder is a costly affair for the people. Singh *et al*. (1994) in an attempt to know the participation of women in agriculture, allied and household activities, concluded that participation of women involved in animal husbandry is affected by education. Though, for taking good quantity of milk, they also purchase fodder from the market. More than 60 per cent of the villagers from all studied villages earn below INR. 2000 per month and they also use milk for self-consumption. The livestock especially cows is a major asset for them (Table 3).

Table 3. Percent share of income generation from sale of milk/month (in INR.)

Below 2000	2000-4000	4000-6000	Above 6000	No Production/ animal
22	9	4	4	61

Source: Survey

Physical and human resource base towards diversification of agriculture

The land utilization pattern in different blocks of Kangra revealed that Baijnath having the highest geographical area was almost nine times of the smallest block of Panchrukhi. The share of landholding is very small and more than 60 per cent of population possesses land holding which is below 1 ha. Only 2 per cent of population possesses more than 3 ha of land holdings. The data also reveals that out of 15 blocks Kangra and Palampur blocks are dependent on the irrigation and the share of agriculture is also low compared to other blocks. The current trend shows the changing land use pattern in these regions due to the impact of tourism and urbanization. The Simpson Diversity Index (SDI) has been calculated for six major crops including Wheat (43%), Maize (27%), Rice (17%), Other (10%), Pulses (2%) and Barley (1%) for which SDI is 0.71. This shows the degree of diversification to be moderately higher in district Kangra. The crop diversification in Himachal has largely focused on fruits and vegetables farming (Pratap, 2003). The share of 15 per cent of total flower area of the state lies in Kangra district. Similarly, the vegetable crops occupied 6,038 hectares with production of 1,00,737 MT in 2005-06. Off season vegetables, Peas, tomato, French beans, onion and garlic, cabbage, cauliflower, raddish, turnip and carrot, cucurbits, capsicum, chillies, brinjal and other varieties are grown in the district (Table 4).

Flower cultivation is one of the potential source of enhancing rural livelihood due to conducive climatic condition prevailing in the region. About 15 per cent of total area is under flower cultivation (Table 5). 70 per cent of quality rose is produced in the district and potential research work is also undertaken at IHBT laboratory, CSIR, Palampur (Statistical Abstract of Himachal Pradesh, 2012-13). The diversification is favourable considering fast declining land holding size of the district.

Kangra tea is insignificant source of income in Baijnath, Kangra and Palampur area. Due to unique local geographical conditions, the aroma of Kangra Tea is different from the tea produced in other parts of India and it also requires less area and in turn provides larger income and employment. But no adequate attention has been paid for its revival and the benefit is restricted to few hands. The overall average land holdings of the study villages are about 1.5 hectare in the study villages. The average agricultural plot size varies from below 1 hectare to 3 hectare in the study

Table 4. Area, production and yield of different vegetables in district Kangra and Himachal Pradesh, 2005-2006

Crop	Kangra			H.P.		
	Area (ha)	Production (MT)	Yield (q/ha)	Area (ha)	Production (MT)	Yield (q/ha)
Peas (Green)	388	3,625	93.43	15,348	1,77,036	115.35
Tomato	345	9,873	286.17	9,211	3,01,249	327.05
Beans	255	2,975	116.67	2,674	27,973	104.61
Onion & garlic	764	11,376	148.9	3,735	49,622	132.86
Cabbage	270	7,487	277.3	3,677	1,15,920	315.26
Cauliflower	368	5,612	152.5	2,263	53,103	234.66
Radish, turnip & carrot	458	11,232	245.24	1,571	32,675	207.99
Bhindi	869	9,570	110.13	1,728	19,659	113.77
Cucurbits	442	9,028	204.25	2,082	43,845	210.59
Capsicum & chillies	216	2,632	121.85	2,081	30,876	148.37
Brinjal	283	5,769	203.85	772	14,267	184.81
Other vegetables	1380	21,558	156.22	3,715	63,817	171.78
Total	6038	1,00,737	166.84	49,858	9,29,706	186.47

Source: Directorate of Agriculture, Govt. of H.P., Shimla and State Statistical Abstract of Himachal Pradesh, 2012-13

villages. Village Dashalni, a tourist village records minimum size of land holdings followed by Jamanabad, a village known for good quality vegetable cultivation for commercial purpose. The village Shibnath records highest percent of land holdings due to its proximity to forest and less exposure of urbanization. The average size of land distribution is about 3 hectare but some high income group people have large size of land holdings ranging from 20 hectare to 40 hectare. The economy based on vegetable cultivation in the village Jamanabad constitutes more than 50% of the high income group which shows the potential impact of diversification of agriculture. Most of the progressive farmers of Jamanabad are engaged in vegetable cultivation due to its good return in less duration. But at the same time benefits of diversification is restricted to few regions. Despite large size of land holdings the village economy of both Dragella and Shibnath are among the highest contributors in low income group which confirms the lesser impact of diversification and associated issues of livelihood options (Table 6).

Table 5. Flower cultivation in district Kangra vis-à-vis Himachal Pradesh, 2006-07 (ha)

Particulars	Kangra	Himachal Pradesh
Gladiolus	6.20 (5.14)	120.59
Carnation	-	25.06
Marigold	12.82 (5.98)	214.43
Lillium	0.70 (15.87)	4.41
Daffodils	-	2.65
Rose	9.85 (70.66)	13.94
Chrysantheum	2.97 (4.48)	66.21
Seasonal flower	24.30 (78.29)	31.04
Other flower	20.86 (77.03)	27.08
Flower seeds	-	0.01
Potted plants	-	4.4
Total	77.70 (15.24)	509.82

Source: Directorate of Horticulture, Govt. of H.P., Shimla and State Statistical Abstract of Himachal Pradesh, 2012-13; Figures in Parantheses are percentage of state total

Table 6. Distribution pattern of surveyed villages by land holding/s and wealth ranking

Villages	Average land holding (in hectare)	Income Categories (%)		
		Low Income	Middle Income	High Income
Dashalni	Below 1	18	26	18
Zamanabad	Below 1	14	29	53
Shibnath	1	37	12	12
Dragella	3	31	33	17

Source: Primary Survey

Changing agricultural production

Honey bee rearing has increased income of the households by 120-132% and employment from 70 per cent to 118% in Himachal Pradesh which can easily sustain under harsh climate and need no migration (Kumar *et al*., 2006).

The quality of soil and productivity of land is considered good by the majority of population but the size of land holding is very small and 62 % own below 1 hectare of land. Majority of the agriculture is rainfed (53%) followed by traditional source viz. *Kuhl* irrigation (27%) in all the study villages. And a very small percent of irrigation is carried out from other sources. 53 per cent depend on rainfall leading to disinterest in agriculture and diversification (Fig. 4). With current situation of agriculture multiplied by increasing population, there has been greater pressure to increase the productivity. Dependence on the chemical fertilizer remains one of the important options to fulfill the required demand of the population. 54 per cent of sampled population use both chemical and organic fertilizer to support self-consumption from their agriculture. About 54 per cent spend below INR 1000 per month in purchasing fertilizers especially chemical and a small percent of about 5 per cent spend more than INR 3000 for the same. The finding indicates that although farmers use the limited quantity of chemical fertilizers, they tend to believe and depend on organic manure which is prepared by themselves and is possible because of the availability of livestock. About 1/3rd of population practice farming because of unavailability of any other livelihood option in the region, 37 per cent believe it to be a profitable means to utilize the land both for self-consumption and livelihood. With the constraints in agricultural production, decrease in size of land holdings and more dependence on rain lead people to diversify their livelihood options to various non-farm activities. The Composite Capital Index has been calculated to categorize the region on the basis of various resources/capital. This helps indicate the strength and weakness of the region to develop essential tools for the promotion of livelihood options. The tourist blocks including Kangra and Baiznath have high capital base compared to non-tourist or agriculture based blocks (Singh and Nitu, 2014).

Farm mechanization and growth drivers

Farm mechanization is essential in the high hill regions for which Extension department of Palampur agricultural university has significant role to play. The suitable agro-climatic condition to grow crops like potato, high value cash crops like rajmash, fruits, vegetables and livestock rearing, rising demand due to growing tourism, potential markets in the nearby states are few growth drivers. The productivity levels of crops and livestock needs further improvement by strengthening extension and research activities to support cultivators. development of frost resistant varieties in fruit and vegetable crops and regular training of farmers are most important measure emerged out of the field research.

CONCLUSION

The existing agriculture scenario of the district is subsistence in nature but has great potential in different enterprises if the area from traditional crop may be diversified towards vegetable, flower and medicinal plant production to meet the growing demand in the local market. The Simpson Diversity Index of 0.71 shows the preference of diversification but the process of crop diversification in the district is, however, facing important challenge and to overcome this there is need of building knowledge and skill among farmers. The most promising enterprises which can provide employment to the rural unemployed youth is Integrated farming which poultry, mushroom farming, dairy, bee keeping, nursery raising, medicinal and aromatic plants processing, vegetable processing and farming and protected cultivation offer.

REFERENCES

District Agriculture Plan 2009. Department of Agriculture, Himachal Pradesh, Vol.IV

Ellis, Frank 2000. *Rural Livelihoods and Diversity in Developing Countries,* Oxford University Press.

Fan, Shenggen and Hazell, Peter 1997. Should India Invest more in less favoured areas in rural India, EPTD Discussion Paper.

Human Development Report (HDR), Kangra 2009. Planning Department, Himachal Pradesh.

Jayachandra, K. and Gurappa Naidu 2006. Impact of dairy cooperatives on ncome, employment and creation of assets of marginal and small farmers- A case study. *Indian Cooperative Review* **43**(4): 719-724.

Kumar, Praduman, Singh, N.P. and Mathur, V.C. 2006. Sustainable Agriculture and Rural Livelihoods: A synthesis. *Agricultural Economics Research Review* **19**:1-22.

Kuniyal, Chandra P., Rawat, Yashwant, S., Oinam, Santaram, S.,Kuniyal, Jagdish, C. and Vishwakarma, S.C.R. 2005. Kuth (*Sausurrea lappa*) cultivation in the cold desert environment of Lahul Valley, North-western Himalaya India: arising threat, and need to revive socio-economic values. *Biodiversity and Conservation* **14**(5): 1035-1045

Maikhuri, R.L., Rao, K.S. and Semwal, R.L. 2001. Changing scenario of Himalayan agroecosystems: Loss of agrobiodiversity, an Indicator of environmental change in Central Himalaya, India. *The Environmentalist* pp 23-39.

Nandi, Rajib 1999. Herbal medicinal plants in Himachal pradesh: an analysis of income and employment potential, Institute of Social Studies Trust, New Delhi, National Council of Applied Economic Research / Ford Foundation.

Pandey, A.K and Brijbala, 2000. Constraints in adoption of dairy husbandry. *Rural India* **63**(9): 165-169.

Pratap, Tez 2003. Himachal farmers' livelihood concerns and opportunities in agriculture, CSK Himachal Pradesh Agricultural University Source: http://www.hillagric.org, accessed on Oct.11th 2015

Reardon, T., Stamoulis, K., Cruz, M.E., Balisacan, A, Berdegue, J. and Banks, B. 1998. *Rural non-farm income in developing countries*. In FAO: the state of food and agriculture, FAO Agriculture series, No. 31, Rome.

Sankhian, Anurag 2007. *Tea Cultivation and Sustainable Development: A Case Study of Kangra Valley*, Ph.D. Thesis submitted to HNB Garhwal University, Srinagar, Garhwal.

Singh, M., Verma, N.C. and Sitalakshmi, S. 1994. Extent of participation of women in agriculture, allied and household activities. *Maharahstra J. Extn. Edu.* **13**: 71-74.

Singh, R.B. and Nitu 2014. Rural Non-Farm and Tourism based livelihood options in livelihood security in Northwestern Himalaya (Eds. R.B.Singh and Reija Hietala), Springer, Japan.

State Statistical Abstract of Himachal Pradesh (2012-13). Department of Economics and Statistics, Himachal Pradesh.

Venkateswarlu, A. 2005. Rural non-farm employment in Andhra Pradesh: 1961-2001. *Journal of Rural Development* **24**(4): 459-480.

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Evaluation of emerging trend of saffron (*Crocus sativus*) vis-à-vis climate change in temperate region of Kashmir valley, India

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ABSTRACT

The present study was conducted in three different sites of saffron growing areas of temperate region of Kashmir valley, India to evaluate emerging trend of saffron vis-à-vis climate change and production trend. The productivity was evaluated climatic data of temperature and rainfall. The soil in the major saffron grown area of Pampore, Srinagar is uniform and clayey in nature with a soil permeability of 0.05 cm/hr. The productivity in the area was shown an increasing trend with temperature and rainfall. The rainfall data during activity period (July- September) and productivity data were collected (2000-2008) from three different locations. It is evident from results that the maximum productivity was found to be 3030 g/ha in year 2000 and minimum productivity was found 940g/ha corresponding rainfall 150.3mm in the year 2004. The correlation coefficient between productivity and rainfall was 0.18 with a P-value of 0.627. Thus the productivity exhibits positive but non-significant correlation with rainfall. Different year temperature (2000-2009) and corresponding productivity was shown significant effect of temperature on productivity. The statistical analysis between temperature variation and productivity of saffron was to be equal (R^2)0.260 with a P-value of 0.468. Thus, the productivity exhibits positive relations but non-significant with mean maximum temperature.

Key words: saffron, irrigation, water requirement, soil properties

INTRODUCTION

Saffron the legendary crop of Jammu & Kashmir belongs to the family of Irrdaceae and genus crocus. Saffron is a spice derived from the flower of *Crocus sativus*, commonly known as the Saffron. Saffron has a long medicinal history as part of traditional healing. Modern medicine has also discovered saffron as having anti-carcinogenic (cancer-suppressing), anti-mutagenic (mutation-preventing), immune modulating, and antioxidant-like properties. Saffron stigmas, and even petals, have been said to be helpful for depression. Early studies show that saffron may

protect the eyes from the direct effects of bright light and retinal stress apart from slowing down macular degeneration and retinitis pigmentosa. Saffron as a cultivated plant grows from altitude of sea level to almost 2000 m, although it is more acclimatized to hill sides, plateaus and mountain valleys ranging in altitudes between 600 and 1700 m (Nehvi *et al.,* 2008). The world's major saffron producing county are Iran, Span and India and their export production is 173t, 26t and 8.8t, respectively (Yasmin and Nehvi, 2013). However, due to lack of renovated technology and other climatic factor are responsible for its decline.

Each saffron corm grows to 20–30 cm and bearing flowers, each with three vivid crimson stigmas. Iran now accounts for the lion's share, or around 90%, of world production. The plants fare poorly in shady conditions; they grow best in full sunlight. Fields that slope towards the sunlight are optimal (*i.e.,* south-sloping in the Northern Hemisphere) (Agavev, 2003). Planting is mostly done in June month, where corms are lodged 7–15 cm deep; its roots, stems, and leaves can develop between October and February. Planting depth and corm spacing and climate, are critical factors in determining yields (Zehan *et al.,* 2006).

The climate has a great significance in planning and interpretation of operations relating to production, protection, fertilization and irrigation

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of saffron. It plays an important role in deciding the yield potential even though other inputs required are supplied at an optimum level (Venkataraman and Krishnan, 1992). Therefore, it is necessary to study critically the effect of different weather elements *i.e.,* temperature, rainfall, humidity, photoperiod etc. on growth and development of saffron as the seasonal variation were largely found to be responsible for the differences in corm production and saffron yield. Saffron grows in a climatically diverse regions varying in altitude, temperature and humidity conditions. The potential productivity of saffron depends not only upon irrigation, fertilizer and quality corms but also upon the optimum weather conditions, as each and every growth phase of saffron plant is significantly influenced by the prevailing weather conditions (Omidbaigi *et al.,* 2001; Ehsanzadeh *et al.,* 2004).

Owing to the incredible utilization of saffron, the world production is not sufficient enough to meet the growing global demand (Nehvi *et al.,* 2007a; Fernandez, 2007). However, in India, there is a tremendous human resource base, and as such saffron industry has an ample scope to expand, provided saffron in India is cultivated on scientific lines and replantation in the traditional and non-traditional areas is taken up (Nehvi *et al.,* 2007b). The present study was conducted to evaluate the emerging trend of saffron (*Crocus sativus*) growing areas with respect to climate change which are responsible for low production.

MATERIALS AND METHODS

Study area

The field study was conducted in three different sites of Pampore, Lethpora and Khonmoh of three different Districts of Kashmir valley. Soil samples were collected from the fields of three locations to analysis the texture properties and physio-chemical properties. The development of soil profile and its physical and chemical composition have a significant bearing on crop performance. The description of the soil profile showed that crop cultivated in the soil was well drained with ground water depth more than 10m. The morphological characteristics of the soil profile under study at different horizons of varying depths indicated variation in the soil colour. The texture was loamy to clay loam in different horizons. The hydraulic properties at different depths of soil are summarized in Table 1.

Spatial and temporal studies of climatic data were done in selected sites of saffron growing areas with the help of the meteorological data. The rainfall and temperature data during activity period (July-September) corresponding productivity data were collected (2000-2008) from three different locations. Further, statistical analysis was also carried out for trend analysis. The trend in area and productivity of Saffron in different districts is shown in Table 2.

Table 2. Trend in area, productivity and production of saffron in Jammu and Kashmir

District	Area (in ha)	Production (MT)	Yield (kg/ha)
Pulwama	2346	4.41	1.88
Budgam	507	1.27	2.50
Srinagar	210	0.38	1.80
Doda	80	0.20	2.50
Total	3143	6.26	2.17

Source: Departments of Agriculture, Jammu and Kashmir Divisions

RESULTS AND DISCUSSION

The present study was conducted in three different sites of saffron growing areas of temperate region of Kashmir valley, India to evaluate emerging trend of Saffron vis a-vis climate change and production trend. The data obtained in the present study were tabulated and statistically analyzed and the results of the investigations are summarized in this section.

The rainfall data during activity period (July-September) with corresponding productivity data were collected (2000-2008) from three different locations. The detail of rainfall and corresponding average season productivity are presented in Table 3. It is evident from Table 3 that the maximum productivity was found to be 3030 g/ha in year 2000 and minimum productivity was found 940g/ha corresponding rainfall 150.3mm in the year 2004.The statistical analysis was carried out to

Table 1. Soil properties of study area

Depth (cm)	Field Capacity		Permanent wilting point		Available moisture		Bulk density
Depth/ unit	(%)	cm	(%)	cm	(%)	cm	g/cm^3
0-20	18	25	8	11	10	14	1.48
20-40	23	30	11	14	12	16	1.59
40-80	25	34	11.5	16	13.5	18	1.66
80-120	27	37	12.4	18	14.6	19	1.70

Table 3. Rainfall received in the months of activity period (July-September)

Year	Rainfall (mm)	Productivity (g/ha)
2000	121.9	3030
2001	116.2	1890
2002	142.6	1270
2003	150.3	940
2004	203.8	1300
2005	226.7	2000
2006	425.8	2500
2007	127.4	2000
2008	149.9	2500

assess correlation between rainfall and productivity of saffron in different year. The graph plotted between average rainfall and corresponding productivity is shown in Fig. 1.The correlation coefficient worked out between productivity and rainfall comes out to be equal to 0.18 with a P-value of 0.627. Thus the productivity exhibits positive but non-significant correlation with rainfall. The regression line is fitted between productivity and rainfall to obtain the regression coefficients that is slope and intercept for which the values obtained were 1.309 and 1694. Also value of coefficient of determination (R^2) comes to be 0.035.

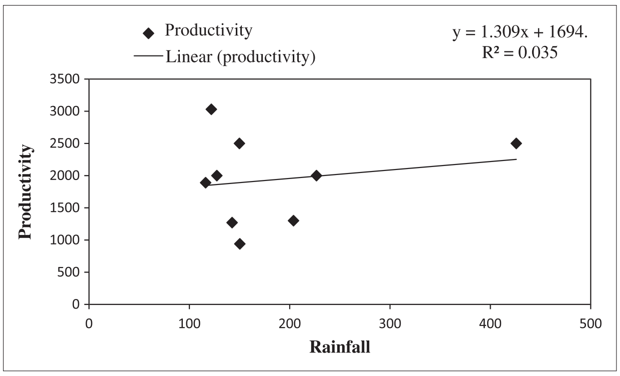

Fig. 1. Relationship between rainfall and productivity during activity period of saffron

In temperature, no variability was found and temperature varied between 29.83 to 28.51^{0}C. Different year temperature (2000-2009) and corresponding productivity is shown in the Table 4.The graphical representation between productivity and maximum temperature is illustrated in Fig. 2. It is evident from Table 4 and Fig. 2 that there is not much variability in temperature. The results showed that there was no significant effect of temperature on productivity. The statistical analysis also carried out between temperature variation and productivity of saffron. The value of coefficient of determination (R^2) comes

Table 4. Mean maximum temperature during the activity period (July-September)

Year	Mean maximum temperature	Productivity (kg/ha)
2000	28.81	3.03
2001	29.303	1.89
2002	28.510	1.27
2003	28.544	0.94
2004	29.019	1.30
2005	29.377	2.00
2006	28.131	2.50
2007	28.855	2.00
2008	28.487	2.50
2009	29.83	3.00

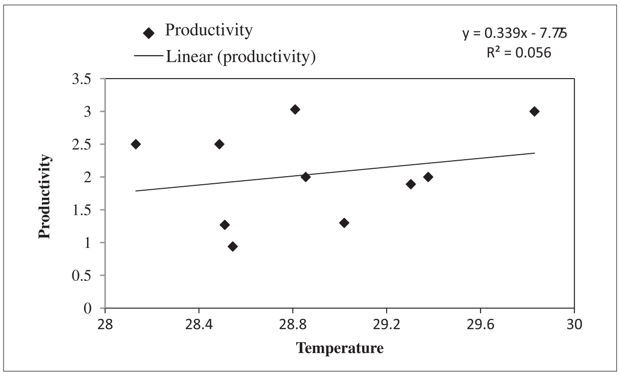

Fig. 2. Relationship between temperature and productivity during activity period of saffron

to be 0.056 with a P-value of 0.468. Thus, the productivity exhibits positive relations but non-significant with mean maximum temperature. The regression equation was fitted between productivity and mean maximum temperature to obtain the regression coefficients, that is slope and intercept for which the values obtained were 0.339 and 7.7.

It is evident from results that, the area under saffron cultivation has declined by 52.5 % in 2001-02 as compared to that in 1996-97. The production suffered badly all these years due to several climatic factors. The year 2001-02 was the worst with as a low production as 300 kg for the whole state. This was due to the acute drought situation faced by the state during the summer that year, causing severe soil moisture stress leading to poor plant growth and flowering

CONCLUSION

Saffron finds its major use in food, beverage, cosmetics and textile industries. In present study dependence of productivity on weather parameters like temperature and rainfall was observed. With the increase in temperature and rainfall, productivity showed an increasing trend. The maximum productivity was found to be 3030 g/ha in year 2000 and minimum productivity was found 940g/ha corresponding rainfall 150.3mm in the year 2004. The correlation coefficient between productivity and rainfall was 0.18 with a P-value of 0.627. Thus the productivity exhibits positive but non-significant correlation with rainfall. The statistical analysis between temperature variation and productivity of saffron was to be equal (R^2) 0.056 with a P-value of 0.468. Thus the productivity exhibits positive relations but non-significant with mean maximum temperature.

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REFERENCES

Agayev, Y.M. 2003. Breeding of saffron (*Crocus sativus* L.): Possibilities and problems. The 1st International Symposium on Saffron Biology and Biotechnology, lbacete, Esparia, p. 70.

Ehsanzadeh, P., Yadollahi, A.A. and Yadollahi-Maibodi, A.M.M. 2004. Productivity, growth and quality attributes of Iranian saffron accessions under climatic conditions of Chahar–MahalBakhtiari, Central Iran. *Acta Hort*. **650**: 183-188.

Fernandez, J. A. 2007. Genetic resources of saffron and allies (*Crocus* spp). *Acta Hort*. **739**:167-185.

Nehvi, F.A., Kaul, G.L. and Wani, S.A. 2008. Status of saffron in Jammu and Kashmir. Saffron Production in Jammu and Kashmir, pp. 1-21.

Nehvi, F.A. and Makhdoomi, M.I. 2007a. Importance of irrigation in saffron production. *Indian Farming* **59**:15-16.

Nehvi, F.A., Wani, S.A., Dar, S.A., Makhdoomi, M.I, Allie, B.A. and Mir, Z.A. 2007b. Biological interventions for enhancing saffron productivity in Kashmir. *Acta Hort*. **739**: 25–31.

Omidbaigi, R. 2001. *Cultivation and processing of medicinal plants.* 2ndEdition. AstanQods Publ., Tehran.

Venkataraman, S. and Krishnan, A. 1992. Crops and weather. Publication and Information Division of ICAR, New Delhi, India.

Yasmin, S. and Nehvi, F. A. 2013. Saffron as a valuable spice: A comprehensive review. *African Journal of Agricultural Research* **8**(3): 234-242.

Zehan, A.A.A., Kamger, H.A.A. and Sepaskhah, A.R. 2006. Effect of irrigation method and frequency on corm and saffron production. *J. Sci. Technol. Agric. Nat. Resour*. **10**(1):45-54.

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Impactful Indigenous Technical Knowledge (ITK) for sustainable agriculture

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ABSTRACT

The advent of the concept of sustainable agriculture in late eighties in Indian agricultural scenario has evoked interest on indigenous technical knowledge (ITK) that has the element of use of natural products to solve the problems pertaining to agriculture and allied activities. Indian farmers, over centuries, have learnt to grow food and to survive in difficult environments, where the rich tradition of ITK has been interwoven with the agricultural practices followed by them. Indigenous Technical Knowledge (ITKs) are treasure troves of ancient wisdom, beliefs and traditional knowledge passed on from generation to generation for preservation, effective utilization and conservation of natural resources, soil, plant and other organisms. It is a well-known fact that India has a charitable and glorious heritage of past, both in richness and variety in performing agricultural and allied practices. ITKs are based on experience, often tested over a long period of use, adapted to local culture and environment, dynamic and changing, and lay emphasis on minimizing the risks rather than maximizing the profits. It has the element of use of natural products to solve the problems pertaining to agriculture and allied activities. But, despite these, the ITK at the farmer's level receive less recognition by the organizations. Also the propriety rights on ITK have often been ignored. It is so, because of the key actors are not working closely with each other. Hence, there is an urgent need to have institutional reforms especially for better coordination, convergence and efficiency in action in recognizing and encouraging the scientific talents behind such grass root level ITKs and widely sharing benefits accrued from such ITKs across the country. The objective of this paper is mainly to get thorough understanding of the role of institutions in promotion and commercialization of ITKs and suggesting effective strategies in up scaling and out scaling of ITKs.

Key words: agro-climatic, indigenous technical knowledge, up scaling, out scaling, resource conserving technologies

INTRODUCTION

Indian farmers, over centuries, have learnt to grow food and to survive in difficult environments, where the rich tradition of Indigenous Technical Knowledge (ITK) has been interwoven with the agricultural practices followed by them. Local or indigenous knowledge refers. In order to manage their farms successfully, small farmers require information and knowledge on a variety of technical and market matters. The information helps the farmers make correct decisions in the world of available choices. This includes the crop, the variety, various other inputs, and how much, when, and how to use them. With development, as the number of options expand and become more and more complex, this decision-making becomes increasingly difficult. Growing variation in the market and agro-climatic environment with globalization and climate change makes this more risky and crucial. Systems to provide good information and knowledge to the small farmers are thus, becoming increasingly important for their viability, well-being and productivity. tothe cumulative and complex bodies of knowledge, know-how, practices and representations that are maintained and developed by local communities, who have long histories of interaction with the natural environment (UNESCO, 2012). It is the basis for decision-making of communities in food security, human and animal health, education and natural resource management (Behera, 2012). ITK is a complex set of technologies developed and sustained by indigenous or local people which is 'crucial for the survival of society' (Dei, 2000). It is

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mainly passed down generations through folklore,myths, customs, folk songs, proverbs, puppetry andother traditional methods (Swathi*et al.*, 2009). It is the information base for a society, which facilitates communication and decision-making. Indigenous information systems are dynamic, and are continually influenced by internal creativity and experimentation as well as by contact with external systems. There are different classes of ITK in agriculture i.e. climatology, local soil and taxonomy, soil fertility, primitive cultivars, intercropping, agronomic practices, irrigation and water management, plant protection, post-harvest technology and methods. As the indigenous practices are inexpensive, easily accessible, locally appropriate and tested in actual farm situation, they are, more rapidly accepted by other farmers than the results of formal research imposed on them. The enhancement of the quality of life of the Indians who in great majority live in and depend on agricultural production systems would be impossible by keeping this rich tradition of ITK aside. Institutions like ICAR,National Innovation Foundation, PPV and FRA (Protection of Plant Varieties and Farmer's Rights) etc has realized the importance of ITK in Agriculture.

The increasing attention that indigenous knowledge is receiving by researchers and policy makers has not yet led to a unanimous perception of the concept of indigenous technical knowledge (ITK). ITK is the locally available indigenous technical knowledge (ITK) is the information based on long time experiences which facilitates proper timely communication and accurate decision-making. The village people have good knowledge of many aspects of their area and can adopt them based on needs to solve regional problems in good agricultural practice and related activities. ITK helps the farmers to properly diagnose the particular disease in their field crops, vegetables, and orchards as well as its economically viable and socially accepted management through their resources as proved by their ancestors. This is mainly based on their assumption, reliable evidences, economic viability, social consent, traditional sound experience and knowledge, and proven result. Farmers in India are more sensitive to adopt ITK practices as they are far away modernize Agricultural researches as well as social and economic issues. They easily follow this traditionally available knowledge that they have learnt from their families. A number of ITK practices are also frequently used by the villagers of Indian farmers. Some very popular ITK practices are used in agriculture in present days also.

Role of Institutions in promoting ITK

Institutions are playing major role in identification, collection, documentation and preservation, validation, up scaling and out scaling of the ITKs, and giving the acknowledgement to the knowledge generated local system or person.

A. Indian Council of Agricultural Research

ICAR launched a nationwide Mission Mode project on collection, documentation and validation of indigenous technical knowledge under National Agricultural Technology Project (NATP). Information on ITK will be collected from the primary sources through the voluntary disclosure. The major task is to collect and compile the practices on ITK from the available literature, books, journals, theses etc. and publish into documents. ICAR is maintaining CD of Inventory of Indigenous Technical Knowledge (ITK) in Agriculture.

It is a major initiative undertaken by ICAR to document and validate the ITKs practiced by the farmers in the country. Through this initiative, a total of 4880 ITKs in 28 thematic areas were collected, validated and published in seven volumes. Further the seven ITK e-books and a resource book for training on ITK was also published. The inventory of all ITK documents have been classified under different subject matter areas *viz.* rain water management, soil and water erosion, tillage and interculture management, crops and cropping systems, pest and disease management, soil fertility management, farm implements, post-harvest technology, grain/seed storage, horticultural crops, veterinary science and animal husbandry, fisheries, ethno-botany and agro-biodiversity, weather forecasting, food product development, agro-animal based yarns/ natural dyes, and low cost housing materials.

Further the Intellectual Property and Technology Management Unit (IP&TM) in ICAR oversees all matters related to intellectual properties and technology transfer/ commercialization. ICAR recognizes that a systematic management of its technology products and services while bringing commercial ethos in their transfer and realization at the user end would result in much-needed dividends for the nation. Therefore, the Council is slowly and steadily but comprehensively moving towards intellectual property management and technology transfer in an organized manner.

B. Protection of Plant Varieties and Farmers Rights Authority (PPVFRA)

In order to provide for the establishment of an effective system for protection of plant varieties, the rights of farmers and plant breeders and to encourage the development of new varieties of plants Plant Varieties and Farmers' Rights Act, 2001 has been enacted in India. It recognizes and protects the rights of the farmers in respect of their contribution made at any time in conserving, improving and making available plant genetic resources for the development of thenew plant varieties. Moreover to accelerate agricultural development, it is necessary to protect plants breeders' rights to stimulate investment for research and development for the development of new plant varieties.Such protection is likely to facilitate the growth of the seed industry which will ensure the availability of high quality seeds and planting material to the farmers. India having ratified the Agreement on Trade Related Aspects of the Intellectual Property Rights has to make provision for giving effect to Agreement.

C. National Research Development Corporation (NRDC)

NRDC was established in 1953 by the Government of India, with the primary objective to promote, develop and commercialize the technologies / know-how / inventions / patents / processes emanating from various national R&D institutions / Universities and is presently working under the administrative control of the Department of Scientific and Industrial Research, Ministry of Science and Technology. During the past six decade of its existence and in pursuance of its corporate goals.NRDC has forged strong links with the scientific and industrial community in India and abroad and developed a wide network of research institutions, academia and industry and made formal arrangements with them for the commercialization of know-how developed in their laboratories and is now recognized as a large repository of wide range of technologies spread over almost all areas of industries, viz. Agriculture and Agro-processing, Chemicals including Pesticides, Drugs and Pharmaceuticals, Bio Technology, Metallurgy, Electronics and Instrumentation, Building Materials, Mechanical, Electrical and Electronics etc. It has licensed the indigenous technology to more than 4800 entrepreneurs and helped to establish a large number of small and medium scale industries.

D. Technology Information, Forecasting and Assessment Council (TIFAC)

TIFAC is an autonomous organization set up in 1988 under the Department of Science and Technology to look ahead in technologies, assess the technology trajectories, and support technology innovation by network actions in select technology areas of national importance. TIFAC continues to strive for technology development of the country by leveraging technology innovation through sustained and concerted programmes in close association with academia and industry.The main objectives of TIFAC include generation of Technology Forecasting/Technology Assessment/ Techno Market Survey documents, developing on-line nationally accessible information system, promotion of technologies and evolving suitable mechanism for testing of technology and enabling technology transfer as well as commercialization.TIFAC embarked upon the "Umbrella Scheme on Technology Vision 2020 Projects in Mission Mode" in the year2000 in which agriculture was taken up as one of the important sectors for commercialization of technologies.

Empowering farmers for validation and promotion of ITK

Indigenous knowledge system has been key to survival strategies for civilizations across the globe. Rural communities used local resources for meeting the demands of food, feed, fuel and fiber. The local wisdom and skill did play a crucial role in decision-making and efficient farm management by the farmers but in the process of modernization they began to lose their significance. However, attainment of plateau in productivity as well as unsustainability and deleterious consequences of frontier technologies have necessitated rigorous search for appropriate, sustainable, eco-friendly and resource conserving technologies. In this endeavor, indigenous technical knowledge with sound sustainability and ecological principles, time tested merits and proven rationality has become an important subject of deliberation and investigation among the researchers and academicians in the recent past. The time-tested principles and practices of indigenous technical knowledge (ITK) have amply demonstrated that much of the problems related to natural resource management and ecology degrading agricultural practices could be effectively managed by their utilization either in their present form or improvisation and even blending with modern technology.

Indian agricultural research perspective began with study of traditional veterinary medicines used by nomads in Himalayan ranges during mid-sixties. Later studies conducted on documentation of traditional knowledge and technologies, testing of their scientific rationality, their validation and comparative analysis with modern technologies were galore. However, all these studies and projects in this area remained focused upon the indigenous technology per se, while the critical issues related to revival and rejuvenation of indigenous technical knowledge base like experimentation and adaptation capability of farmers, their capacity building for understanding and laying hands upon experimentation and grassroots innovations, augmentation of participatory research process, etc are yet to get adequate attention in technology development and dissemination system.

To provide continuity to grassroots experimentation and evolution of indigenous technologies it is imperative to transfer science among the farmers and also develop their experimentation capabilities. Endeavour in this direction was made through farmer participatory validation of indigenous technologies under NATP Mission mode project of ICAR on documentation and validation of indigenous technology.

Identification of ITK's being used by the Farmers

Farmers are with vast collection of knowledge, practices and traditional way of doing things. Identification of the ITKs and practices is the basic step in the up scaling and out scaling of the location specific ITKs. Famers and old people in the village are with good knowledge about the various herbs and plants and its parts which are suitable for curing of many human and animal diseases and controlling of plant pests and pathogens. Many of the medicines identified for the human and animal diseases are rooted from the knowledge of the villagers regarding use of plants and its parts. Survey methods, case studies, focus group discussion with the farmers, agro-ecosystem analysis, linguistic and historic analysis of concepts, vocabulary and key words, conducting documentation workshops, critical incident analysis and old repository or books are the sources for collecting the ITKs by the extension persons. Grass root level organizations, KVKs and field level extension workers with bottom level contacts are able to collect the ITKs from the farmers.

Validating the ITKs identified from the Farmers

Most important and simplest form of validation of the ITKs is compare the result of the identified ITKs integrated with the technologies and with the results of the non-use of the technologies. On station testing and on farm trails can be used to determine the validity of identified technologies alone and integrated with the modern technologies. Validation should be in accordance with the value system and beliefs of the villagers or farmers which sometimes form the basis of that ITK use in particular situation or location. During the process of interactive ITK validation and technology development, scientists at the research station should conduct research by building on recorded IK systems.During the validation it is necessary to understand the rationale behind farmer knowledge and practice system. Beside this recording of the all observations and identifying farmers' evaluation criteria are essential for proper validation of ITKs.

Documentation of validated ITK's

Documentation helps in the wider spared of the identified and validated indigenous knowledge from the farmers. Documentation also helps to the researchers to refer many of the knowledge for future uses. The contribution of community as well as individual is very vital for maintaining the traditional knowledge and skill generation after generation and these must be recognized in a formal way(Anil Gupta, 2009). Category wise documentation and collection ofITKs with due acknowledgement to the persons or locality where it developed are important for the future reference.

Upscaling and Outscaling of ITKs

An important thing relating to ITK is the need to add value to this knowledge by converting it into economically profitable investments or enterprises to use in an effective way by people in all over the world. For this integration of the ITKs with the modern knowledge and multiplication trails to test the upgradation are the two important components. Many of the local communities or tribal groups or persons, however, do not have the capacity for adding value to identified ITKs. Institutional support is needed for locating, sustaining, and scaling up these ITKs, and to enhance the technical competence and self-reliance of these identified knowledge.

CONCLUSION

ITKs are evolving under specific agro-climatic and socio-economic conditions and such traditional knowledge should be widely preserved and sustained. It is highly essential to document traditional knowledge and disseminate them further by various organizations. Involvement of Research Institutions is quite critical to understand and blend the traditional knowledge with scientific refinements for their large scale adoption and popularization.

Since, information on ITK are seldom documented, it often happens that such

SOME POPULAR INDIGENOUS TECHNICAL KNOWLEDGE IDENTIFIED FOR RAIN WATER MANAGEMENT, SOIL AND WATER CONSERVATION AND SOIL EROSION	
A. Rain water Management	
• Moisture conservation through mulching	• Farm pond for water harvesting
• Sand mulching for improving soil properties	• Technique of rain water harvesting and conservation
• Indigenous water-storage structures	• Water harvesting with hand pump
• Rain water harvesting in the fields by making *khadins*	• Rain water management through construction of tank and auger
• Storage of water in pond	• Rain water management for teak, mango and neem in arid and semi-arid regions
• Man-made tunnel for water harvesting	• Rain water conservation in*pakhar*
• Technique of water harvesting	• Rain water harvesting from roof
• Technique of rain water harvesting	• Harvesting of water from melting snow
• Storage of rain water in tanks locally known as *talabs*	• Harvesting of dew and fog water for farming
• Indigenous technology for water storage using wooden logs	• Flooding of agricultural fields with glacial water for higher crop productivity
• Harvesting of spring water in small ponds for irrigation and domestic use	• Utilization of uphill water in Himalayan region
• Rain water management rain water measurement using role (Indigenous rain gauge)	• Management by the practice of *kuhls* (canals)
• Use of white soil (suddamannu) as tank sealant / lining material	• Rain water management by flooding the field with rain water
• Bamboo drip irrigation system in hills	• Dry sowing of paddy
• Rainfed indigenous crops	• *Matka* method for irrigation in dryland area for fruit crops
• Water-diversion channels to check waterlogging	• Technique to recharge ground water
• Use of drip-irrigation method for irrigation	• Water storage for domestic irrigation purposes
• Construction of *kuhls* or water channels for irrigation	• Indigenous natural resource management in Shiwaliks
• Water management for farming	• Collection of water by making channel
• Indigenous method of rain-water harvesting	• Bandh made of bud and stone
• *Chari*-a small ponds for rain-water storage	• Water lifting using lat
• *Bada bandh yojana* for rain water harvesting	• Rain water harvesting and moisture conservation by *mehandi* (Lawsonia alba) through tillage practices
• *Pukur* (Pond) *khanan* for rain-water harvesting	• Summer ploughing for moisture conservation
• Construction of *naada* for silt harvesting	• Harrowing for soil and moisture conservation
• Splashing of water to arecanut trees	• Tillage across the slopes to reduce runoff
• Submergence bundh for run off harvesting	• Traditional tillage practices for in-situ moisture conservation
• A run off farming by *Khadin* practice	• Vegetative barriers for soil and water conservation
• Ad-Bandh for rain water harvesting	• Application of groundnut shell to conserve moisture
• Khatri: A water harvesting structure	• Use of finger millet husk as mulch
• *Rela* farming, a traditional irrigational irrigation system	• Pebble mulching to control runoff
• Hill-side conduit system to channelize runoff water	• Use of dry leaves for mulching in cardamom
• *Tobas*: water harvesting for grazing land	• Use of tree needles and grasses for mulching for conservation of soil moisture
• Conservation ditches	• Zabo system of rice cultivation
• Traditional earthen bunding	• Planting of banana to protect young coconut plant from wind erosion
• Using *murram* for soil and water conservation	• Intercropping as vegetative barrier
• Stone waste weir for safe disposal of surplus water	• Curved land plughing for soil conservation and water retention
• Strengthening of bunds by growing crops	• Set tow planting for better plant growth
• Cover cropping to control soil loss	• Use of Pang (Spang) grass for controlling seepage and side losses in water tanks and irrigation *Kuhls*
• Intercropping of maize and groundnut for rain water conservation	• Pitcher irrigation for establishment of seelings

• Ownership of plots in different pockets for risk distribution	• *Nadi* (village pond) for water harvesting
• *Kuhl* water for running water mills	• Indications of irrigation requirement
• Irrigation method for use of Khul water	• Moisture measurement with *Belcha* (spade)
• Conservation of *Kuhls* (water channels) for irrigation	• Methods of in situ moisture conservation and run-off management
• Dividing the fields into sub-plots for irrigation water management	• Vetiver grass for controlling soil erosion
• Conservation of rain water in small ponds	• Checking of soil erosion by growing trees along the fields
• Use of surface-bed irrigation system to supplement rainfall	• Soil and water conservation by plantation
• Control of soil erosion due to wind	
B. Soil and Water Conservation	
• Traditional system for controlling soil erosion in *jhum* field	• Aal bandha or *bandh deoya* (field bunding)
• Basin preparation	• Bench terracing on steep hill slopes
• A furrow at the top of the field to check land-slide	• Use of logs, bamboo and stones for control of soil and water erosion in the hilly *jhum* cultivation
• Control measures to prevent soil and water erosion	• Construction of pits (Mizo method) on the hill side slopes to check soil and water erosion
• Check-dam and *pakhar* to check soil erosion	• Terrace-riser slicing to check land slide
• Use of forest black soil for enhancing crop productivity	• Use of natural gradients for irrigation
• Stirring and planking of fields fallow in *kharief* with effective shower/rain	• Terracing: an ethno-engineering technique for soil and water conservation
• Rain water management by tillage operation before starting of rainy season	• Terracing with materials such as stones, soils etc. to check soil erosion
• Check the soil erosion by using stone/rock	• Traditional stone wall to check soil erosion
• To prevent soil erosion through plantation of desi *baboo*l and *siris* on the redges of rice fields	• Conservation technique in cultivation of apple in Himalayan region
• To check soil and water erosion	• Stone wall for controlling soil erosion
• To control different types of soil erosion such as splash, sheet, rill and gullies	• Soil and water conservation
• Cross-ploughing with frequent harrowing to check soil and water erosion	• Control of soil and water erosion
• Mixed pulses as vegetative barrier	• Checking soil and water erosion by crop residues
• Checking of soil and water erosion using bamboo structure	• Preparation of bunds in rice field
• Traditional system for controlling soil erosion in *jhum* field	• Aal bandha or *bandh deoya* (field bunding)
• Method to check soil and water erosion	• Use of grasses on field bunds
• Use of Indigenous material	• Soil mulching for conservation of moisture in soil
• Checking erosion	• Mulching of sugarcane crop with its trash
• Contour system of cultivation	• Reservoir prepared by soil, branches, leaves and straw
• Cedrusdeodara leaves to check soil erosion	• Methods of water harvesting
• To check soil and water erosion by planting *rees* along the fields	• Stone terracing for soil and water conservation
• Checking soil and water erosion through *sisam* (Dalbergiasisso) and *semal* (Salmaliaceiba) plantation	• Vertical mulching to control soil and water erosion
• Cover cropping for soil and water conservation	• Planting of cashew on hill slopes to conserve soil and water
• Use of kaki*veduru* and *dharba* for checking soil erosion	• Planting of pineapple to check soil and water erosion
• Soil-conservation practices	• Soil conservation through combination of sarpat grass (Saccharumatoudinceum) and acacia *indica L.*
• Indigenous method of soil and water conservation	• Soil conservation by planting banana
• Indigenous methods of soil and water conservation under rainfed agro-ecosystem	• Stabilization of sand dunes and checking of soil erosion by using kairas a live fence

C. Soil and Water Conservation	
• Bench terracing for rain water management	• Sand bags for fully check
• Grassed water ways to avoid water logging in terrace farming	• Method for control of gully erosion
• Interplot stone bunding for soil conservation	• Palm leaf for removing salinity
• Vegetative barriers for control of sheet erosion	• Loose boulders for soil and water conservation
• Ash for softening of hard soils	• Sand bags for fully check

information are lost, if not passed on from generation to generation or protected and practiced by the local people. Hence, in today's concept of IPR regime, it is all the more imperative to document and protect our valuable ITK for posterity. In the context of agricultural sustainability, ITK is also required to be properly documented for the benefit of researchers, planners and development officials Validation of ITK is a logical step to qualify and quantity effectiveness of the practices. Suitable modifications of the local practices, through research and development will help to develop appropriate and acceptable technologies that are more suited to our farming situations. ITK which is treasure of our agriculture, without this agriculture cannot sustain and will not fulfill the requirement of future.

REFERENCES

Behera, P.C. 2012. Situating Indigenous Knowledge: Policy and Practice of Education in India. Paper for the 'Regional Seminars on Philosophy of Education', Jaipur: Aug 30-3.

Das, P., Das, S. K., Arya, H. P.S., Singh, R. P., Mishra, A., Bujarbaruah, K. M., Bujarbaruah, G., Subba Reddy, L. R.,Verma, M., Rani, G., Gupta, H. S., Satapathy, C. and Kavia, Z. D. 2003. Inventory ofITK in agriculture. NATP Mission mode project on collection, documentation and 110 validation of Indigenous technical knowledge. Agricultural Research, Document 2, p. 2.

ICSU. 2002. Science and Traditional Knowledge: Report from the ICSU Study Group on Science andTraditional Knowledge. International Council for Science.

Inventory of Indigenous Technical Knowledge in Agriculture, Mission Mode Project on Collection, Documentation and Validation of Indigenous Technical Knowledge, Document 1 (2002), Indian Council of Agricultural Research, New Delhi, June 2002.

Inventory of Indigenous Technical Knowledge in Agriculture, Mission Mode Project on Collection, Documentation and Validation of Indigenous Technical Knowledge, Document 2 (2003), Indian Council of Agricultural Research, New Delhi, March 2003.

Inventory of Indigenous Technical Knowledge in Agriculture, Mission Mode Project on Collection, Documentation and Validation of Indigenous Technical Knowledge, Document 2 (Supplement 1) (2003), Indian Council of Agricultural Research, New Delhi, July 2003.

Inventory of Indigenous Technical Knowledge in Agriculture, Document 2 (Supplement 2) (2004), Indian Council of Agricultural Research, New Delhi, December 2004.

Cross-sectoral Validation of Indigenous Technical Knowledge in Agriculture, Document 4 (2004), Indian Council of Agricultural Research, New Delhi, December 2004.

Swathi L. and DineshBabu, P. S. 2009. Indigenous technical knowledge and ancient proverbs of the coastal fisher folk of Kerala and their implications. *Indian J. Traditional Knowl*. **8**(2): 296 297.

UNESCO. 2012. Report on Local and Indigenous Knowledge Systems (LINKS). Available at http:// portal. unesco.org/

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Short Communication

Impact of small ditches (Dhobha) in rainfed areas in Dumka district of Santhal Pargana, Jharkhand-A case study

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ABSTRACT

In Santhal Pargana, Jharkhand, most of the farmers are not able to meet sufficient food for their families due to lack of awareness and modern technologies. Although there is sufficient rainfall and the area has rich natural resources. With an objective to make the water available, as water conserving structures like small ditches was introduced and impact was analyzed. From the study it was found that the small ditches in the medium and low land was most successful with 1000 ft m^{-3} storing water. Area irrigated was also enhanced in villages of Dumka District, Jharkhand. Area irrigated increased about 618.86% and 421.89%, respectively in rabi and kharif season. In all selected village of project area of Dumka district of Jharkhand the area irrigated increased from 0.53 ha to 3.28 ha in rabi season and from 1.07 ha to 4.51 ha in kharif season. Small ditches were used for vegetable cultivation in winter and summer seasons. It was noticed that ditches were more useful in the low land than medium and upland ecology.

Key words: rainfed, ditches, rainwater, harvesting, vegetable cultivation

INTRODUCTION

With rapid population growth and rising expectation for better life, the natural resources of our globe are facing increasing pressure. It is of paramount importance that the basic resources for human survival *viz*. air, land and water must be properly managed. Water resources have profound impact on society with regard to quality of life, calls for judicious management. In the 21st century, one of the most critical challenges is the resolution of the water crisis (Chennamanent, 1998). Inspite of massive water development efforts for the food security, the poor are most affected due to lack of knowledge and their inability to obtain and maintain the reliable and safe water. In order to find solutions to the water problems, there is need to get to the grass-root level for better understanding of how to use the water for food in the efficient way. Out of 10.13 million working population, 76.86 percent are engaged in agriculture. Vast working force and natural resources are able to produce food grain to meet only 50% requirement. Santhal pargana of Jharkhand have typical rain fed agriculture (89% area rain fed) vast stretch of barren cultivable waste land (46%), inhabited mostly by tribal population. Studies by Chauhan *et al.* (2009) showed the impact of farmers participation in the development of watershed. There is a good average rain fall i.e. 1200 mm but still water is the major constraint in agriculture along with soil erosion. People have to migrate for work as laborers for their livelihood. It is reported and revealed the importance of small water holding structure for mitigate the effect of drought (Aziz, 1998).It has been felt that if rain water (1200 mm /annum) is tapped properly, it may improve the irrigation facilities and make it possible to grow a second crop in rice fellow areas. The need of participatory integrated watershed structure is play important role for techno-socioeconomic feasibility of promising strategies for crop intensification and reduction of soil degradation, and to learn lessons on the benefits of scaling-up and scaling-out of watershed-based integrated genetic and natural resource management (IGNRM) as cost effective natural resource management (Wani *et al.*, 2003). Government has invested heavily on measures of soil and water conservation structure on watershed basis but due to lack of knowledge and interest among the farmers these structures are kept unused or dead (Desai *et al.*, 1997). Complementarily

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between conservation and productivity objectives makes watershed development attractive in semi-arid areas (Kerr, 2002). Many structures are not successful because they are not sufficiently rooted in the priorities and perception of local farmers. Indigenous soil and water conservation structures specific to location made from available resources in the surrounding will be more successful in rainwater harvesting (Singh, 2000). Harvested rainwater on watershed basis enhances the crop yield as well as farm income in rainfed regions when the water was used for supplemental irrigation (Gupta *et al*., 2009; Sharma and Sharma, 2015). Thus, keeping this in view an attempt has been made by NAIP project to overcome the water scarcity through cheap and indigenous structures viz. small ditches called *"dhobha"* so that it can easily be adopted and maintained by the farmers of Mayurakshi watershed in Santhal Pargana.

Study area

To carry out the study, two blocks Dumka and Jama of Dumka district of Santhal Pargana was selected as shown in Fig 1. Out of 10 villages 7 villages were considered (Table 1) to carry out the analyses, which are falling under the Mayurakshi watershed area. The farmers in these regions are generally poor and living their life in below poverty. They are mostly landless and marginal farmers. Four villages are under Dumka block about 5-8 km from Dumka town and the rest 3 villages are under Jama block which is 13 km away from the town. The preliminary observation showed that the villages selected for the study falls under two distinct ecologies. The villages in the Jama block of Dumka district are dominated by forest ecology while in Dumka block have open and forest ecology. The major crop grown in these regions is rice in kharif season and major portion of land are left fallow during Rabi and summer seasons. Other crops grown are wheat and boro rice in pockets and vegetables in kitchen garden where water is available for irrigation. The average rainfall is 1281 mm with about 61 rain days.

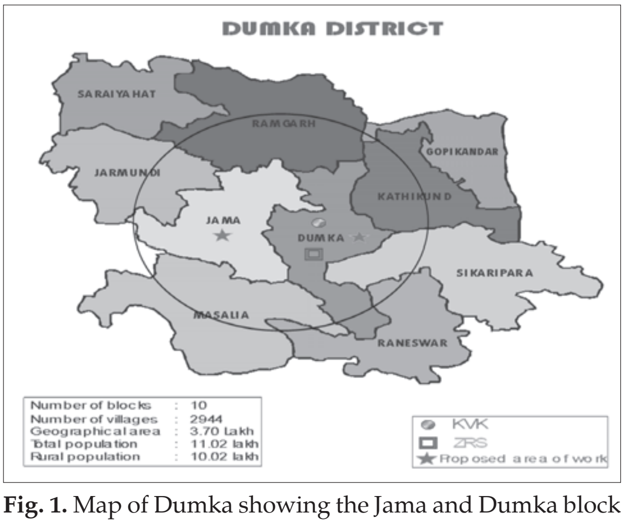

Fig. 1. Map of Dumka showing the Jama and Dumka block

Source of data

The primary data regarding the *dhobhas* were collected from the farmers who irrigated their bari or land for cultivation. Each village is having about 10 *dhobhas* but the data from the Andipur was not available and is not incorporated in the study. There are no dhobhas in the village Ganjanda. Total number of *dhobhas* was classified according to their location *viz*. up-land (UL), mid-land (ML) and low land (LL). The size of each *dhobhas* is 10′x10′x10′ comprising volume of 1000 ft^3 with vertical wall. There was no side slope. The data collected was compared to show the impact of *dhobhas* in respect to change in the irrigated land after introduction of *dhobhas* through NAIP projects.

The analysis of the data showed that the *dhobhas* had positive effect on the farmers as they were able to irrigate more area with these water structures. The study showed that the dhobhas were constructed in the low-land was more successful. As shown in the Fig. 2, it is observed that water stored in dhobhas in the low-land area are for almost 11 to 12 months in a year but those constructed in up-lands are found to be less

Table 1. Study areas villages in Dumka district under NAIP project

S.No.	Name of Village	District	Block	To number of household	Total land (ha)
1.	Karmatarn	Dumka	Dumka	91	40.356
2.	Kodokicha-6	Dumka	Dumka	48	32.352
3.	Kodokicha-7	Dumka	Dumka	68	87.396
4.	Guhiajori	Dumka	Dumka	152	129.920
5.	Karela	Dumka	Jama	130	76.009
6.	Bhourna	Dumka	Jama	55	61.636
7.	Ragat	Dumka	Jama	71	118.272

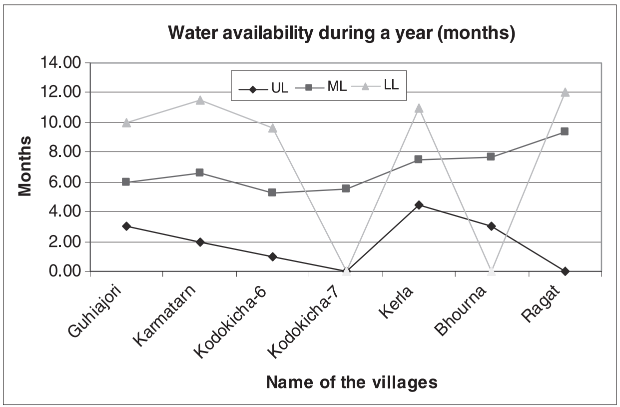

Fig. 2. Average availability of water in small ditches (dhobha)

effective as water is lost due to high percolation and seepage in upland soil. The water stored in the structure in up-land were in the range of on average 2-3 months while in the case of the dhobhas in the mid-land also proved to be boon to the farmers as they were able to irrigate the up-land as well as their mid-land. The water conserved was also fairly good i.e. in the range of 6-8 months. There are no small ditches (dhobhas) in low-land in villages Kodokichcha-7 and Bhourna. Some of them were destroyed, as in case of Ragat and Bhounra, due to landslide. Keeping in the view the interest of the farmers, the small ditches (dhobhas) were constructed in those lands that were in general left as fallow land due to shortage of water. This has helped them to enhance the cropping intensity as well as they were able to irrigate more areas. The land and water productivity was also reported to be enhanced in rainfed areas where rainwater was harvested and utilized for irrigating crops (Hadda and Arora, 2010).

Apart from that, the farmers now need not have to depend upon the monsoon for pre irrigation seedling in nursery for paddy. Now they can grow seedling in nursery on time and go for transplanting as soon as monsoon arrives without any time loss. The comparative analysis shows that area irrigated after introduction of the small ditches (dhobhas) were more as compared to earlier times when there were no such water conserving structures. The farmers are now able to cultivate even those lands that were left fallow due to non-availability of water. With the help of the tins or buckets the farmers irrigated even the uplands. In the village Karela, farmers found these structures to be more fruitful as due to small ditches (dhobhas) the area irrigated has increased manifold. After introduction of the small ditches (dhobhas) the farmers of village Karela could irrigate about 1.73 ha and 1.82 ha of more land respectively in rabi and kharif season. In the village Guhiajori the irrigated area increased to 0.4 ha from 0.048 ha in rabi season and to 0.88 ha from 0.19 ha in kharif season. Similarly we noted the similar results in all other villages as shown in the Table 2.

CONCLUSION

The small ditches (dhobhas) constructed found to be very fruitful for the farmers. Though these structures are unlined and cheap and require no technology, farmers can also make them of their own and sustain this technology in future. The dhobhas in the low-land were most successful as water availability was for almost throughout the year i.e. 11-12 months in a year, while dhobhas in upland were unsuccessful as water availability was only for 2-3 months i.e. they got dried soon after rainy season. Use of these water conserving structures has help the farmers to irrigate more land as 0.2 ha area covered and enhance the cultivated area 618.86 % in rabi season and 421.49 % in kharif season crops. It was most suitable in rabi season. Now the farmers can take more crops in year not only to meet demands of their family but they can also earn after selling the products.

Table 2. Impact of small ditches (dobha) for irrigation and increase the area (in ha)

Village	Area (in ha) Rabi			Area (in ha) Kharif		
	After	Before	Average area Increase %	After	Before	Average area Increase %
Guhiyajori	0.40	0.04	618.86	0.88	0.19	421.49
Karmatarn	0.17	0.00		0.19	0.00	
Kodokicha-6	0.16	0.00		0.12	0.00	
Kodokicha-7	0.08	0.00		0.24	0.00	
Karela	1.85	0.12		2.06	0.24	
Bhourna	0.14	0.01		0.30	0.08	
Ragat	0.48	0.36		0.72	0.56	
total	3.28	0.53		4.51	1.07	

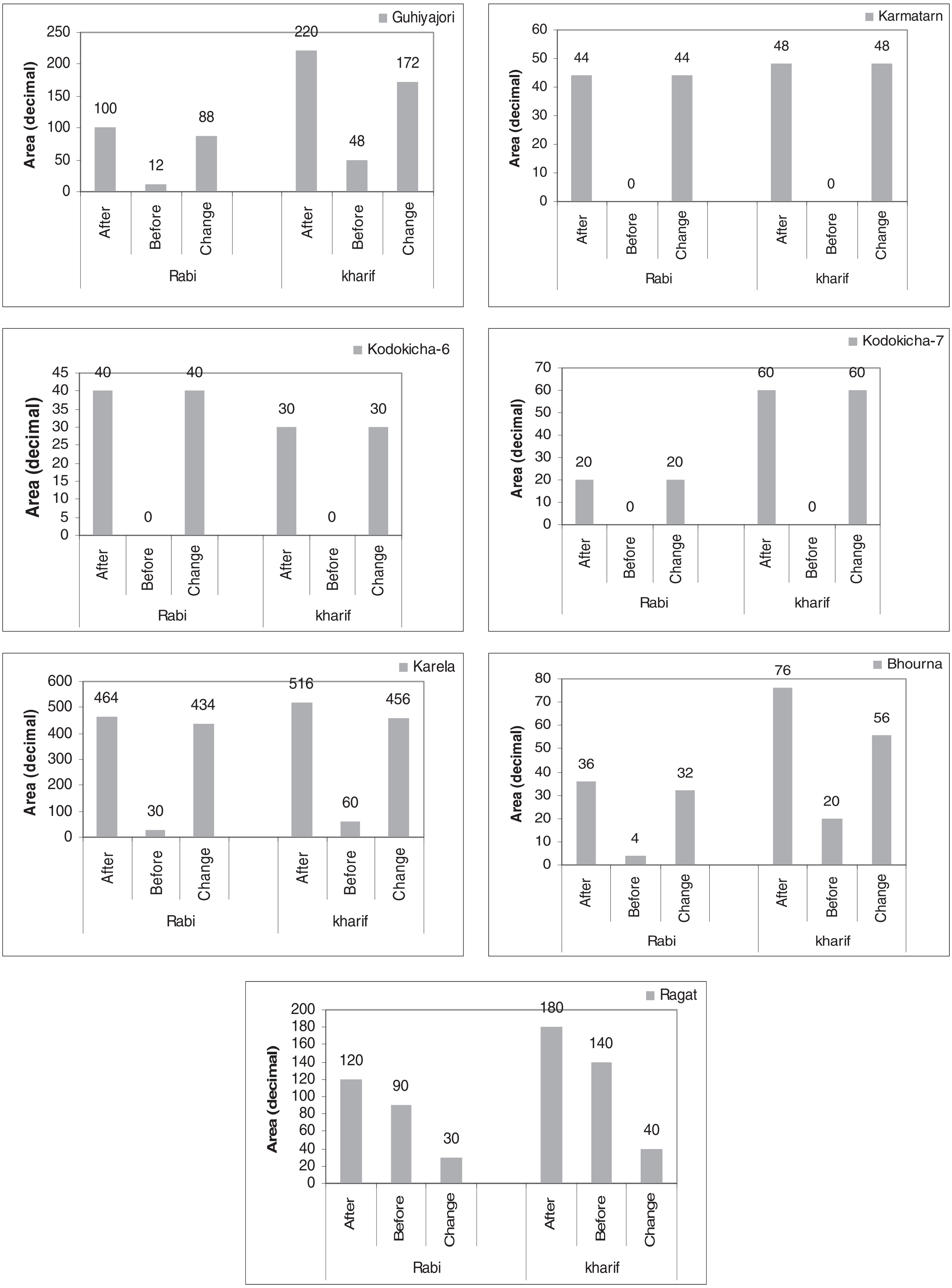

Fig. 3. Showing change in irrigated area after introduction of *dhobhas*

REFERENCES

Aziz, Abdul. E. 1998. *Adoption of Drought Management Practice by Framers-A Critical Analysis,* M.Sc. (Ag), Thesis (Unpub.), KAU, Vellanikkara.

Chauhan, J., Singh, A.K., Sharma, R. and Meena, B.S. 2009. Implications of Watersheds in Bringing Change in the Cropping System and its Productivity. *Indian Res. J. Ext. Edu.* **9(1):** 14-16

Chennamanent, R. 1998. Watershed management and sustainable land use in semi-arid tropics of India. *Advances in Geo-ecology* **31:** 1125-1134.

Desai, R.B., Girase, K.A. and Kokate, K. D. 1997. Assessment of micro-watershed development project on land use and cropping pattern in scarcity zone. *Maharashtra J. of Ext. Edu*. **XVI:** 162-166.

Final Report (2007-14) Developing Sustainable Farming System Models for Prioritized Micro watershed in Rainfed areas in Jharkhand, BAU, Ranchi, NAIP, Component -3

Gupta, R.D., Arora, Sanjay and Sharma, V. 2009. Rainfed agricultural production through watershed management: Success in Jammu region. *Journal of Soil and Water Conservation* **8**(1): 19-24.

Hadda, M.S. and Arora, Sanjay 2010. Water productivity through rainwater harvesting and land treatment in rainfed sub-montane region. *Journal of Soil and Water Conservation* **9**(2): 109-113.

Kerr, John 2002. Watershed development, environmental services, and poverty alleviation in India. *World Development* **30**(8): 1387–1400.

Rao, C. H. Hanumantha. 2000 Watershed Development in India: Recent experience and emerging Issues .*Economic and Political Weekly* **35**(45):3943-3947.

Sharma, K.R. and Sharma, V. 2015. Supplemental irrigation from harvested rainwater to enhance yield and economic returns from wheat in sub-montane region of Jammu, India. *Journal of Soil and Water Conservation* **14**(3): 219-226.

Singh, P.K. 2000. Indigenous Soil and Water Conservation Measures. *Watershed Management (Design and Practices).* **9:** 121-125.

Wani, S. P. Singh, H. P., Sreedevi, T. K., Pathak, P., Rego, T. J., Shiferaw, B. and Iyer, S. R. 2003. Farmer-participatory integrated watershed management: Adarsha watershed, Kothapally India - An innovative and upscalable approach. *EJournal of SAT Agricultural Research* **2**(1):1-26.

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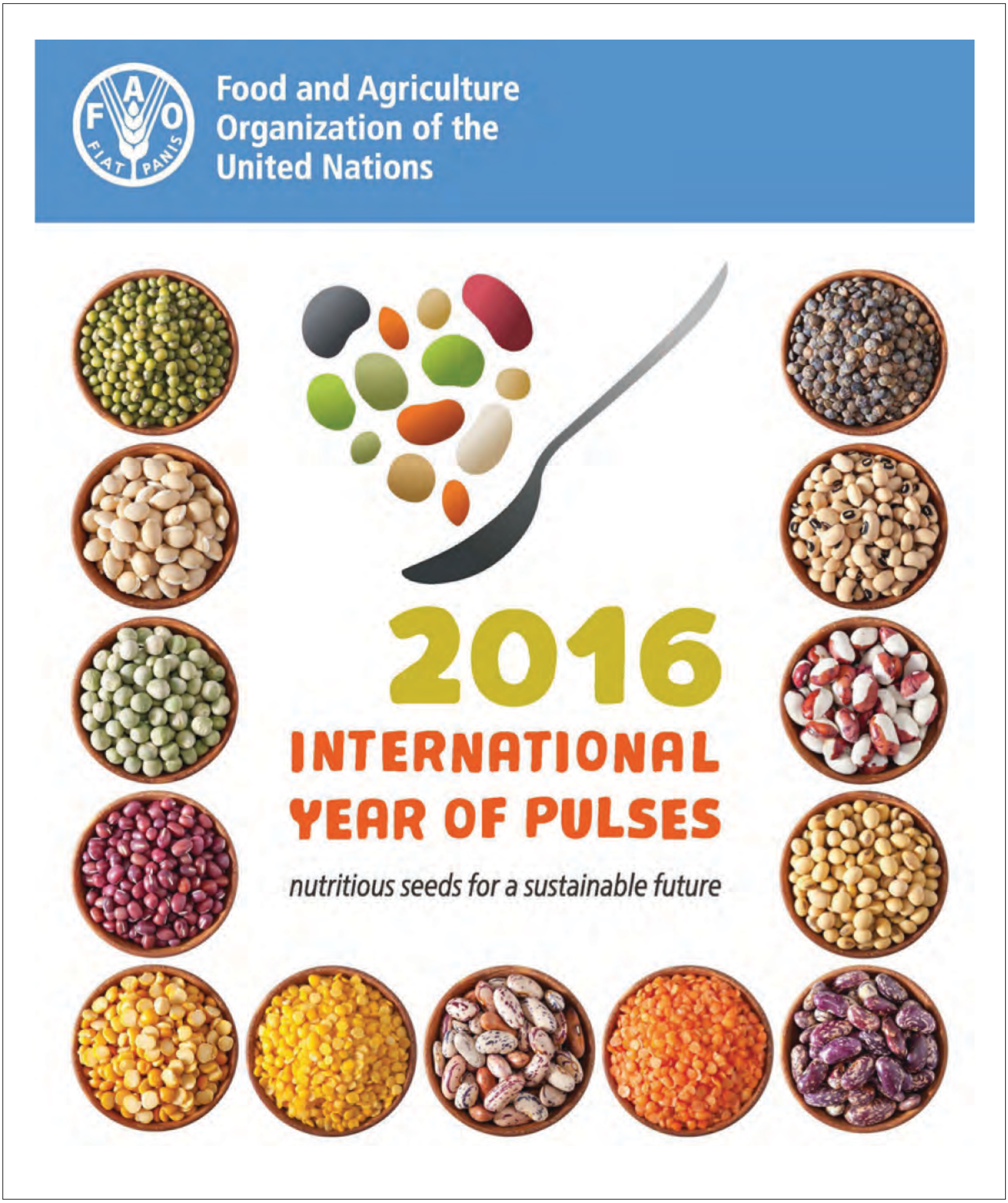

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