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Soil bin studies on the selection of furrow opener for conservation agriculture

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ABSTRACT

Conservation agriculture is a set of soil management practices include conservation tillage, residue management and crop rotation. Conservation tillage deals with tillage practices that retain at least thirty per cent of previous crop residues. Present study is aimed to assess the effect of furrow openers and their forward speed on soil physical properties, soil disturbance and maize stalk residue cutting under soil bin condition. Four types of furrow openers were tested *viz.*, Inverted T-type furrow opener with plain rolling coulter, single disk furrow opener, double disk furrow opener and double disk furrow opener with plain rolling coulter operated at three forward speeds (1.5 km h^{-1}, 2 km h^{-1} and 2.5 km h^{-1}). Results showed that forward speed was inversely proportional to soil moisture retention, soil bulk density and soil penetration resistance. It was also observed that double disk furrow opener with plain rolling coulter resulted in maximum soil moisture retention (11.2%), higher bulk density (11.2 gm cc^{-1}), higher penetration resistance (1.37 MPa), minimum soil disturbance profile at forward speed of 1.5 km h^{-1}. The maize stalk residue cutting was effective at all forward speeds with double disk furrow opener with plain rolling coulter. Hence, the double disk furrow opener with plain rolling coulter was best suited for conservation agriculture.

Key words: Conservation agriculture, Conservation tillage, Soil physical properties, Soil disturbance profile, Coulter, Residue management

INTRODUCTION

Conservation agriculture management practices minimize disruption of soil structure and improves natural biodiversity. The basic principles of conservation agriculture are conservation tillage, residue retention and crop rotation. Conservation tillage is defined as tillage and planting system that retains at least 30% of cover crop residues of previous crop on the soil (McCarthy *et al.*, 1999). Conservation tillage system reduces erosion and labor requirement, improves soil environment for crop growth and conserves energy.

Conservation tillage has advantages along with associated risk of poor stand establishment and therefore limits its adoption by farmers. In conservation tillage, furrow characteristics influence the germination and emergence of crop in different soil conditions. Some of these characteristics are compaction of soil in the furrow, draft power requirement, operational speed and planting depth. Furrow opener is the only component of any seed drill which opens soil for seed bed preparation and sowing. Furrow opener opens slit in the soil and seeds and fertilizer are dropped in it. If furrow opener widens the slit, soil disturbance increases. Furrow opener selection depends on soil and operating conditions. Furrow openers used in conservation tillage are different than conventional tillage. In order to assess the performance of furrow opener, it is important to identify the factors which affect soil physical properties and germination of seed. Therefore, designing of furrow opener depends on many factors like type of soil, speed of operation and depth of operation. Numbers of experiments had been carried out to optimize rake angle of furrow openers (Siemens *et al.*, 1965). Johnson and Buchele (1961) studied the effect of varying soil granule and degree of compaction on soil moisture loss and plant emergence in sandy soil. A soil granule of 0.18 mm at top layer showed better moisture retention capacity as compared to 0.76 mm soil granule. Bateman (1963) studied the effects of soil compaction on soil properties and it was found that clay soil was susceptible to compaction which caused high mechanical impedance in crop establishment.

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Furrow opener can be evaluated in lab conditions to assess depth of sowing and soil disturbance profile and seed germination and crop yield and can be evaluated in the field. Researchers have studied different furrow openers and their effect on soil moisture and seed germination. Baker (1976) studied the performance of furrow openers including disc, chisel and hoe types in the lab. It was observed that germination was significantly higher with chisel (77%) than hoe (26%) and disc (27%). It was mainly due to more soil moisture retention achieved in chisel than hoe and disc furrow openers. Wilkins *et al*. (1983), evaluated single disc, double disc, hoe type and deep opener and it was observed that moisture retention was higher for hoe and deep furrow openers. Freebairn *et al*. (1986), studied 64 different openers in heavy soil texture and it was observed that coulter (50 mm diameter) with spear point furrow opener followed by a rubber press wheel was the most promising arrangement. Choudhary *et al*. (1988), introduced an inverted-T opener and observed that germination percentage was more compared to other furrow openers. According to Raoufat and Mahmoodieh (2005), planters equipped with rolling coulter attachment improves seeding indices in conservation tillage systems. They observed that plain rolling coulter had better performance as compared to notched ones specially for planting corn in irrigated wheat residues. Karll *et al*. (1978), reported that plain and rippled coulters cut the maize trash more clearly as compared to notched ones. Keeping in view the above studies and their outcomes, present study was undertaken to assess the effect of furrow opener and their forward speed on soil physical properties, soil disturbance profile and residue cutting.

MATERIALS AND METHODS

Experiments were conducted in the soil bin at Division of Agricultural Engineering, IARI, New Delhi, India during Jan-March 2014. The dimensions of soil bin was 25 m long, 1.8 m wide with one metre deep, filled with loamy clay soil (sand 80%, clay 10% and slit 10%) as shown in Fig. 1. The soil was tilled by tiller to a higher depth than the derived working depth. To maintain uniform soil conditions such as soil moisture, bulk density, cone index, water was sprinkled on the soil and the moisture content was periodically monitored throughout the soil bin until derived moisture was achieved. The seedbed was prepared by levelling and compacting with smooth roller. Before test runs, three random samples were collected for measuring initial soil moisture content and soil bulk density. The soil moisture content was measured by keeping the sample in oven at 105 ^{o}C for 24 h. The tests were performed 96 h after achieving desired soil moisture condition (Abbaspour *et al*., 2009). A cone penetrometer of 28 mm base diameter and 30^{o} cone angle was used to measure the soil resistance. Before starting the test for uniformity of compaction, three observations of soil penetration resistance were taken in the soil bin. The soil-tool trolley was operated for uniform bulk density (1.5 gm/cc) and soil penetration resistance (1.45 MPa). Subsequent changes in soil moisture content, bulk density, penetration resistance and soil disturbance profile were observed after operating four types of furrow openers.

Furrow openers investigated were; inverted T with plain rolling coulter, single disk, double disk and double disk with plain rolling coulter. The degree of disturbance and displacement of soil mainly depends on the rake angle, depth and speed of operation. The design of furrow openers was based on optimum rake angle. Rake angle is angle which a furrow opener makes with horizontal line parallel to the direction of travel (Shiri and Raoufat, 2006). Furrow openers are generally of two types, one with rake angle less than 90^{o} and the other with rake angle greater than 90^{o}. The inverted T-type

Fig.1. Soil bin preparation

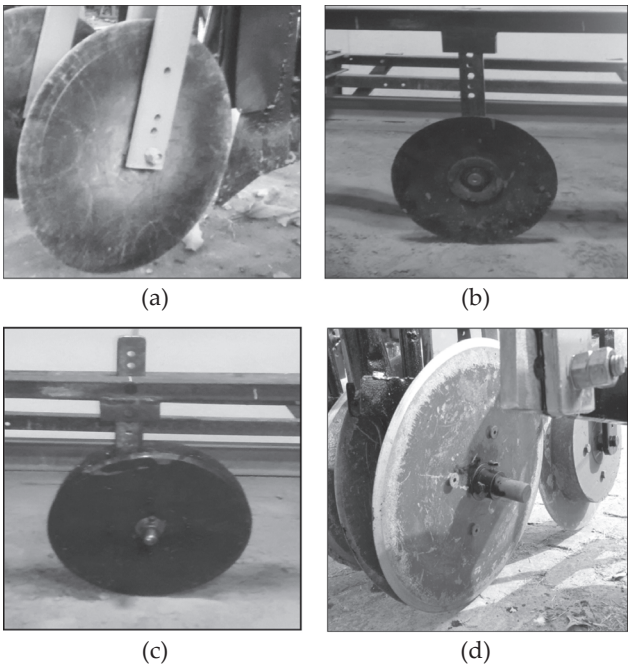


Fig. 2. Different furrow openers used for experimentation. (a) Inverted T-type furrow opener with plain rolling coulter (b) Single disk type furrow opener (c) Double disk type furrow opener (d) Double disk type furrow opener with plain rolling coulter

furrow opener with plain rolling coulter consisted of a single plain rolling coulter (36 cm Õ) followed by inverted T-type furrow opener [Fig. 2 (a)]. The plain rolling coulter cuts residues and makes a fine slit in soil and inverted T-type furrow opener widens the slit by displacing the soil outward. Single disk (Disk angle 30^0) furrow opener consisted of high carbon steel disk of diameter 38 cm and positioned at 10^o of tilt angle in the direction of travel [Fig. 2 (b)]. It had tendency to cut residues with minimum disturbance of soil and form a narrow slit in the soil. Double disk furrow opener consists of two plain rolling disks arranged in such a way that outer edges of the discs cut and displace soil downward and outward which results in 'V' shaped furrow in the soil [Fig. 2 (c)]. Double disk furrow opener with plain rolling coulter consists of a flat vertical disk coulter mounted in front and close to inclined double disc assembly [Fig. 2(d)]. The front mounted coulter assisted in cutting residues and form a vertical slit which tends to give less disturbance and more uniform furrow as well as more control over subsequent soil fracture.

A completely randomized factorial design with four furrow openers and three operating speeds (1.5, 2 and 2.5 km h^{-1}) was performed. The effect of furrow openers and operating speed on soil physical properties, soil disturbance profile and maize stalk residue (5 t/ha) cutting was studied. Each treatment was replicated three times. The selected depth for operation was 5 cm. After each test run the soil surface disturbance profile and cross-sectional area opened by the tool were measured at three random locations. The effect of furrow openers and operating speeds on the soil physical properties and maize stalk residue cutting were assessed by least significant difference method ($p \leq 0.05$).

RESULTS AND DISCUSSIONS

This section focuses on the effect of four furrow opener and forward speed on the soil moisture retention, soil bulk density, soil penetration resistance, soil disturbance profile and maize stalk residue cutting under soil bin condition. Results indicated that the furrow opener had a significant effect on soil moisture retention, soil bulk density, soil penetration resistance and maize stalk residue cutting at the 5% level of significance. Whereas, the forward speed singificently effected soil moisture retention, soil bulk density and soil penetration resistance at the 5% level of significance but it did not effect maize stalk residue cutting significantly.

Soil moisture retention

Furrow opener and forward speed significantly affected the soil moisture retention (Table 1). The initial soil moisture content in the soil bin was 12% which reduced subsequently, after 24 hours of test run. The soil moisture retention was maximum in case of the double disk furrow opener with plain rolling coulter (11.2%), followed by double disk furrow opener (10.61%), single disc furrow opener

Table 1. ANOVA for effect of furrow openers and forward speed on soil moisture retention

Source of Variation	Degree of Freedom	Sum of square	Mean Square	F- Calculated	Significance
Furrow opener (A)	3	11.71	3.903	46,799.13	0.00*
Forward speed (B)	2	4.16	2.081	24,948.67	0.00*
A X B	6	0.49	0.081	972.292	0.00*
Error	24	0.002	$8.3x\ 10^{-5}$		
Total	35	16.36			

*Indicates significance at the 5% probability level.

(10.18%) and inverted T-type furrow opener with pain rolling coulter (9.35%) at 1.5 km h^{-1}. It was observed that the soil moisture retention decreased with increase in furrow openers speed (Fig. 3). This could be due to the fact that with speed, more soil gets disturbed and get exposed to wind. This is also supported by the fact that double disk furrow openers with rake angle more than 90° pushed the soil to the furrow wall making them firm resulted in minimum soil disturbance hence the soil moisture reduction was lowest in case of double disk furrow openers with coulter attachment. Similar reults of double disk openers are reported by Tessier *et al.* (1991).

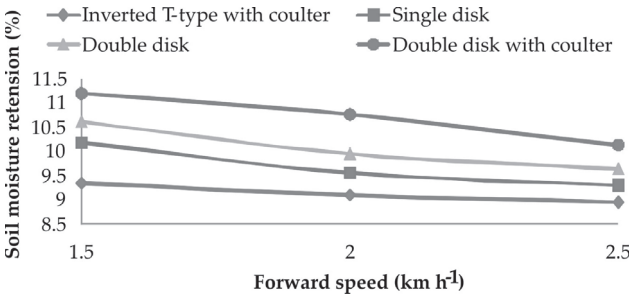


Fig. 3. Effect of furrow openers and forward speeds on soil moisture retention

Soil bulk density

The effect of furrow openers and forward speeds on soil bulk density at 5 cm depth was measured (Fig.4). Because of different soil disturbance with various types of furrow openers the soil bulk density is varied. Results indicated that there was a significant difference in soil bulk density after furrow openers operation at different forward speeds (Table 2). The highest bulk density (1.52 gm cc^{-1}) was observed at speed of 1.5 km h^{-1} in case of double disk furrow opener with pain rolling coulter whereas minimum bulk density (1.28 gm cc^{-1}) was found in Inverted T-type furrow opener with plain rolling coulter at speed of 2.5 km/h. As the forward speed increased the bulk density decreased. This may be due to fact that at higher speeds of operation, tractor's tractive efficiency

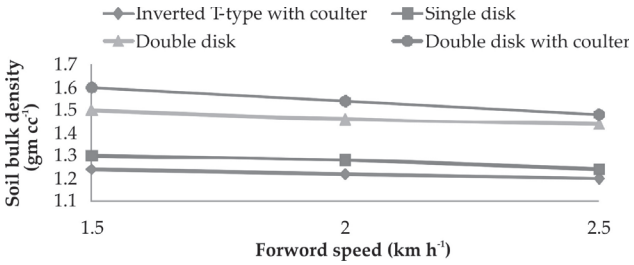


Fig. 4. Effect furrow openers and forward speed on soil bulk density

becomes very low leading to skidding. Similar results were reported by Kasap (2001) who found that bulk density decreased with increase in operating speed in conventional tillage and direct drilling, but there was no statistically significant difference on soil bulk density with operational speed. In contrast to this, Morad *et al*. (2007) reported that the soil bulk density increased with increasing forward speed this could attributed to vibrations of tractor and agricultural machine which increases bulk density.

Soil penetration resistance

Penetration resistance of the soil depends on its physical and mechanical properties, operating conditions (speed and depth) and penetrating tool geometry. Changes in the soil penetration resistance for four types of furrow openers were significant at 1% level of significance (Table 3). The highest soil penetration resistance (1.36 MPa) was observed at 1.5 km/h forward speed for double disk furrow opener with plain rolling coulter followed by double disk furrow opener (1.3 MPa), single disk furrow opener (1.21 MPa) and inverted T-type furrow opener with plain rolling coulter. The forward speed had significant difference with soil penetration resistance and furrow openers. However, the soil penetration resistance decreased with increased forward speed (Fig.4). Minimum soil penetration resistance was the effect of higher forward speed (2.5 km h^{-1}). This may be attributed to the more pulverization that tends to expose soil particles, increases soil void ratio, which in turn

Table 2. ANOVA for the effect of furrow openers and forward speed on soil bulk density

Source of Variation	Degree of Freedom	Sum of square	Mean Squares	F-Calculated	Significance
Furrow opener (A)	3	0.65	0.216	3,111.44	0.00*
Forward speed (B)	2	0.03	0.015	212.683	0.00*
Interaction A X B	6	0.006	0.001	13.321	0.00*
Error	24	0.002	$8.3x10^{-5}$		
Total	35	0.69			

*Indicates significance at the 5% probability level.

Table 3. ANOVA for the effect of furrow openers and forward speed on soil penetration resistance

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F-Calculated	Significance
Furrow opener (A)	3	0.813	0.251	2567.25	0.000*
Forward speed (B)	2	0.105	0.053	498.96	0.000*
Interaction A X B	6	0.014	0.002	22.44	0.000*
Error	24	0.003	$1.25x10^{-4}$		
Total	35	0.935			

*Indicates significance at the 5% probability level.

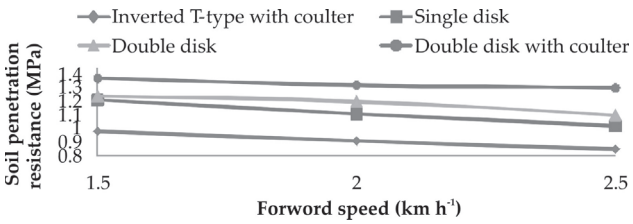


Fig. 5. Effect furrow openers and forward speed on soil penetration resistance

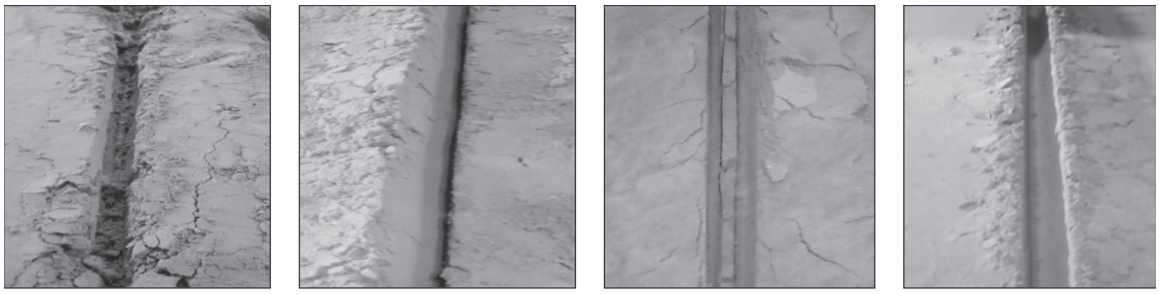
decreases soil penetration resistance. These results generally agree with earlier findings elsewhere under varying soil conditions that soil penetration resistance decreased with increase in speed of operation (Altuntas *et al.,* 2006).

Soil disturbance profile

It was observed that as the forward speed of furrow openers increased, the soil disturbance increased. The slit opened by inverted T-type furrow opener with plain rolling coulter was widest (30 mm) compared to single disk furrow opener (25 mm), double disk furrow opener (20 mm), double disk furrow opener with plain rolling coulter (16 mm) (Fig.5). The soil disturbance profile made by double disk furrow opener and double disk furrow opener with plain rolling coulter attachment was similar with difference of furrow width and slit opening (Fig. 6).

Maize stalk residue cutting

The furrow openers had a significant effect on maize stalk residue cutting. Based on the Duncan's Multiple Range Test, the double disk furrow opener with plain rolling coulter had cut all maize stalk residue at all three forward speeds followed by inverted T-type furrow opener, double disk furrow opener and single disk furrow opener (Table 4). The maize stalk residue cutting performance of the furrow openers with plain rolling coulter works satisfactory compared to furrow openers without coulter. This may due to sharp coulter cutting of residue in front of furrow openers which prevented clogging of loose stalks by fixed tine furrow openers. Similar results were also observed by



(a) (b) (c) (d)

Fig. 6. Soil disturbance profile made by (a) Inverted T-type furrow opener with plain rolling coulter; (b) Single disk furrow opener; (c) Double disk furrow opener; (d) Double disk furrow opener with plain rolling coulter.

Table 4. ANOVA for effect of furrow openers and forward speed on maize stalk residue cutting

Source	Degree of freedom	Sum of square	Mean square	F calculated	Significance
Replication	2	1.055	0.5277	0.07	0.9289
Furrow opener (A)	3	22252.08	7417.36	1039.74	<0.0001*
Forward speed (B)	2	7.055	3.52	0.49	0.6165
Interaction (A) x (B)	6	9.16	1.52	0.921	0.9683
Error	22	156.94	7.13		
Total	35	22426.3			

R^2= 0.99; CV= 4.55; RMSE= 2.67; *Significant at 5 % level

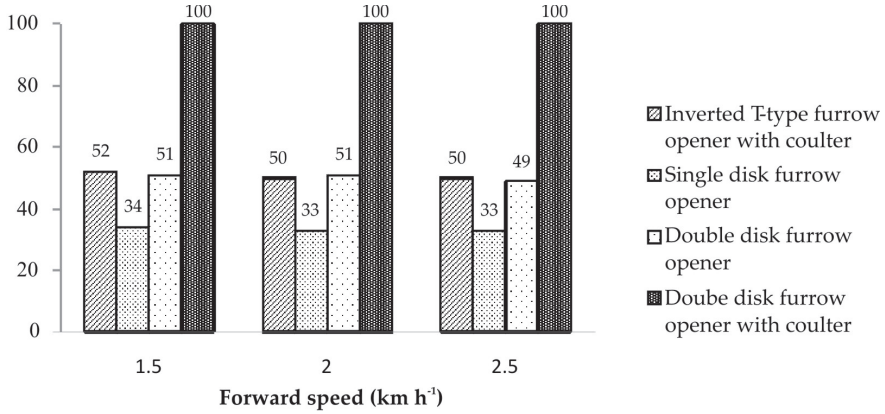


Fig. 7. Effect furrow openers and forward speeds on maize stalk residue cutting

Chang *et al.* (2013), they reported that sharpness was the most important coulter characteristic which influenced maize stalk residue cutting.

CONCLUSIONS

The effect of furrow opener and forward speed had a significant effect on soil physical properties such as soil moisture retention, soil bulk density and soil penetration resistance. The maize stalk residue cutting significantly differ with furrow openers. Forward speed did not have signifficant effect on maize stalk residue cutting (Fig. 7). The soil moisture retention, soil bulk density and soil penetration resistance decreased with increasing forward speed for all types of furrow openers. Lowest changes in soil moisture content, soil bulk density and penetration resistance were observed in case of double disk furrow opener with plain rolling coulter. Double disk furrow opener with plain rolling coulter attachment opened fine slit in the soil without much soil disturbance. The double disk disk furrow openers with plain rolling coulter cut all maize stalk residue at all selected forward speeds. Hence, the double disk furrow opener with plain rolling coulter is best suited for conservation agriculture in maize-wheat cropping system.

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Estimation of erosivity index using daily rainfall for Dehradun, Uttarakhand

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ABSTRACT

The present study was undertaken to develop the rainfall erosivity models for Dehradun district, Uttarakhand, India for estimating the erosivity index values and for establishing the most effective relationship between erosivity and daily rainfall values for the study area. For this, two models namely linear and exponential relationship between erosivity and daily rainfall values were developed and results were compared with the model proposed by Central Soil and Water Conservation Research and Training Institute, Dehradun for their suitability in the region. Model performance was evaluated using two statistical indices such as absolute prediction error and coefficient of efficiency. Absolute prediction error was found to be 13.09 % and 19.58 % for linear and exponential relationship respectively whereas coefficient of efficiency was found to be 99.24 % and 98.54 % for linear and exponential relationship respectively. APE of 55.10 % and CE of 45.37 % were found for the model proposed by Central Soil and Water Conservation Research and Training Institute, Dehradun. It was observed that both the developed models are valid for estimating erosivity index values for Dehradun region. However, based on evaluation criteria, the linear model was found to be better than exponential model and it was also observed that the model developed by Central Soil and Water Conservation Research and Training Institute is not applicable for Dehradun region.

Key words: Erosivity index, Absolute prediction error, Coefficient of efficiency

INTRODUCTION

India is a country with more than fifty percent of its population, depends upon agriculture for their livelihood, but the contribution of agriculture in GDP is just 14 percent, which is causing underemployment or disguised employment. Over-dependence on agriculture is resulting in over exploitation of agricultural land, which is making soil more vulnerable to erosion, along with other natural and anthropogenic (human induced) causes (Rawat *et al.*, 2013). Progressive degradation of soil leading to soil erosion is the major cause for low productivity in agriculture. Soil erosion involves two processes i.e. first is detachment of individual particles from the soil mass, and second is transportation by erosive agents such as flowing water and wind (Neto, 1979; Ram Babu *et al.*, 1978). Soil erosion is of four main types i.e. splash erosion, sheet erosion, rill erosion and gully erosion. Splash erosion is generally seen as the first and least severe stage in the soil erosion process and it is the major agent for detachment of soil particles in initial stage, which is followed by sheet erosion transporting loosened soil particles by overland flow, then rill erosion and finally gully erosion which is considered as most severe form of soil erosion.

Four basic steps in erosion process (Wischmeier, 1959; Wischmeier and Smith, 1958) are detachment by raindrop splash, transportation by raindrop splash, detachment by surface runoff and transportation by surface runoff. Therefore, having sufficient knowledge about all the factors that are causing soil erosion and their relationship among themselves are very necessary for a proper and scientific planning of soil conservation and water management (Gupta *et al*., 2010). And this is possible only through precise study of these parameters under controlled and repeated experimentation (Raghunath and Erasmus, 1971). Over the past many years several models have been developed for estimation of erosion index on the basis of rainfall amount at different time scales (Singh *et al.* 1981; Jaiswal, 1982; Richardson *et al.*, 1983; Gordon and Madramootoo, 1989; Selkar *et al.*, 1990; Jain and Narain, 1996; Elangovan and Seetharaman, 2011; Cecellio *et al.*, 2013). Keeping in views the above mention facts, in the present study, an attempt was made to establish a

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relationship between observed daily rainfall amount and erosivity index for Dehradun district, Uttarakhand, India with the following three objectives: (i) To determine erosivity index of some randomly selected storm events. (ii) To develop and compare with existing soil erosivity estimation model suggested by CSWCRTI (now ICAR-IISWC), Dehradun.

MATERIALS AND METHODS

Study area and data

Dehradun is located between latitudes 29°58′ N and 31°2′N and longitudes 77° 34′E and 78°18′E, at the foothill of Himalaya's Shivalik range with an elevation of about 640 m above mean sea level (Fig.1). The hourly rainfall data from recording type rain gauge for Dehradun was collected from National Data Centre, India Meteorological Department, Pune. Eight rainfall events, having magnitude greater than 17.7, were selected from a period of 6 years viz.2002-2007.

Determination of erosivity index

Rainfall erosivity (R factor) describes the soil loss potential caused by rainfall and it is calculated as total kinetic energy (E) of the storm times its 30 minutes intensity (I_{30}). This product indicates the combined potential of rainfall impact and turbulence of runoff to transport dislodged soil particles from the field (Das *et al.*, 1967; Wischmeier and Smith, 1978) and it is given as:

$$EI = E.I_{30} \quad \ldots (1)$$

where, E is the Kinetic energy in MJ/ha, I_{30} is the 30 minutes maximum energy in mm/h and EI is erosivity index.

Erosivity index is not simply an energy parameter and it is not just a good indicator of erosive potential (Erasmus *et al.*, 1970; Satapathy, 2000) but also indicates the volume of rainfall and runoff, however, rain of lower intensity occurring for a longer duration may have the same energy value as a short duration rain of much higher

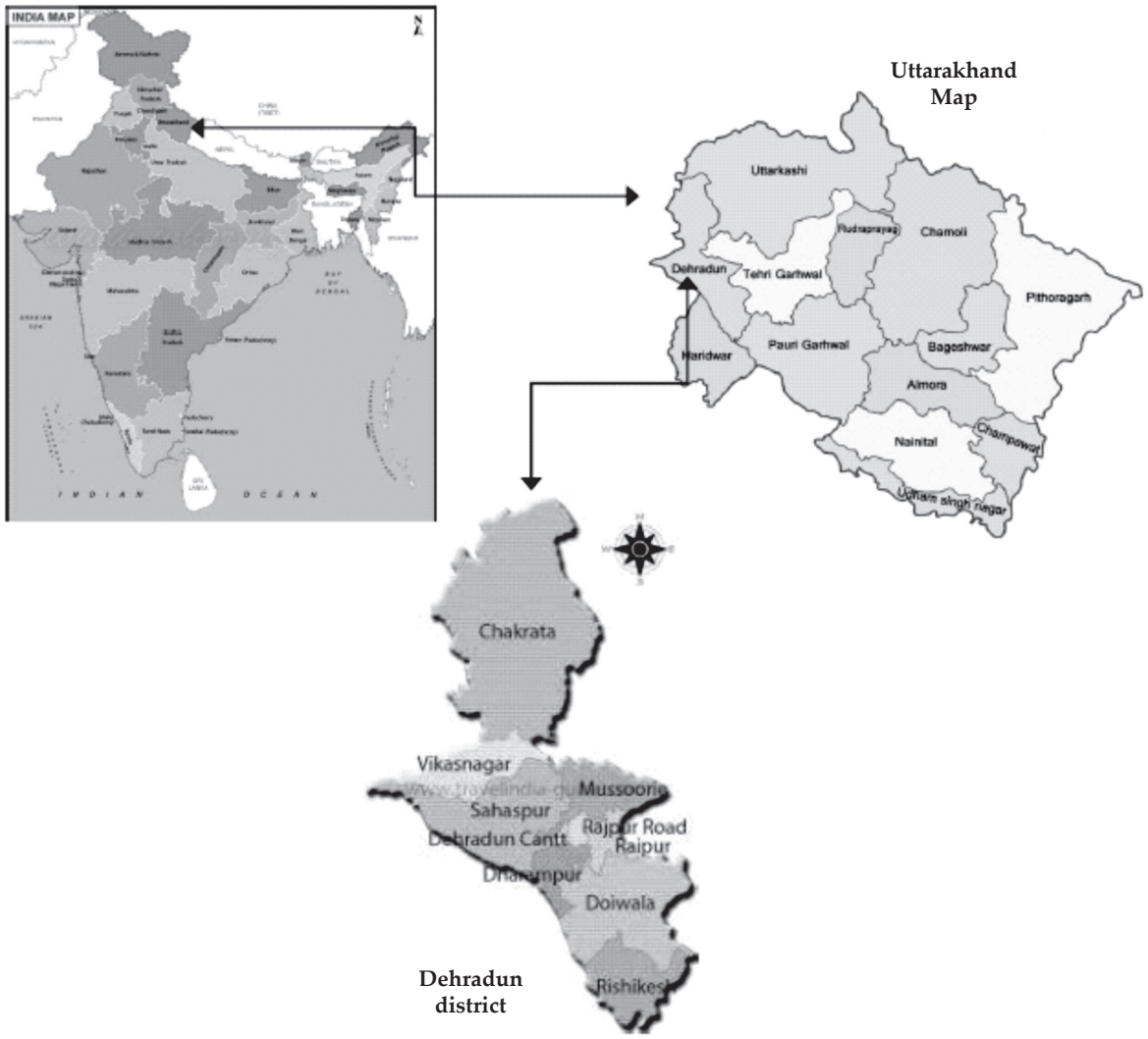

Fig. 1. Map showing the location of Dehradun, Uttarakhand

intensity. The I_{30} components specify the prolonged peak rates of detachment and runoff. Thus, the term erosivity index is a statistical interaction that shows how total energy and peak intensity are combined in each particular storm. Technically, it indicates how detachment of soil particle is being combined with its transporting capacity (ARS, 1961; Jaiswal, 1982).

In practice, the total of the storm energy is calculated for time intervals of equal intensity with the help of the following equation (Foster, 1981).

$$E = \Sigma ej.pj \quad \ldots(2)$$

in which,

$$ej = 0.119 + 0.0873 \log 10\ Ij; \qquad Ij \leq 76 \text{ mm/h}$$

$$ej = 0.283\ ;\ Ij > 76 \text{ mm/h} \quad \ldots(3)$$

where, ej is the Kinetic energy for time interval j in MJ/ha-mm, Ij is the intensity of rainfall for time interval j in mm/h, E is the energy for the event in MJ/ha and Pj is the rainfall for time interval j in mm. A limit of 76mm/h is imposed on intensity 'I' because medium drop size, which directly affects the rain intensity, does not continue to increase when intensities exceeds 76 mm/h (Laws and Parson, 1943; Das *et al*., 1966).

Rainfall of less than 17.7 mm is not included in the computation of erosivity index in the present study in reference with the observations made by Wischmeier and Smith (1978), who observed that rains lower than 15 mm are usually very less for practical significance and have very little effect on monthly percentage of erosivity index (Gordon and Madramootoo, 1989; Meusburger *et al*., 2011).

The storm wise erosivity index values are calculated by using the continuous record charts of self-recording rain gauge installed at the site. The procedure for estimating erosivity index is described stepwise as : (i) The storm is subdivided into the time intervals of uniform intensity; (ii) The Kinetic energy of rainfall per millimeter of rainfall for the j^{th} time interval is calculated using Eq. 3; (iii) The total storm energy is obtained using Eq. 2; (iv) The 30 minute maximum intensity 'I_{30}' of rainfall is determined by selecting that 30 minute period during which the slope is maximum in the rain gauge chart; (v) The obtained storm energy (step 4) and the 30 minute maximum intensity I_{30} are multiplied to get the erosivity index for that storm as in Eq.1.

Development of models

Linear and exponential relationships were derived between erosivity index and daily rainfall values for Dehradun. Daily rainfall is not always tantamount with an event. A daily rainfall amount may include only one event, multiple events or only part of an event. However, since the objective of this study was to develop a method for estimating erosivity index from daily rainfall amount, daily rainfall values were treated as individual storm events (Elsenbeer *et al*., 1993; Jain and Narain, 1995).

Linear model

A regression analysis was performed between erosivity index 'EI" and daily rainfall amount 'P' with the help of following form of the linear equation:

$$EI = a + bP \quad \ldots(4)$$

where, EI is the dependent variable and P is independent variable. a and b are regression parameters and can be obtained as below:

$$a = \frac{\sum EI - b\sum P}{n} \quad \ldots(5)$$

$$b = \frac{n\sum EI.P - \sum P\sum EI}{n\sum P^2 - \left(\sum P^2\right)} \quad \ldots(6)$$

Coefficient of correlation

$$r = \frac{n\sum EI.P - \sum P.\sum EI}{\sqrt{\left(n\sum P^2 - \left(\sum P\right)^2\right)}\sqrt{\left(n\sum EI^2 - \left(\sum EI\right)^2\right)}} \quad \ldots(7)$$

Exponential model

The exponential form of equation as given by Richardson *et al.* (1983) has been incorporated in the present study:

$$EI = aP^b + \varepsilon \quad \ldots(8)$$

where, EI is the erosivity index in MJ-mm/ha-h and P is the daily rainfall amount in mm.

In this equation a P^b is the deterministic component with a and b as equation parameters and ε is the random error component with zero mean and unit variance. It is the difference between computed erosivity index and the deterministic component aP^b for the given storm. The random error component is the result of rainfall intensity that can occur within an event of a given rainfall amount.

Now, the equation is linearized by logarithmic transformation as

$$\log EI = \log a + b \log\ + \varepsilon \quad \ldots(9)$$

Thus, the equation parameters can be estimated by the least square method as described above through Eq.5 to 6.

The random component ε is determined by rearranging the Eq. (9) as

$$\varepsilon = \log EI - (\log a + b \log P) \quad \ldots(10)$$

Quantitative performance evaluation

The acceptability of the model is judged by the goodness of fit between observed and estimated values by a model. For quantitative performance between observed and estimated values, the following statistical measures are employed in this study.

Absolute prediction error

The absolute prediction error values are determined by the following equation as proposed by the World Meteorological Organization Statistics (1975) as:

$$APE = \frac{\sum (O_i - P_i)}{\sum O_i} \times 100 \quad \ldots(11)$$

where, APE is absolute prediction error in percentage, O_i and P are calculated and predicted values respectively.

Coefficient of efficiency

The use of another goodness of fit parameter known as coefficient of efficiency (CE) for evaluating model performance has been recommended by many researchers in the field of hydrology. The coefficient of efficiency as defined by Nash and Sutcliffe (1970) is the proportion of the initial variance accounted by that model. The coefficient of efficiency is determined by the following equation:

$$CE = \frac{\sum (O_i - O)^2 - \sum (O_i - E_i)^2}{\sum (O_i - O)^2} \times 100 \quad \ldots(12)$$

where, CE is coefficient of efficiency in percentage, Oi and Ei are respectively calculated and predicted values at corresponding time and O is the mean of computed values.

Relationship proposed by Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehradun

Ram Babu *et al.* (1969**)** proposed the following relationship between erosivity index and rainfall amount which can be written as:

$$EI = 0.533 P + 3.1 \quad \ldots(13)$$

where, EI is the erosivity index in t.m.cm/ha.h and P is the rainfall amount in mm.

RESULTS AND DISCUSSION

The erosivity index (EI) values for various storm events have been estimated using the procedure described above. The estimated values of erosivity index for storm events dated August 22, 2002 and are presented in Table 1. For better comparison, EI and I_{30} for all 8 storm events are shown in (Table 2).

Table 1.Computation of erosivity index for storm event dated August 22, 2002

Time Period	Duration (min)	Cumulative Rainfall (mm)	Rainfall (mm)	Intensity (mm/h)	Kinetic Energy (MJ/ha-mm)	Total Kinetic Energy (MJ/ha)
1.00-1.30	30	23	23	46	0.264159	6.075651
1.30-2.00	30	46	23	46	0.264159	6.075651
2.00-2.30	30	71	25	50	0.26732	6.683002
2.30-3.00	30	96	25	50	0.26732	6.683002
3.00-3.30	30	97.35	1.35	2.7	0.156658	0.211488
3.30-4.00	30	98.70	1.35	2.7	0.156658	0.211488
4.00-4.30	30	99.70	1	2	0.14528	0.14528
4.30-5.00	30	100.70	1	2	0.14528	0.14528
5.30-6.00	30	100.75	0.05	0.1	0.0317	0.001585
6.00-6.30	30	100.80	0.05	0.1	0.0317	0.001585
6.30-7.00	30	100.9	0.1	0.2	0.05798	0.005798
7.00-7.30	30	101	0.1	0.2	0.05798	0.005798
TOTAL			101			26.2456

I_{30} = 50 mm/h

EI_{30} = 1312.28 MJ-mm/ha-h

Table 2. Storm-wise computed EI and I_{30} values

Date	Rainfall (mm)	Computed EI (MJ-mm/ha-h)	I_{30} (mm/h)
August 22, 2002	101	1312.28	50
July 5, 2003	117.1	1822.40	63.51
Jan 23, 2004	43.4	446.234	40.80
July 27, 2004	116.5	1720.40	58.50
Sept. 10, 2004	23.2	92.01	18.80
Aug. 19, 2005	30	178.89	26
Aug. 26, 2005	55.7	752.03	52
July 1, 2007	101.5	1379.59	56

EI is the erosivity index and I_{30} is the 30 minute maximum rainfall intensity

From Table 2, it can be observed that EI values varied from 92.01 MJ.mm/ha. h to 1822.40 MJ.mm/ha. h to where I_{30} values ranges from 18.8 mm/h to 63.51 mm/h.

Development of models for erosivity index and rainfall amount

The linear and exponential relationships have been developed between erosivity index and rainfall values for Dehradun.

Linear model

Linear relationship between erosivity index (EI) as dependent variable and rainfall (P) as independent variable has been developed as per the procedure discussed in previous section and the following equation has been obtained with correlation coefficient equal to 0.994.

$$EI_{30} = 17.24104\ P - 305.099 \quad \ldots(14)$$

where, EI_{30} is the erosivity index in MJ.mm/ha. h and P is the daily rainfall amount in mm.

From the above equation, it is clear that the calculated value of erosivity index for rainfall amount less than 17.7 mm comes out to be negative which is physically impossible. Hence, the equation proves to be good for rainfall depth exceeding 17.7 mm only.

Wischmeier and Smith (1978) also observed through their study that the rainfall amounts less than 15 mm contributes very little to erosivity. Thus, the rainfall amounts less than 17.7 mm have been neglected for the development of the above relationship in this study.

Exponential model

An exponential relationship has been obtained between erosivity index (EI) as the dependent variable and rainfall amount (P) as the independent variable as per the procedure described before with coefficient of correlation equal to 0.984. The following equation is obtained in the form as:

Table 3. Estimation of storm-wise random component ε

Date	Rainfall (mm)	Exponentially Predicted EI (MJ-mm/ha-h)	ε
Aug. 22, 2002	101	1467.124781	-0.04845
Sept. 10, 2004	23.2	119.9970229	-0.11534
July 5, 2003	117.1	1887.104511	-0.01516
Jan. 23, 2004	43.4	348.4327578	0.107435
July 27, 2004	116.5	1870.677148	-0.03638
Aug. 19, 2005	30	185.8536641	-0.01659
Aug. 26, 2005	55.7	532.7914911	0.149669
July 1, 2007	101.5	1479.507871	-0.03038

Mean = -0.000648

SD =0.0865

$$EI_{30} = 0.569\ P\ 1.702 + \varepsilon \quad \ldots(15)$$

where, EI_{30} is the erosivity index in MJ-mm/ha-h and P is the daily rainfall amount in mm, and ε is the random error component.

The random error component ε is linearized by logarithmic transformation and the predicted storm-wise values of ε have been presented in Table 3. It is apparent from the table that the mean of ε values is zero and the standard deviation is 0.0865. The values of coefficient a, exponent b and residual term ε are within the range according to Richardson *et al.* (1983).

Quantitative performance of models

The legitimacy of the developed relationships was checked using two statistical indices i.e. APE and CE for eight randomly selected storm events from years 2001-2007 and their quantitative performance is shown in Table 4. For better understanding, the event wise observed erosivity index and predicted erosivity index for linear and exponential relationships respectively are presented in Fig. 2 and Fig. 3. The APE and CE were found to be 13.09 % and 99.24 % for linear model and 19.58 % and 98.54 % for the exponential model respectively. These values are within the recommended range of below 25 % for APE (World Meteorological Organization Statistics, 1975) and above 75 % for CE (Nash and Sutcliffe, 1970). Thus, it is apparent that both the relationships give good results and both of them can be functionally applied for Dehradun in particular and it's surrounding areas in general. However, linear relationship gave

Table 4. Quantitative performance evaluation of models

Date	Rainfall (mm)	Computed EI (MJ-mm/ha-h)	Linearly Predicted EI (MJ-mm/ha-h)	Exponentially Predicted EI (MJ-mm/ha-h)	CSWCRTI model Predicted EI (MJ-mm/ha-h)
July 29, 2001	141.8	1854.97	2139.68	2613.46	786.79
July 5, 2003	116.8	1820.69	1708.65	1878.88	653.54
Jan 3, 2004	98.7	1468.63	1396.59	1410.72	557.07
July 6, 2004	73.4	770.59	960.39	852.17	422.22
July 27, 2004	116.4	1720.22	1701.76	1867.95	651.41
July 11, 2005	110.9	1022.74	1606.93	1720.23	622.09
Sept. 4, 2007	70.3	604.62	906.95	791.83	405.69
Aug. 28, 2007	75.4	841.15	994.49	934.38	432.88
APE (%)			13.09 %	19.58 %	55.10 %
CE (%)			99.24 %	98.54 %	45.37 %

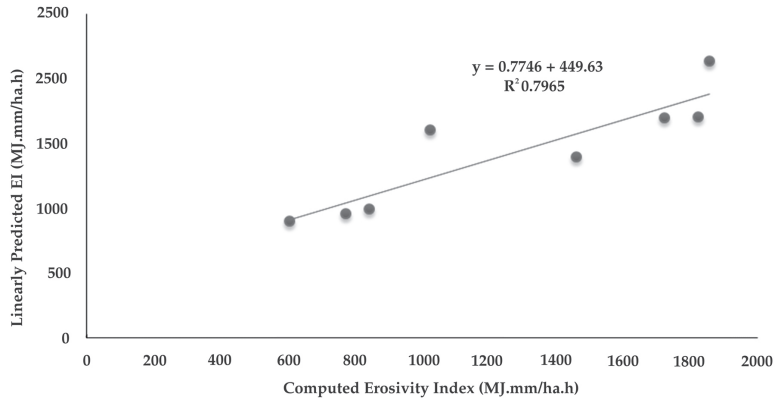

Fig. 2. Relationship between computed and linearly predicted erosivity index

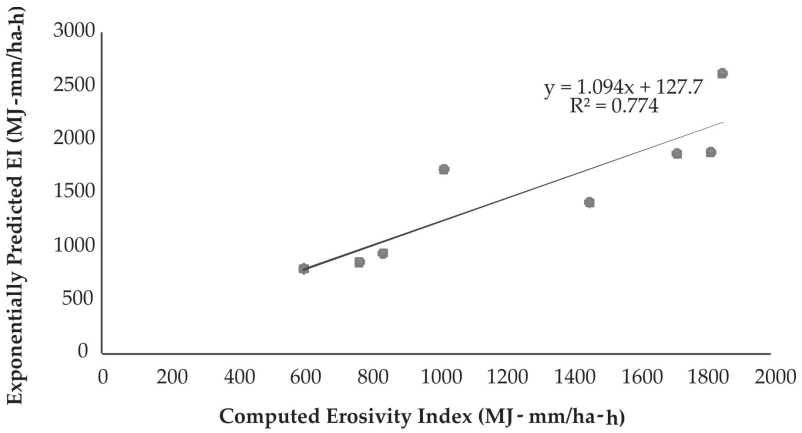

Fig.3. Relationship between computed and exponentially predicted erosivity index

better results in comparison to exponential relationship. The linear model is recommended for use because of its simplicity in computational procedure for EI values.

The performance of the erosivity index relationship proposed by Ram Babu *et al.* (1969) has also been studied with a view to establish the applicability of the model for Dehradun and its surrounding region. The predicted values of erosivity index by this model for the same eight storm events are also shown in the Table 4 with APE of 55.10 % and CE of 45.37 %. It is clear from Table 4 that both the models viz. linear as well as exponential, developed are more preferable than the model proposed by Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehradun for prediction of EI for Dehradun region and its surrounding regions.

CONCLUSIONS

From the present study it was found that both the linear and exponential models developed for estimation of erosivity index were applicable for Dehradun region. However, the linear model was found to be better on the basis of evaluation criteria. The developed models performed better than the model earlier developed by CSWCRTI Dehradun.

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Improving irrigation water productivity using Tensiometers

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ABSTRACT

Tensiometer-an instrument which delineate time of applying irrigation water perhaps cheapest, simple and reliable in saving irrigation water amounts and thus in improve the water use efficiency. In the current scenario of water shortage, scientists are busy in find out the ways to improve the water use efficiency. Among the whole world, conditions are somewhat more serious in countries like India because of its agricultural backgrounds. The story is more severe in states where rice is the major kharif crop viz. Punjab, Haryana, Uttar Pradesh etc. The current indigenous practice of flood irrigation to field crops is both injudicious and energy inefficient which leads to lower water productivity. Declining water productivity and low water table are the major problems that stand in front of agricultural scientists as additional water of worth Rs. 2500 million withdrawn every year only in Punjab. Thus, there is a need to look into detail benefits of the tensiometers in terms of water use efficiency, productivity and grain yields terms throughout the world under texturally divergent soils under different agroclimatic conditions. In the present review, attempts had been made as per published literature to check tensiometers performance and our reviewed data delineate that tensiometers in the region result in saving of 11 – 31% of water and 52 – 127 Kwh acre^{-1} of power without putting much adverse effect on the grains and thus overall improving the water productivity. Finally, we reached at the conclusion that tensiometer works but still it needs to be tested on the long term basis for ranking among different resource conservation technology.

Key words: Tensiometer, water productivity, irrigation water

INTRODUCTION

WATER-perhaps the most important gift of the nature is not judiciously used by the man and now almost throughout the world it is scarce. Soil moisture (water) is an inevitable part of the three phase system of the soil, which comprises of soil minerals (solids), moisture and air. Hence, soil moisture content has quite significant influence on engineering, agronomic, ecological, ecological, biological and hydrological behavior of the soil mass (Arora *et al*., 2008). The intensive rice-wheat cropping sequence has many sustainability issues which needs to be addressed soon for the sustainable agriculture in the region (Bhatt *et al*., 2016). In the Indian Punjab, water table is declining at an alarming rate because of increase in the rice area from 6% (1960) to 60% (2015). Further, annually, in the state >13 Lakh ha-m of additional water worth US $ 39 million withdrawn for irrigation purposes. NASA's gravity mapping satellite "GRACE" tracks that in North India, in an area of 440,000 km^2, ground water has declined at an alarming rate of 1 ft year^{-1} which has further resulted in the loss of 4 cm loss of raw ground water or 18 km^3 year^{-1} (Check). Some resource conservation technologies (RCTs) recommended for the region to uplift water productivity are direct seeded rice (Bhatt and Kukal, 2015), bed planting, mechanical transplanting (Bhatt *et al*., 2015), laser levelling (Bhatt and Sharma, 2008), soil matric potential based irrigation (Bhatt and Sharma, 2010) etc. Among all, the tensiometer is in the spotlight as it guides the farmers when to irrigate (Karimi *et al*., 2015) by measuring soil water tension. Among advantages direct reading of soil matric potential, inexpensive, non-destructive, automatic for continuous reading, relative reliability as compared to other methods[11]. Moreover, tensiometer reading not affected by soil temperature.

RESULTS OF THE CARRIED OUT STUDIES

A. Tensiometer and irrigation water saving

Generally, soil water content instruments measure the amount of water in the soil, while soil matric potential (SMP) instruments give a

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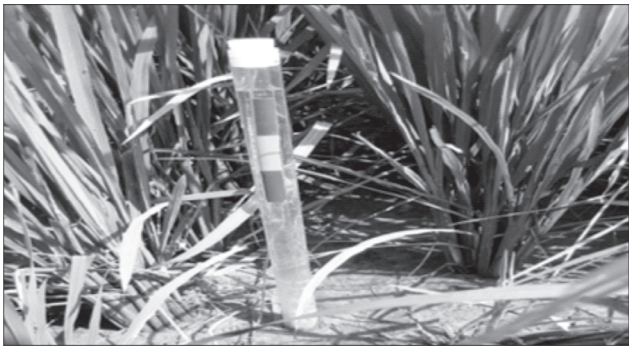

Fig. 1. PAU tensiometer

measurement of how easy it is for plants to extract water from the soil. Tensiometers which measures the SMP are rapid, cheap, not influence of temperature and easy devices (Hodnett *et al*., 1990; (Thalheimer, 2003). All this render them suitable also for automated fertirrigation control. Although the tensiometric technique is straightforward, relatively easy to use and its range of measurement is adequate for most of the agronomic applications (Young and Sisson, 2002), but its performance is doubtful where soil water limits plant growth, for instance (Durner and Or, 2006). Results of the carried out studies revealed tensiometer saved from 11.1 to 30.7% of irrigations as compared to the farmers practice without having any adverse effect on crop yield (Table 2) which depicts that during 2006 the water saved varies from 29.6 to 30.7 with almost similar yields. However, the water saving in terms of irrigation saved varies from 25.0 to 27.2, 18.0 to 27.8, 16.6 to 20.8 and 11.1 to 21.4 in consecutive 2007 to 2010 with a non-significant difference in the grain yield. Similar, trends were noticed by Hira *et al*. (2007) whereas Kukal *et al*. (2005) reported an improvement of 75.8 % in water productivity with tensiometer as compared to the flood irrigation (Table 1). Bhatt (2015) reported that tensiometer during second year of their investigation results in saving of one complete irrigation in wheat which further helps in having higher water productivity in zero tilled mulched plots as compared to the conventionally tilled unmulched plots.

However during intervening period after rice, soil matric tension (SMT) readings revealed that permanent zero tillage (ZT) plots dried out faster than plots which were under conventional tillage (CT) from the last four seasons irrespective of soil depth and tillage in rice (Fig. 2, a-i) which was mainly because of no mulch load, continuous supply of water from deeper layers due to continuity of soil pores and recorded higher soil temperature throughout intervening period while

Table 1. Water productivity of puddle transplanted rice

Irrigation schedule	Irrigation water productivity (g kg^{-1})
Continuous flooding	0.28
Intermittent irrigation (2 day gap)	0.34
Tensiometer based	0.50

Source: Kukal *et al.* (2005)

Table 2. Soil matric potential-based irrigation scheduling results in farmers fields in Kapurthala district

Year	Per cent Irrigation water savings	Yield differences
2006	29.6-30.7	+0.5 – 1.5%
2007	25.0-27.2	At par
2008	18.0-27.8	At par
2009	16.6-20.8	+0.5 – 1.0%
2010	11.1-21.4	At par

Source: Bhatt and Sharma (2010)

in CT plots, the continuity of soil pores broken by tillage operations which further results in lesser supply of water to evaporating site from the deeper layers and finally resulted in lesser evaporation (Bhatt and Kukal, 2015). However, magnitude of drying (more particularly in CTW plots) decreases as studied soil depth increases. At all the soil depths viz. 10, 20 and 30 cm soil depths, SMT values go on increasing as the days after harvesting increases. On an average, SMT reported to be 36% higher in CTWDSRZT than CTWDSRP plots at 10 cm soil surface while at 20 and 30 cm SMT reported to be varied at almost same pace in all the plots of DSRP, DSRCT and DSRZT plots (Bhatt and Kukal, 2015). At 30 cm depth, in DSRP plots, SMT values increased 12% and 11% higher under CTW block and ZTW blocks, respectively than its allied plots. SMT readings in all the ZTW plots on an average increased at much more faster rates (24%) than CT plots at all the soil depths indicating greater and prolonged retention of soil moisture in later plots (Bhatt and Kukal, 2015).

The ground water and energy saving with the use of tensiometers at farmer's fields has been estimated (Table 2). On an average, tensiometer brought down the water consumption in rice by 14-15 percent during both the years viz. 2012-2013 while the proportion varied from 11-16 percent in 2012, it varied between 11-19 percent in 2013. Further, Buttaro *et al*. (2015) reported that, a water saving of 35% and 46%, on average, for tomato and cucumber, respectively, was obtained using tensiometer at the lowest potential as irrigation set-point. Wang *et al*., 2007 and Patanè *et al*., 2011 on

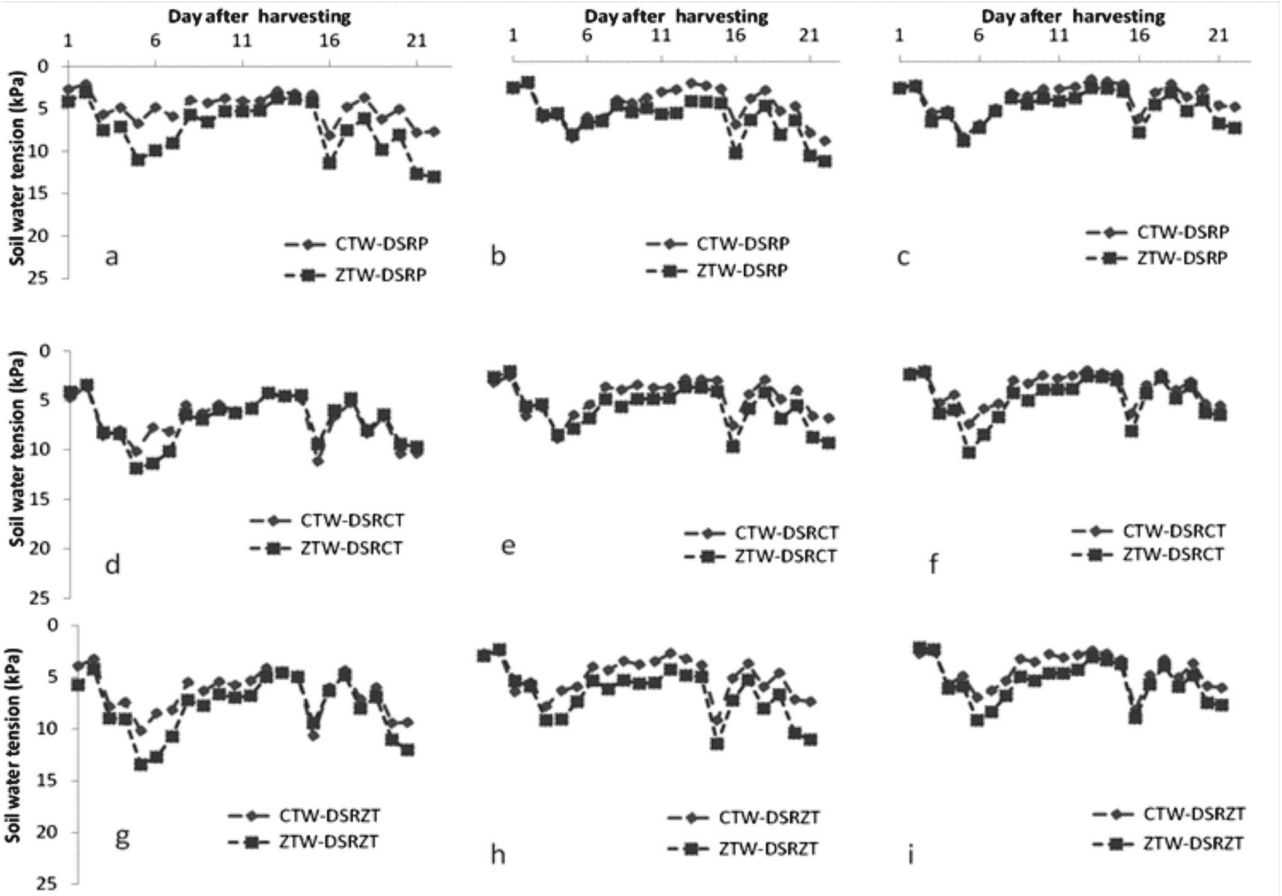

Fig. 2. Temporal fluctuations in soil matric potential in CTWDSRP vs ZTWDSRP from 10-30 cm soil depth (a-c), in CTWDSRCT VS ZTWDSRCT from 10-30 cm soil depth (d-e) and CTWDSRZT vs ZTWDSRZT from 10-30 cm soil depth (g-i)

the same tract observed that where the adoption of deficit irrigation strategies allowed to save water improving the WUE, minimizing fruit losses and maintaining high fruit quality levels. Shae *et al*. (1999) suggested that tensiometer based methods produce yields and quality potato equivalent to those from conventional method with significant savings in seasonal irrigation totals. Under fine sandy soils of Florida, Smajstrala and Locascio (1996) reported 40-50% of the irrigation water saving in tomatoes using tensiometers at 15 cm. Highest yields of maize have been obtained when matric potential in the upper 300 mm of soil has been maintained above -25 kPa (for sands) to -40 kPa (for clays) (Rhoads and Stanley, 1973,1974; Bruce, 1972; Phene and Beale, 1976).

B. Tensiometer and power saving

Tensiometer could save considerable amount of the irrigation water without having any adverse effect on the grain yield as it works on the principle of the soil matric potential and delineate the need for irrigation in a more meaningful way. On an average, irrigation scheduling on one acre of rice with the help of tensiometer helped in reducing the ground water use by 538,179 litres in 2012 and by 372,042 litres in 2013. The water savings due to use of tensiometer led to reduction in the power consumption by 101 kwh acre^{-1} in 2012 and by 70 kwh acre^{-1} in 2013 (Table 3; Vitta *et al*., 2014).

Thus, the faulty cropping pattern along with faulty agricultural practices has created a hydrological imbalance in Punjab.

Advantages of tensiometers

1. Tensiometers measure the soil matric potential of the soil with good accuracy in the wet range.
2. Tensiometers are inexpensive and easy to use, suitable for irrigation scheduling purposes for some crops, particularly crops viz. rice that must remain well watered.
3. Tensiometers measure soil suction directly, hence calibration for soil type, salinity or temperature is not needed.
4. A set of tensiometers installed at increasing depths in the soil is a basic tool for assessing gradients of hydraulic heads and movements of soil water according to the Darcy law (Bhatt

Table 3. Residual effects Tensiometer on water and power saving

District	Water saving (litres acre^{-1})		% saving in water		Power saving (kwh acre^{-1})	
	2012	2013	2012	2013	2012	2013
Amritsar	380,878	346,840	14	14	74	67
Jalandhar	393,762	416,679	12	19	69	73
Kapurthala	452,880	267,000	11	11	88	52
Ludhiana	601,593	329,543	14	12	113	61
Moga	612,138	486,450	13	19	127	100
Tarn Taran	548,831	300,801	16	12	104	57
Overall	538,179	372,042	14	15	101	70

and Kukal, 2015a,b). The same set is used for measuring the soil hydraulic conductivity through the "internal drainage" process (Bhatt, 2015).

Disadvantages of Tensiometers

1. Tensiometers are not affected by the osmotic potential of the soil solution (the amount of salts dissolved in the soil water). This means that the tensiometer reading does not reflect the entire soil water potential experienced by the plant. Further, there is a slow reaction time due to hydraulic resistance of cup and surrounding soil. Tensiometer operates between 0 and approximately –80kPa, not useful for drier ranges experienced under dryland agriculture which limited its scope in dryland agriculture.
2. Tensiometers need periodic maintenance which is labour intensive. Tensiometers are simple instruments, but without regular maintenance they are likely to give wrong readings. They require frequent service and refilling after dry periods. Measures matric potential only in the vicinity of the sensor; several units are needed to give a reliable spatial average.
3. Tensiometers are susceptible to hysteresis relationship between soil water content and soil water potential of wetting/drying soils.

Conditions under which tensiometer might not work properly

Though the tensiometers working very well in delineating the soil matric potential even then there are conditions when the working operations of this instruments is hampered.

Conditions when a tensiometer is not working correctly (Gillett, 2000)

A. Gauge reading is zero (if working properly, a zero reading means the soil is saturated from irrigation, rainfall or poor drainage).

   Possible causes: No water in the tensiometer, or lost suction due to low water level. The gauge is faulty: check and replace. A connection is leaking: check the general assembly including ceramic tip and other connections.

B. Demanding frequent refilling.

   Possible causes: ceramic cup is leaking. Check other connections.

C. Responds slowly to irrigations.

   Possible causes: Water is slow to move between the ceramic tip and the soil. The ceramic tip may be sealed by salts.

D. Records wrong reading

   Possible causes: Tensiometer is not installed correctly in the soil or there is a gap between surrounding soil and the tensiometer or the soil has become too dry and the tensiometer has lost suction.

E. Problem soils

   In some of the soils viz. Cat clay (Shrink-swell clay) which may shrink away from the porous cup during drying, resulted in loss of contact with the soil, very coarse sands which creates capillary barrier at the interface between micro and macropores, saline-sodic soils as their salts might block the pores of the ceramic cup. In all soil types the ability of the tensiometer to track soil water potential changes is under doubt.

CONCLUSIONS

At last, it could be stressed that tensiometers played an important role in delineating the soil matric potential and finally, helps in deciding the time that when to irrigate. Thus the farmers could save a considerable amount of the irrigation water, which further helps in improving the water use efficiency or grain yields or water and land productivity. The demand of water is increasing due

to increasing population, while the water resources are being exploited mercilessly without thinking for the future. Strategies for the rational use of water through tensiometer have been discussed which are not difficult to adopt. Farmers can easily save upto 20-30% of irrigation water without having any adverse effect on the grain yield of paddy which further helps in improving the water productivity. Now the time has come when the scientists, researchers, extension workers and farmers should join hand to save irrigation water through tensiometer. However, their performance varied in texturally divergent soils under different cultivar grown, sowing date and establishment technique, rainfall frequencies and amounts.

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Chemical composition of groundwater in capital city Bhubaneswar, Odisha

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ABSTRACT

In this study, ground water samples were collected for two years i.e. 2010 and 2011 from the monitoring wells of 30 different places in the study area of capital city of Bhubaneswar, Odisha. Water samples were analyzed for major ions and toxic metals using standard techniques in laboratory. Different chemical composition like pH, total dissolved solids (TDS), electrical conductivity (EC), values of cations like sodium, potassium, magnesium and calcium, values of anions like bicarbonate, sulphate, chloride, nitrate, fluoride and iron of groundwater of all the 30 places were determined for both the years. Presence of different heavy metals like manganese (Mn), chromium (Cr), cadmium (Cd) and lead (Pb) in the groundwater samples of various places were also determined. The pH of the groundwater is near neutral to slightly basic, with an apparent increase in the year 2011 as compared to 2010. In the year 2010, EC value varied between 111 to 956 μmhos/cm while in the year 2011 it varied between 132 to 980 μmhos/cm. Study of different water quality parameters in both the years including pH, TDS, EC, different anions and cations, iron and fluoride as well as heavy metals indicate that ground water is safe for drinking in almost all places in Bhubaneswar. To understand the water quality and utilitarian aspects of groundwater, the chemical indices of Sodium Adsorption Ratio (SAR) were further calculated and compared with the limits given by WHO. It was observed that the quality of groundwater is suitable for drinking and irrigation purpose in the study area.

Key words: Groundwater, Chemical composition, Quality, Cations, Anions, Heavy metals, Electrical conductivity, Sodium adsorption ratio

INTRODUCTION

Seventy per cent of the earths' surface is covered with water. But in reality, 97.3% of total water on the earth is saline and only 2.7 % is available as fresh water. About 77% of this fresh water is locked up in glaciers and permanent snow and 11% is considered to occur at depths exceeding 800 m below the ground, which cannot be extracted with the technology available today (CGWB, 2007). Ground water is one of the most important sources of drinking water but is not abundant in nature. About 11% of the resources are available extractable groundwater within 800 m depth and about 1% is available as surface water in lakes, reservoir and river systems. Agriculture sector is the largest consumer of water (82.8%) but with growing population, urbanization and industrialization in the country, the requirements of water from competing sectors like domestic and industrial needs, are increasing. The rate of deterioration will depend on the rate at which the water is extracted from the source and the levels of pollution that enter the source from time to time. Testing water samples regularly is advisable to keep track of the changes (deterioration). Hence an understanding of both quality and quantity of ground water is needed when evaluating ground water resource. Chemical analysis of water samples for major cations and anions in ground water is helpful in determining it's sustainability for agricultural, industrial and domestic purposes. Groundwater and sediments are regarded as polluted when their original quality and composition are changed directly or indirectly and becomes unsuitable for drinking, domestic and agricultural purposes.

Odisha has an annually replenishable groundwater resource of 2101128 ha-m. Out of which 112272 ha-m is committed for the domestic and industrial requirement for coming 25 years based on the population growth (CGWB, 2007). Bhubaneswar is situated in the eastern coastal plains of Odisha and south-west of the Mahanadi River. Geographical area of Bhubaneswar city is 467.17 km^2 and it is situated between 21° 15' North Latitude 85° 15' Longitude and at an altitude of 45 meters above sea level. The city area is characterized

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by undulating upland topography in western and central part while eastern part shows more or less flat with gentle sloping topography having altitude varying from 60 m in the western part to 15m in the extreme eastern part.

According to the survey made by Central Ground Water Board (CGWB) in the year 2010, the total groundwater in Bhubaneswar was 7313 ha-m from which 5255 ha-m was from rainfall and 2058 ha-m was from other sources. From the total availability 503 ha-m of water was lost through natural processes. Hence the net ground water available for utilization was 6810 ha-m. The total groundwater utilized in the city was found to be 3320 ha-m in which 1243 ha-m was used in irrigation sector, 1913 ha-m in domestic sector and 164 ha-m in industrial sector.

The city has a tropical climate, specifically a tropical savanna climate. The average temperatures range between a minimum of around 12 °C in the winter to a maximum of 45 °C in summer. The average annual rainfall is 154 cm, most of which is recorded between June and October. The soils of the city may be sub-divided into Alfisols and Ultisols. The Alfisols mainly include sandy loam and Altisols include laterite and laritic soil. The alluvial deposits which include sand, silt, clay etc occur in the extreme eastern part of the city. The lateritic mainly occur as capping cover over the country rocks in the western and central part of the city. The main drainage channel is the Kuakhai River, distributaries of the Mahanadi River which flows along the eastern margin of city. This river has been sub-divided into the Bhargavi and the Daya River in the extreme south eastern part of the city.

METHODOLOGY

Groundwater samples in the year 2010 and 2011 were collected from different shallow and deep tube wells in 30 different places of the capital city of Bhubaneswar. Parameters like EC, pH and alkalinity were measured during sampling on the spot. Samples were carefully transported to the laboratory and were preserved. Electrical conductance was measured with a conductive meter and result was displayed in μmhos/cm. The TDS was measured by gravimetric method. The concentration of some cations (Na^+, K^+, Ca^{2+}, Mg^{2+}), anions (Cl, HCO_3^-, NO_3^-, SO_4^{2-}), minor and trace elements were determined in the laboratory of Odisha state pollution control board. Groundwater samples were collected, preserved and analyzed as per standard methods. Calcium and magnesium were determined by EDTA titration method. Sodium and potassium concentration were determined using a flame photometer. Sulphate concentration was measured by nephelometry method. Carbonate and Bicarbonate were measured by titometry method. Chloride was measured by argentrometric titometry method. Fluoride was measured by SPADNS method. Iron was measured by phenanthralin monohydrate method. Nitrate was measured by Spectrophotometry method. All the data have been compiled and observations have been noted below.

RESULTS AND DISCUSSION

In the present study, the groundwater quality analysis was carried out on the basis of aerial distribution of field test parameters and hydro chemical investigation. Various field test parameters (pH, EC, TDS) were carried out for shallow and deep tube wells of the study area during the month of November, (2010) and April, (2011). Physical properties of different water samples of the entire municipal area were collected and the properties of groundwater samples like pH, total dissolved solids (TDS) and electrical conductivity (EC) were determined (Table 1). The values of different parameters in the year 2010 and 2011 are given in Table 1.

Analysis of Different Parameters

pH

Water having lower pH value has metallic taste and has corrosive quality. Water having higher pH value tastes bitter. Value of pH can be increased by adding soda ash in the water and can be decreased by adding vinegar or citric acid. According to BIS standards the permissible limit for pH is 6.5 to 8.5. In the year 2010 the pH of samples varied between 4.93 to 7.5. Total 10 samples were found to be having pH below 6.5. In the year 2011, value of pH of ground water sample was found to range from 5.56 to 7.6 which indicated slightly alkaline nature of groundwater.

Electrical Conductivity

EC of water is an indicator of salinity hazard and gives the total salt concentration in water. The EC values of groundwater at different location of the study area were determined. In the year 2010, the EC value varied between 111 μmhos/cm to 956 μmhos/cm while in the year 2011, the EC valued varied between 132 μmhos/cm to 980 μmhos/cm.

Table 1. Values of pH, TDS and EC in groundwater at different places in Bhubaneswar

Location/Year	2010				2011			
	Water level below ground, m	pH	TDS mg/l	EC (milli mhos/cm)	Water level below ground, m	pH	TDS mg/l	EC (milli mhos/cm)
Tankapani Road	3.75	6.45	311	460	5.50	6.75	123	290
Dumduma	4.55	7.56	242	339	3.00	5.56	85	650
Aigania	5.42	7.14	280	414	3.65	6.36	286	430
Jagamara	4.44	7.16	218	301	4.30	6.73	436	600
DharmaVihar	5.15	6.04	85	120	4.98	7.21	239	890
Nayapalli	7.28	7.03	196	282	8.10	6.44	440	620
Shastri Nagar	3.85	7.55	474	666	3.90	5.71	711	450
Unit-4	4.58	7.49	398	547	5.25	6.69	198	345
Unit-9	6.90	6.89	184	255	7.20	6.6	210	330
Unit-2	6.80	7.45	229	328	6.40	7.05	205	132
Unit-8	7.12	6.83	217	333	8.25	6.53	314	410
OUAT colony	2.65	5.61	134	205	3.50	6.36	334	430
Ganganagar	3.17	7.43	131	197	5.75	6.49	203	319
Forest Park	7.00	6.77	107	135	6.70	7.23	457	650
Pokheriput	8.15	6.12	65	79	8.35	5.12	605	569
Kapileswar	6.68	7.11	274	322	6.85	6.01	484	502
Old Town	2.45	7.32	377	503	1.90	7.71	298	476
Samantrapur	1.05	6.3	213	294	1.28	6.75	472	630
BJB Nagar	3.15	6.91	331	483	4.60	7.83	134	384
Uparsahi, Bargarh	2.48	6.66	316	481	2.85	6.13	186	920
Baramunda	5.85	6.01	687	837	4.85	7.71	467	609
Jayadev Vihar	6.50	8.24	125	184	3.48	7.21	265	584
Chandrsekarpur	15.80	6.36	92	134	8.45	7.52	710	340
Niladri Vihar	2.88	6.13	133	202	3.45	5.83	660	785
Patia	6.50	6.51	203	288	6.20	5.75	306	345
VSS Nagar	3.70	7.17	332	444	2.50	6.12	49	980
Vanivihar	5.99	5.92	74	111	7.00	7.66	265	350
Rasulgarh	2.22	6.89	202	289	4.00	5.56	78	309
Laxmi Sagar	5.67	7.44	737	956	5.30	6.44	731	430
Jharpada	4.51	6.28	181	264	5.20	5.68	451	900

Electrical conductance is directly related to the abundance of changed ionic species i.e. higher electrical conductance is the reflection of higher ionic concentration and this is especially true in case of chloride and bicarbonate concentration (Hem, 1989).

Total Dissolved Solids

TDS is the most important single criteria of irrigation water quality because salinity of soil solution is usually related to and often determined by the salinity of irrigation water. In the year 2010, the TDS varied from 92 mg/l to 737 mg/l. In the year 2011, TDS varied from 85 mg/l to 731 mg/l. According to BIS standards the desirable and permissible limits of TDS are 500 mg/l and 2000 mg/l, respectively. In the year 2010, two wells were found to have TDS of 687 mg/l and 737 mg/l which are above desirable limits and in the year 2011, four wells were found to have TDS of 605 mg/l, 660 mg/l, 711 mg/l and 731 mg/l which are above desirable limits. Higher TDS value causes hardness, cloudy colour and salty or bitter taste of water. The sources of TDS are livestock, waste, septic tank and nature of soil. The water having higher TDS value can be treated by reverse osmosis and distillation.

Sodium (Na^+)

Sodium is abundant member of alkali-metal group. The presence of Na^+ in groundwater

primarily results from the chemical decomposition of feldspar, feldspathoid and some Fe-Mg minerals. Secondary sources of Na^+ in groundwater are agriculture by products and industrial effluents (Hem, 1989).

The increased concentration of sodium in irrigation water increases it's concentration in soil solution that in turn replaces calcium and magnesium from the soil complex leading to sodic soil. In Bhubaneswar area the values of sodium ranges from 5 mg/l to 78 mg/l in 2010. In 2011, the value of sodium ranges from 4.6 mg/l to 64.8 mg/l (Table 2). The concentration of Sodium more than 50 mg/l makes the water suitable for domestic use. The sodium ion concentration decreases with increase depth. This variation is believed to be effect of the agriculture byproducts (Karim *et al*., 2002). Na^+ concentration in the study area is moderate which is suitable for domestic application.

Potassium (K^+)

Potassium is also less abundant parameter in groundwater. In most fresh water aquifers if the Na^+ concentration substantially exceeds 10 mg/l, the K^+ concentration commonly is half or tenth of that of Na^+. It is an essential element for plant growth. High concentration of potassium may induce magnesium deficiency and iron chlorosis. In 2010 the values of potassium ranged from 0.3 mg/l to 86 mg/l and in 2011 the values of potassium ranged from 0.9 mg/l to 38 mg/l. In both the years the wells carry the good values as the safe limit for drinking water is 12 mg/l. no distinct variation was observed in potassium

Table 2. Values of different cations in groundwater at different places in Bhubaneswar

Location/Year	2010				2011			
	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)
Tankapani Road	36	7.29	41.3	7.4	28	4.79	19.93	9.4
Dumduma.	18	4.86	27.5	28	32	5.06	23.95	16
Aigania	20	4.86	36.8	32	24	8.5	45.5	11.7
Jagamara.	16	6.075	24.4	14.5	46	10.94	46.5	16.5
DharmaVihar	8	3.645	9.4	1.5	56	7.64	42.7	49
Nayapalli	16	6.075	21	12	34	12.15	57.8	8
Shastri Nagar	58	13.37	58	10.2	6	8.5	33.5	3.9
Unit-4	50	10.94	47.2	5.7	40	1.94	34.2	7.7
Unit-9	24	4.86	19.9	4.4	24	4.86	26.6	7.9
Unit-2	24	9.72	25.9	9.3	34	7.72	21.9	4.3
Unit-8	22	7.29	25.8	4.6	26	8.505	28.2	9.4
OUAT Colony	8	3.645	22	4.6	18	6.64	42.5	17.6
Ganganagar	14	4.86	14.8	3	28	5.65	64.8	31.5
Forest Park.	12	2.43	16.1	1.3	38	17.01	61.1	16.3
Pokheriput.	6	2.43	5	0.3	50	23.53	53.7	0.9
Kapileswar	30	7.29	31.5	10.9	4	67.70	63.5	16.9
Old Town.	32	12.15	33.5	37	12	62.06	35.9	17
Samantrapur	20	6.075	24.6	9.1	60	14.58	50.6	3.4
BJB Nagar	36	8.505	37.7	12	16	4.50	48.5	1.2
Uparsahi,Bargar	24	10.94	41	21	44	1.41	51.6	1.89
Baramunda	56	9.72	66	86	66	2.22	36	1.6
Jayadev vihar.	8	3.745	20.9	2.4	6	15.74	58.5	7.8
Chadrasekarpur	14	2.43	10.9	1.8	4	4.86	9.43	0.7
Niladri Vihar	14	3.645	18.4	1.6	6	4.86	4.6	0.4
Patia.	14	3.645	19.4	25	16	2.78	49.4	39.7
VSS Nagar	36	9.72	42.1	7.7	6	1.02	6	0.7
Vanivihar.	2	2.43	14.9	1.1	40	4.86	19.5	3.6
Rasulgarh.	20	7.29	23	5.5	27	5.29	13.9	3.7
Laxmi sagar.	76	15.8	78	46	15	5.8	8	4.6
Jharpada	16	2.43	31.5	7.4	6	1.04	61.7	6.45

concentration with depth and season. Potassium plays a vital role in plant metabolism.

Calcium(Ca^{2+})

Calcium is principally responsible for hardness of water. It is one of the very important nutrients required by the organism; however calcium may be injurious to health if the groundwater is excessively hard. Besides, high concentration of calcium in water is not desirable as it suppresses the formation of soap. It coagulates with soap and makes dirty layers on sinks, tubes etc. below the 100 ppm of calcium is suitable for potable water.

The cation Ca^{2+} which is generally more abundant than Mg^{2+} in groundwater together with the later are the main cause of hardness of water. Calcium, magnesium and total hardness in the water are interrelated. The upper limit for calcium for domestic use is 75mg/l. In Bhubaneswar area in 2010 the values of calcium from 2 mg/l to 76 mg/l and in 2011 the values of calcium from 4 mg/l to 66 mg/l (Table 2). According to BIS standards the desirable and permissible limits of calcium are 75 mg/l and 200 mg/l respectively. In both the years all wells were found to have calcium value below the desirable limit of BIS.

Magnesium (Mg^{2+})

Magnesium is an essential and beneficial element for human bodies. Approximately 70 % of the total magnesium content (21 g) of the body is combined with calcium and phosphorous in the complex salts of bone. It is the principal cation of the soft tissue. An adult person needs 200-300 mg magnesium per day. Its deficiency causes depression, muscular weakness, and liability to convulsions. The serum magnesium level is below 1mg/100ml.

Natural water contains some amount of magnesium. It makes the water hard and has similar effect on physical and chemical properties of soil as calcium. In the study area the values of magnesium ranged from 2.43 mg/l to 15.79 mg/l in 2010 and it ranges from 1.02mg/l to 67mg/l (Table 2). According to BIS standards the desirable and permissible limits of magnesium are 30 mg/l and 100 mg/l respectively. In both the years all the wells were found to have magnesium value below the desirable limit of BIS.

Bicarbonate

Bicarbonate and carbonate are usually present in groundwater due to the weathering of carbonate minerals and presence of carbon dioxide, which helps to dissolve these ions and make them readily available (Rain and Thatcher 1960). Sources of carbonate and bicarbonate include CO_2 produced by the biota of soil or by activity of sulfate reducers and other bacteria's in deeper formations and the various carbonate rocks and minerals. Accumulation of sodium bicarbonate as evaporates in closed basin causes high carbonate burial in ground water. The presence of dissolved CO_2 species; carbonate and bicarbonate in almost all-natural water produce the alkalinity and also increase the carbonate hardness of water. Bicarbonate, carbonate and cation equilibrium determine the water pH and holds it reasonably constant for long period of time. It is not harmful to plant directly. In 2010 the values of carbonates range from 24.4 mg/l to 292.8 mg/l and in 2011 the values of carbonates range from 18.3 to 277.9 mg/l.

Chlorides

Chloride is a good indicator of ground water quality. The primary sources of chloride in groundwater are evaporates, salty connate water and marine water. Chloride excess of 100 mg/l imparts a salty taste. The chloride concentration in ground water will increase if it is mixed with sewage or sea water. In 2010, values of chlorides range from 10.635 mg/l to 116.99 mg/l and in 2011, values of chlorides ranged from 10.63 mg/l to 106.35 mg/l (Table 3). According to BIS standards, the desirable and permissible limits of chloride are 250 mg/l and 1000 mg/l, respectively. In both the years, no well was found to have chloride value above the desirable limit of BIS. Higher value of chloride causes high blood pressure and salty taste of water. Sources of chloride in ground water are fertilizer, industrial waste and sea water. It can be treated by reverse osmosis and distillation.

Nitrates

The principal sources of nitrate in water are nitrogen fixing plants legumes, bacteria, chemical fertilizers, sewerage and decaying organic matter etc. The presence of nitrate in ground water is an indication of very recent sewage contamination. In 2010, values of nitrates range from 0 mg/l to 50.85 mg/l and in 2011, it ranges from 0.86 mg/l to 68.56 mg/l (Table 3). According to BIS standards, the desirable limits of nitrate in ground water are 45 mg/l. In both the years, many wells were found to have nitrate value less than the desirable limit of BIS. Higher value of nitrate causes blue baby

Table 3. Values of different anions (mg/l).in groundwater at different places in Bhubaneswar

Location/year	2010				2011			
	Cl^-	SO_4^{--}	HCO_3^-	NO_3	Cl^-	SO_4^{--}	HCO_3^-	NO_3
Tankapani Road	77.99	6.91	115.9	0	64.08	2.37	134.9	0
Dumduma	46.09	0	79.3	22.4	78.09	0	89	21.6
Aigania	70.9	11.51	42.7	39.7	81.53	3.37	32.5	38.9
Jagamara	53.18	0	91.5	0	70.9	16.9	164.7	0
DharmaVihar	17.73	0	36.6	0	75.73	0	66.6	0
Nayapalli	28.36	49.4	36.6	0.021	16.35	40.08	115.9	0
Shastri Nagar	81.54	49.9	176.9	2.74	49.63	7	30.5	2.14
Unit-4	77.99	0	183	0.931	97.99	0	267	0.89
Unit-9	35.45	7.1	73.2	0.06	31.9	28.2	48.8	0
Unit-2	49.63	7.79	91.5	2.19	50.33	1.79	101	5..41
Unit-8	53.18	0	73.2	1.93	42.54	0	73.2	1.93
OUAT Colony	53.18	0	48.8	0	102.01	0	117.5	0.93
Ganganagar	28.36	0	61	0	82.16	0	71.34	0
Forest Park	31.91	0	36.6	0	70.91	1.75	213.5	1.01
Pokheriput	10.64	0	30.5	0	70.64	0.7	45.5	0
Kapileswar	49.63	0	128.1	7.41	39.87	0	234.1	7.1
Old Town	60.27	0	189.1	2.04	10.67	0	191.1	2.74
Samantrapur	46.09	0	97.6	0	70.9	0	244	0.86
BJB nagar	60.27	14.71	134.2	2.11	40.97	9.89	274.9	2.78
Uparsahi, Bargar	60.27	15.47	115.9	19.24	13.37	12.3	178.9	19.81
Baramunda	102.8	12.25	268.4	41.01	26.8	11.5	277.9	36.90
Jayadev vihar	42.54	0	36.6	0	49.6	0	125.9	0
Chadrasekarpur	28.36	0	30.5	0.03	21.28	0	67.7	0.20
Niladri Vihar	31.91	0	54.9	0	10.63	0	24.4	0
Patia	31.91	0	61	29.69	67.79	0	163	27.13
VSS Nagar	63.81	0	128.1	19.26	11.63	0	18.3	13.27
Vanivihar	21.27	0	24.4	0	31.9	2.37	122	0.20
Rasulgarh	39	0	79.3	13.07	45.9	0	135.3	15.14
Laxmi sagar	11.7	14.21	292.8	50.85	11.7	7.8	186.8	48.58
Jharpada	42.54	13.76	48.8	9.32	62.79	10.78	85.90	9.02

disease in infant. Sources of nitrates in ground water are fertilizer, waste water and natural deposit.

Sulphate

Sulphate ion is one of the major anions occurring in natural waters. It is of importance in public water supplies because of its catheratic effect upon humans when it is present in excessive amounts. In 2010, the values of sulphates range from 0 mg/l to 49.9 mg/l and in 2011, it ranged from 0 to 40.08 mg/l (Table 3).

According to BIS standards, the desirable and permissible limits of sulphates are 200 mg/l and 400 mg/l, respectively. In both the years, all the wells were found to have sulphate value below the desirable limit of BIS. Sources of sulphate in ground water are animal sewage, septic tank and industrial wastes. It can be treated by reverse osmosis and distillation.

Fluoride

Fluoride in small amount is necessary for good health for preventing dental carries but high concentration causes health risk. Fluoride bearing minerals in the rocks and their interaction with water and agricultural activities are considered to be the main cause for fluoride in ground water. In 2010, the values of fluoride range from 0.11 mg/l to 1.27 mg/l and 2011, the values of fluoride range from 0.08 mg/l to 0.827 mg/l (Table 4). According to BIS standards the desirable and permissible limits of fluoride are 1 mg/l and 1.5 mg/l, respectively. In 2010, only one well was found to have fluoride value above the desirable limit of BIS

whereas ion 2011, water of all the wells were safe. Sources of fluoride in groundwater are industrial wastes and geological wastes. It can be treated by reverse osmosis and ion exchange.

Iron

The presence of iron in ground water is not anthropogenic and is harmful to human health. The presence of iron may be due to iron bacteria in ground water. In 2010 the values of iron range from 0 mg/l to 2.202 mg/l and in 2011 the values of iron range from 0.017 mg/l to 4.44 mg/l (Table 4). According to BIS standards the desirable and permissible limits of iron are 0.32 mg/l and 1 mg/l, respectively. In the year 2011, 14 wells were found to have iron value above the desirable limit and 10 wells have iron value above permissible limit of BIS. In the year 2010, 8 wells were found to have iron value above the desirable limit and 2 wells have iron value above permissible limit of BIS.

Sodium Adsorption Ratio

In 2010, the SAR value of ground water ranged from 0.43 mg/l to 2.13 mg/l and in 2011, from 0.383 mg/l to 2.796 mg/l (Table 4). In both the years, the SAR value was found to be within the acceptable range given by WHO. Hence the water is suitable for irrigation purpose.

Heavy Metals in Groundwater

Presence of different heavy metals like manganese (Mn), Chromium (Cr), Cadmium (Cd) and Lead (Pb) in the groundwater samples of

Table 4. Values of fluoride (F^-), iron (Fe) in mg/l. and sodium adsorption ration (SAR) in groundwater at different places in Bhubaneswar

Location/Year	2010			2011		
	F^-	Fe	SAR	F^-	Fe	SAR
Tankapani Road	0.462	0	1.639	0.311	0.99	2.027
Dumduma	0.142	0.84	1.483	0.245	0.77	2.596
Aigania	0.158	0.29	1.912	0.08	0.41	2.028
Jagamara	0.158	0.1	1.316	0.08	0.53	1.59
DharmaVihar	0.174	0.08	0.691	0.114	6.078	1.678
Nayapalli	0.222	0.34	1.132	0.124	0.371	2.162
Shastri Nagar	0.398	0.202	1.783	0.111	4.514	2.063
Unit-4	0.27	0.436	1.574	0.086	2.031	1.77
Unit-9	0.254	0.158	0.967	0.109	0.136	1.2930
Unit-2	0.222	0	1.126	0.324	2.056	2.045
Unit-8	0.158	2.202	1.217	0.158	2.202	1.217
OUAT Colony	0.11	0.083	1.617	0.413	1.83	2.32
Ganganagar	0.148	1	0.868	0.493	1.678	1.108
Forest Park	0.142	0.114	1.107	0.220	2.08	2.068
Pokhariput	0.174	0	0.435	0.827	4.25	1.15
Kapileswar	0.249	0.114	1.337	0.112	4.44	2.733
Old Town	0.457	0.058	1.277	0.235	1.28	2.732
Samantrapur	0.158	0	1.235	0.08	0.26	1.518
BJB Nagar	0.158	0.108	1.466	0.048	0.123	2.236
Uparsahi,Baragarh	0.2	0	1.74	0.017	0.784	2.74
Baramunda	0.377	0.272	2.139	0.167	1.634	2.739
Jayadev vihar	0.169	0.366	1.536	0.196	3.056	2.095
Chandrasekharpur	0.126	0.573	0.706	0.121	1.808	0.748
Niladri Vihar	0.19	0.146	1.131	0.091	0.017	0.338
Patia	0.291	0	1.193	0.042	0.028	2.053
VSS Nagar	0.217	1.438	1.605	0.034	0.067	0.673
Vanivihar	0.153	0.09	1.673	0.108	0.213	0.713
Rasulgarh	0.27	0.045	1.118	0.067	0.279	2.076
Laxmi sagar	1.27	0	2.124	0.348	0.453	0.453
Jharpada	0.233	0.278	1.937	0.113	2.157	1.747

Table 5. Values of different heavy metals (micro gram per liter) in groundwater at different places in Bhubaneswar

Location/Year	2010				2011			
	Mn	Cr	Cd	Pb	Mn	Cr	Cd	Pb
Tankapani Road	47	2	nd	30	45	3	nd	32
Dumduma	57	nd	1	26	55	nd	1	25
Aigania	381	nd	1	26	312	nd	1	27
Jagamara	26	1	nd	1	28	1	nd	4
DharmaVihar	13	nd	2	11	15	nd	1	12
Nayapalli	27	nd	nd	14	25	nd	1	13
Shastri Nagar	204	1	nd	9	201	nd	nd	8
Unit-4	288	nd	nd	nd	278	1	nd	nd
Unit-9	115	nd	nd	nd	103	nd	nd	nd
Unit-2	45	nd	nd	nd	39	nd	nd	nd
Unit-8	6	nd	1	3	4	nd	1	2
OUAT Colony	34	nd	2	nd	32	1	2	nd
Ganganagar	52	nd	1	nd	51	2	1	nd
Forest Park	88	nd	2	1	77	2	2	1
Pokhariput	126	nd	2	nd	105	2	2	nd
Kapileswar	358	nd	2	nd	367	2	2	nd
Old Town	269	nd	1	4	274	1	nd	3
Samantrapur	66	nd	3	nd	68	2	2	nd
BJB Nagar	22	nd	2	6	20	2	2	5
Uparsahi,Baragarh	74	nd	2	nd	71	3	2	nd
Baramunda	65	nd	2	nd	60	nd	2	nd
Jayadev vihar	79	nd	2	nd	82	nd	2	nd
Chandrasekharpur	102	nd	1	nd	100	nd	1	nd
Niladri Vihar	77	nd	2	4	70	nd	2	3
Patia	234	nd	2	5	247	1‘	2	5
VSS Nagar	120	nd	nd	nd	135	nd	1	nd
Vanivihar	156	nd	nd	nd	145	nd	nd	nd
Rasulgarh	35	nd	nd	nd	32	nd	nd	nd
Laxmi sagar	90	nd	nd	nd	83	1	nd	nd
Jharpada	62	nd	nd	2	57	nd	1	3

N.B. nd-Not detectable

various places for both the years 2010 and 2011 were determined and are shown in Table 5.

Studies of heavy metals/trace metals (Table-5) indicate that Chromium, Cadmium, Manganese and Lead are found in traces in the ground water in many places. Even the trace metals like Chromium, Cadmium, and Lead were not detected in many of the wells in Bhubaneswar in both the years. Thus, from the point of view of the presence of concentration of trace or heavy metals, it may be inferred that ground water in many places in Bhubaneswar is safe for drinking for the time being.

CONCLUSION

In this paper, various ground water qualities of different wells of 30 places covering the whole capital city of Bhubaneswar, Odisha was analysed for two years (2010 and 2011) to ascertain whether the water is suitable for domestic uses or not. Different parameters as associated with drinking purposes like pH, TDS, EC, different anions and cations, iron and fluoride as well as heavy metals like manganese, chromium, cadmium, and lead were evaluated using standard procedure. Values of pH of the water are found to vary from 4.93 to 7.5 in 2010 whereas in 2011, it is found to vary from 5.56 to 7.6. The electrical conductivity of the groundwater was found to vary from 111 μmhos/cm to 980 μmhos/cm in both the years. In the year 2010, the TDS of ground water was found to vary from 92 mg/l to 737 mg/l. In the year 2011, TDS varied from 85 mg/l to 731 mg/l which shows that water is safe for drinking being within the

permissible limit. However, wells of some places contain ground water having more concentration of iron which needs attention for amelioration. The concentration of sodium and magnesium in the water bodies are low in comparison to permissible limit. Since the SAR values are within the permissible limit value given by WHO, the water is suitable for drinking as well as irrigation purpose. Evaluation of different quality parameters of two years indicate that ground water presently is safe for drinking in almost all places in Bhubaneswar.

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Artificial conservation measures on groundwater recharge, irrigation potential and productivity of crops of Bharkatia Watershed, Odisha

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ABSTRACT

A study was undertaken in Bharkatia watershed in Athagarh Block of Cuttack District, Odisha during 2011-2014. The objective of the research work was to study the recharge of groundwater through different recharge structures like dug wells, tanks, recharge pit, tube wells, check dams etc., the resulting rise of ground water level and study the impact on increasing irrigation area, production and productivity of different crops in the watershed. Up to the year 2011, no conservation measures were taken up in the watershed. However, in 2011, twenty recharge dug wells, twenty recharge farm ponds, two recharge tube wells, 1120 recharge pits and one check dam were constructed in the watershed. Data on groundwater table rise, irrigation area and productivity of different crops throughout the study period of 4 years were collected and anlysed. The study reveals that average groundwater table came up by 0.27, 0.40 and 0.35 m during pre-monsoon, monsoon and post-monsoon periods in 3 years period after construction of various conservation structures with an average rise of 0.34 m. Increased groundwater recharge helped in augmenting the groundwater potential in the watershed. Because of increased groundwater irrigation, the cropped area in the watershed increased by 308 ha in 3 years period. The productivity of different crops also increased. The yield of *kharif* and *rabi* paddy increased by 36.8 and 17.1% in 2014 as compared to 2011 when no conservation measures were taken up for groundwater recharge. The yield of other crops including vegetables also increased substantially due to application of more irrigation water from the raised groundwater table.

Key words: Groundwater, *Kharif*, Monsoon, *Rabi*, Recharge, Summer, Production, Productivity, Watershed

INTRODUCTION

Land and water are the two most vital natural resources Due to urbanization and industrialization, per capita availability of cultivated land in the country have declined from 0.48 ha in 1951; 0.20 ha in 1980 to 0.1 ha in 2010. Prime soil resources of the world are finite, and prone to degradation through misuse and mismanagement. Like soil, the availability of fresh water is declining day by day. With the projected population growth, urbanization and industrialization, the average per capita water availability may decline to about 1200 m^3 by 2050. As a result, the share of water for irrigation may decline to 70% in 2050 as compared to its 84% share being available now (Panigrahi, 2011).

Eastern India including the state of Odisha, is bestowed with ample rainfall resources with average annual rainfall of 1500 mm, 80% of which is received during the rainy season between June to September. During this period, about 50% of the annual rainfall comes from a few intense storms (Pisharoty, 1990). Such intense storms give rise to high runoff and the consequent soil and nutrient losses. The fate of millions of poor farmers in the region can be greatly improved by use of technological advances such as effective rainwater conservation and management. Rainwater conservation may be achieved in any of the following three ways: in soil reservoir, in surface reservoir and in groundwater reservoir. Among these three, conservation in groundwater reservoir is the best option, as it does not require vast areas for water storage. Conservation of water in soil reservoir though is the cheapest method but the stored soil moisture cannot held it for a long period. Conservation of in-situ rainfall as well as surface runoff in the form of groundwater recharge is also a cheap and eco-friendly method.

Artificial recharge is the planned, man-made increase of groundwater levels, and is becoming increasingly relevant in India. In 2007, on the recommendations of the International Water Management Institute, the GoI allocated Rs 1800 crore to fund dug-well recharge projects in 100

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districts in seven states where water stored in hard-rock aquifers had been over-exploited.

Watershed management including soil and water conservation measures plays a crucial role in increasing groundwater recharge. Prasad (1999) studied the impact of watershed management including contour bund, graded bund etc. in the degraded watershed and reported that these structures could substantially increase the groundwater status in Chhaljawa watershed of Baran district of Rajasthan that augmented the production and productivity of different crops. Panda (2009) constructed various soil and water conservation measures like trenching, bunding, loose boulder check dams, ponds and other water harvesting structures in the Barapitanala watershed of Odisha and found that the groundwater level increased successively that resulted in increasing the irrigated area in the watershed by 2.53 times within a period of 4 years. Sharda *et al.* (2005) also studied the impact of participatory watershed management and observed that the groundwater recharge could be facilitated due to the construction of various soil and water conservation structures in the watershed. Similar conclusions on enhancement of groundwater recharge by soil and water conservation measures have been reported by other researchers (Mondal *et al.*, 2006; Goel *et al.*, 2007; Kumar and Kumar, 2015; Kumud *et al.*, 2016). Panda (2009) observed the water table level in wells in watershed areas with various soil and water conservation measures to rise by 3.9 m more as compared to the non watershed areas.

The objective of the present research work is to study groundwater recharge through different water conservation structures such as dug wells, tanks, recharge pit, tube wells, check dams etc. through water table rise and its impact on increasing irrigation area, production and productivity of different crops in the watershed.

MATERIALS AND METHODS

The study was undertaken during 2011-2014 in Bharkatia watershed in Athagarh Block of Cuttack District, Odisha. The watershed is located 15 km away from the river Mahanadi. The project area is located at 20°31′20′′ to 20°34′45′′ N latitude and 85°17′05′′ to 85°50′55′′ E Longitude. The project area covering an area of 20 km^2 includes the villages: Jemadeipur, Kusupangi, Sarkoli, Korikol, Chabjaunri, Torada, Parbatia, Gurudijhatia, Kotar, Pithakhia, Ramchandrapur, Radhapriya, Balisasan, Bali, Sitarampur, Oranda, Chotiamba and Kaduanuagaon. The area gets an average annual rainfall of 1450 mm in 72 rainy days with 78% occurring in 4 rainy months from June to September. Rainfall distribution is very erratic and uneven. The maximum temperature in the area goes up to 46 °C in May and the minimum temperature goes down 8 °C in the month of December. Relative humidity ranges from 43 to 91%. The watershed is generally flat (fan shaped) with undulating topography. Physiographically the zone is located in the coastal belt and has an altitude ranging from 38 to 65 m above msl. The soil is mostly sandy loam to sandy clay loam of about 90 cm depth. Table 1 represents the various morphometric parameters related to the watershed.

Soil and Water Conservation Measures/Structures

Recharge pits, Recharge ponds, Recharge dug wells, Renovation of medium irrigation (MI) tanks, Renovation of existing ponds, Check dams and Recharge tube wells were constructed in the watershed in consultation with the farmers and the Soil Conservation Department. Periodically the groundwater table position in various tube wells and dug wells were measured for three consecutive years i.e. 2012, 2013 and 2014 at various locations. Descriptions of different structural measures are as follows:

Table 1. Morphometric parameters of watershed

Sl. No.	Morphometric parameters	Value	Sl. No.	Morphometric parameters	Value
1	Stream order	III	6	Basin parameter, km	14.47
2	Number of streams				
	I	5	7	Basin area, km^2	15.70
	II	2	8	Drainage density, km^{-1}	0.85
	III	3	9	Length of overland flow, km	0.68
3	Stream length, km				
	I	5.45	10	Circulatory ratio	0.98
	II	4.87	11	Elongation ratio	0.88
	III	1.78	12	Stream frequency (per km^2)	0.64
4	Length ratio	1.40	13	Bifurcation ratio	2.72
5	Basin length, km	5.66	14	Form factor	0.60

Recharge Dug wells

Twenty recharge dug wells were excavated to a depth of 9 m in sloping lands nearer to the renovated ponds. Diameter of the dug wells were 3.5 m each. Excess water after filling the pond was allowed to enter into the constructed dug wells. In addition, the runoff from the sloping catchment was also channelized to these dug wells. The dug wells were back filled with gravel and sand charcoal layer by layer to facilitate in recharging the dried aquifer. The effect of recharged runoff water on groundwater levels were regularly observed in 7 observation wells in the entire watershed. These 7 observation wells are located in the villages Chhotiamba, Kaduanuagaon, Parbatia, Gurudijhatia, Oranda, Chabjaunri and Jemadeipur. The recharge water is guided through a pipe to the bottom of well or below the water level to avoid scouring of bottom and entrapment of air bubbles in the aquifer.

Recharge Ponds

Twenty ponds of size 15 m x 10 m (bottom dimensions) and depth 2.5 m were excavated in the lateritic sloping open fields in the watershed. The recharge ponds were constructed near the dug wells. Initial depth of the pond (constructed in two compartments) in the lower compartment was 1 m and the depth of the upper compartment was 1.5 m (Fig. 1). Top dimensions of the ponds were 20 m x 15 m. It was observed that entire volume of water that enters the small ponds percolated down into the aquifer within a week, as the beds are totally lateritic. Fig. 1 shows the plan and cross section of the constructed recharge pond. Stone packing on upstream side of the pond was undertaken to avoid soil erosion. The length, breadth and height of stone packing were 15 m, 2.45 m and 0.3 m, respectively.

Recharge Tube Wells

In the watershed, two numbers of recharge tube well were constructed. The first was in the village Sitarampur and the second one in village Pithakhia. The depth of the tube wells were 148.2 m. The total volume of excavation for each tube well was found to be 108 m^3. The tube well was put inside a recharge pit of dimension: length = 6 m, width = 6 m and depth = 7 m. The pit was packed with alternate layers of sand and pebbles as shown in Fig. 2.

Recharge Pit

Recharge pits are constructed for recharging the shallow aquifer. Recharge pit may be circular, square or rectangular in cross section. If the pit is of trapezoidal shape, the side slopes should be steep enough to avoid silt deposition. In the present case

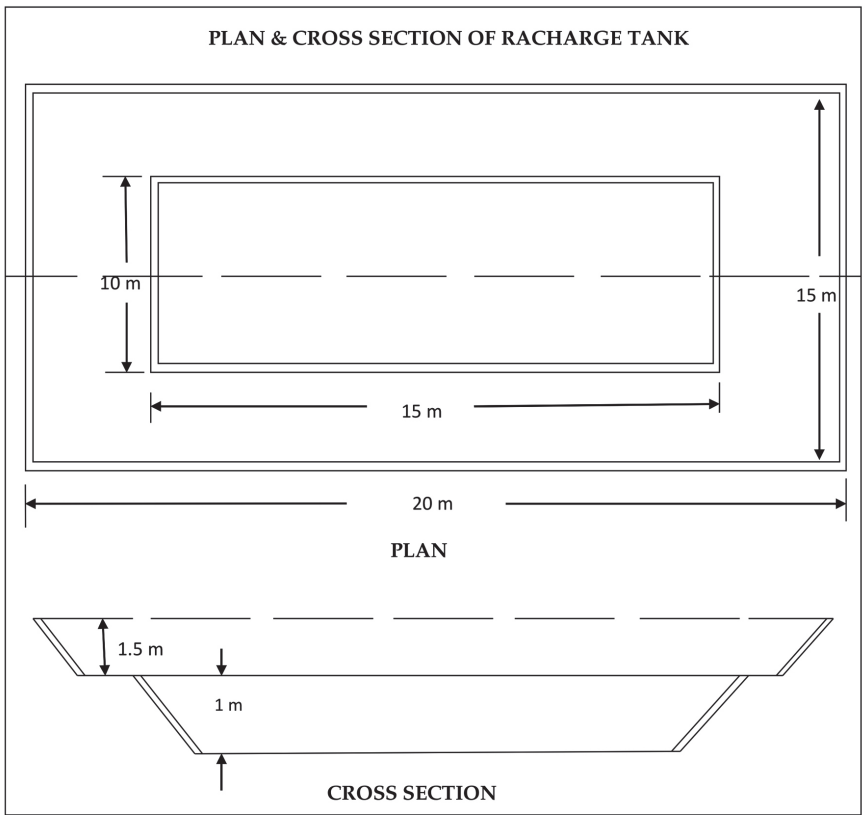

Fig. 1. Plan and cross section of recharge pond

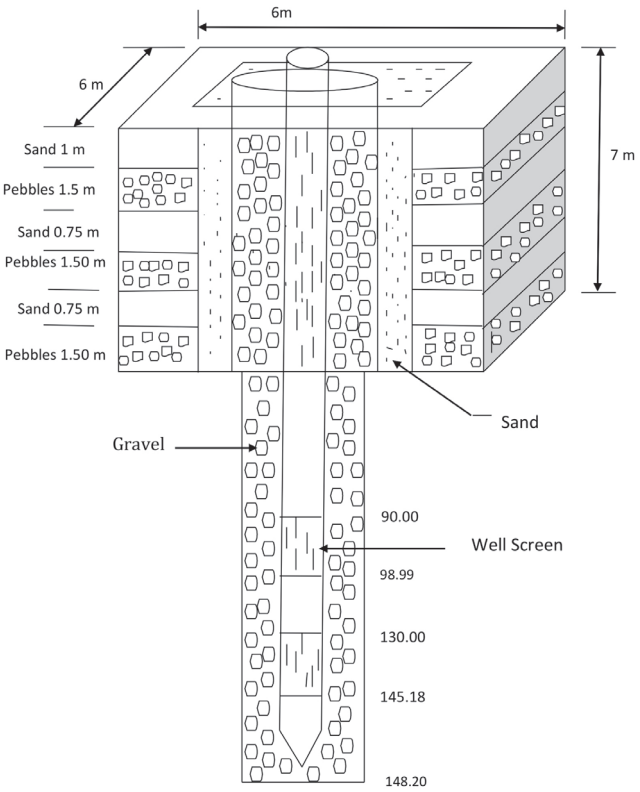

Fig. 2. Plan and cross section of recharge tube well

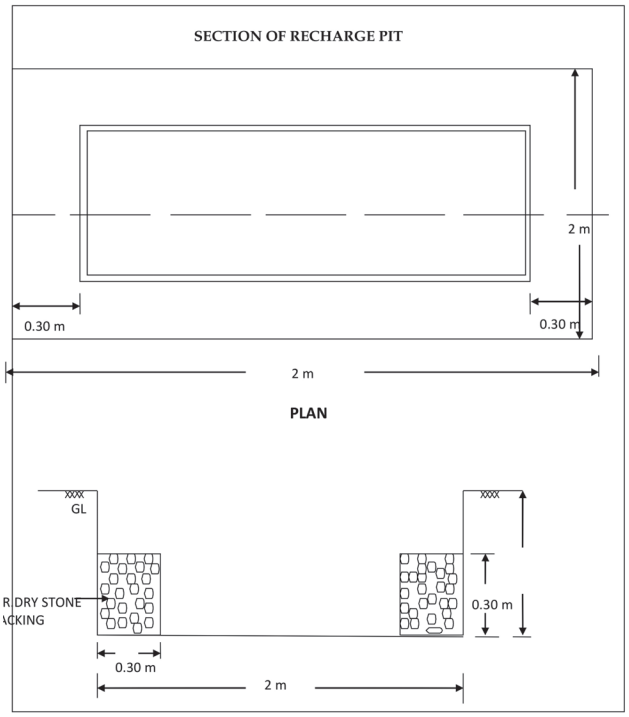

Fig. 3. Section of a recharge pit

Fig. 4. Preparatory work for construction of check dam

Fig. 5. Check dam for groundwater recharge

the recharge pits were rectangular in shape. Recharge pits were excavated and filled with dry rubble stone on the upstream side. The length, breadth and height of the recharge pit were all equal to 2 m. The length, breadth and height for random rubble dry packing were 2 m, 2 m and 0.3 m, respectively and volume of random rubble dry packing upstream of recharge pit was 1.20 m^3. In the watershed, total 1120 numbers of recharge pits were constructed at different places. Fig. 3 shows the section view of recharge pit.

Recharge through Check dam

One check dam was constructed in the Barakatia Nala. The check dam arrested the flow of the nala partially thus enhancing the scope of ground water recharge. Besides augmenting the recharge, the structure is used to facilitate flow irrigation of about 20 ha of land. Fig. 4 shows the preparatory work for construction of check dam. Fig. 5 shows the check dam in the watershed.

The different structures as mentioned above were constructed at various places in the watershed. The construction was over in the year 2011. Data on groundwater table, area coverage of different crops and their productivity in the watershed were collected for three years i.e. 2012, 2013 and 2014. For comparison, data on groundwater table position in the watershed in the pre-treatment period i.e. 2011 were also collected on daily basis. Data on area covered by different crops, and productivity of different crops in the watershed in the pre-treatment period i.e. 2011 were also collected. Because of several constraints including man power, funds etc. it was not possible to monitor the groundwater levels in all the wells in the watershed. For this, representative locations were selected. In this study, the groundwater levels were measured in each week for three years (2012 to 2014) in 7

Table 2. Average depth of water level in dug well (below ground level, m) in different places in the watershed

Location Week*	Chhotiamba	Kaduanuagaon	Parbatia	Gurudijhatia	Oranda	Chabjaunri	Jemadeipur	In whole watershed
1-4	8.92	9.0	9.0	8.97	8.825	9.02	9.05	8.96
5-8	9.42	9.52	9.42	9.47	9.425	9.37	9.35	9.41
9-12	9.6	9.62	9.87	9.92	9.65	9.62	9.67	9.7
13-16	9.17	9.25	9.42	9.35	9.5	9.67	9.47	9.4
17-20	9.75	9.67	9.77	9.75	9.95	10.07	9.77	9.8
21-24	10.17	10.22	10.32	10.12	10.27	10.47	10.2	10.25
25-28	9.1	9.15	9.37	9.27	9.3	9.25	9.27	9.24
29-32	8.15	8.27	8.4	8.42	8.05	8	8.27	8.22
33-36	7.45	7.47	7.4	7.2	7.22	7.42	7.57	7.38
37-40	7.57	7.57	7.62	7.2	7.47	7.42	7.27	7.44
41-44	8.1	8.1	8.65	8.15	8.15	8.3	8.1	8.21
45-48	8.8	8.65	9.02	8.82	8.72	8.82	8.95	8.82
49-52	8.92	9.0	9.17	8.95	9.1	8.9	8.9	8.98

N.B. * Standard meteorological week which starts as week 1 from Jan. 1 to Jan. 7, week 2 from Jan. 8 to 14 etc.

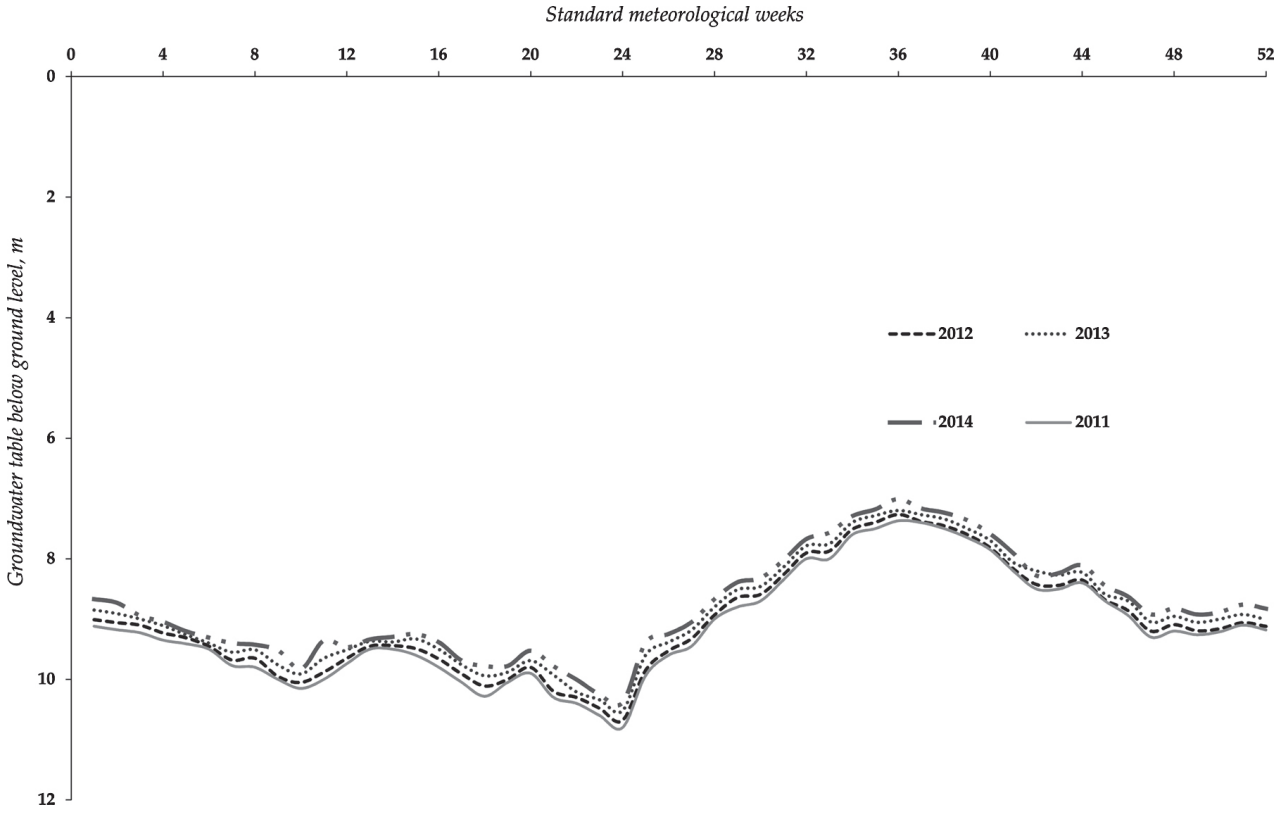

Fig. 6. Groundwater table position in the watershed in different years due to groundwater recharge

representative stations as mentioned in Table 2. The average groundwater table data (average of 2012, 2013 and 2014) of these stations are presented in Table 2. Groundwater table positions in the entire watershed for different years on weekly basis are shown in Fig. 6. Area coverage and productivity of crops grown in the entire watershed for various years are presented in Table 3.

RESULTS AND DISCUSSION

Effect of Different Conservation Measures on Ground Water Recharge

In this study the impact of different water conservation measures were studied on rise of ground water table. The construction of different conservation measures were completed by 2011. The groundwater table during pre-conservation

Table 3. Area (ha) coverage of different crops in the watershed in different years

Crops	Area covered, ha				Productivity of crops, q/ha			
	2011	2012	2013	2014	2011	2012	2013	2014
Paddy (*Kharif)*	700.4	740.6	785.5	805.5	20.1	23.2	25.3	27.5
Paddy *(Rabi)*	135.3	155.3	205.2	259.1	25.8	28.3	29.5	30.2
Mustard	8.2	10.3	12.6	15.3	7.1	8.6	8.8	9.1
Sunflower	2.1	2.0	5.5	7.8	12.2	17.5	18.3	18.0
Maize	20.2	22.6	24.5	28.3	37.5	45.8	49.5	54.6
Potato	3.2	5.1	7.3	10.2	108.3	120.9	128.2	132.7
Tomato	4.5	6.0	9.9	15.6	122.3	140.2	138.9	148.3
Brinjal	15.8	17.3	20.5	21.3	150.4	168.8	170.6	170.5
Chili	15.3	17.7	26.0	25.2	28.5	30.7	35.6	37.2
Cowpea	14.0	15.1	17.3	19.0	80.2	83.6	85.2	82.0
Raddish	2.3	2.2	4.5	6.6	70.5	80.2	86.4	95.2
Cauliflower	3.3	4.9	6.0	7.2	150.3	164.7	168.2	170.3
Cabbage	3.6	6.3	8.0	10.1	180.2	185.5	196.4	201.2
Sugarcane	-	1.1	2.5	5.0	-	378.5	381.6	380.2

period i.e. 2011 was measured on daily basis and the average weekly values were calculated. The water table below ground level varied from 7.37 m to 10.8 m. The water table was shallow during the monsoon because of higher recharge on account of rainfall. Water table positions were found to be deeper during the pre-monsoon period (Fig. 6) due to scanty rainfall. Further, withdrawal of groundwater for irrigation during the post monsoon period and for domestic use throughout the year causes water table to decline. The water conservation and recharge measures generally caused a rise in water table in the watershed.

Further, the groundwater table rose gradually over the years in all places in the watershed, as may be seen from Fig. 6.

Effect of Ground Water Recharge on Enhancing Irrigation Potential and Productivity

The groundwater recharge helped in augmenting the groundwater potential. The raised groundwater table helped the farmers to discharge more ground water through different pumps and other water lifting devices. As a result, area under irrigation of different crops increased and ultimately production and productivity of different crops also increased. In addition to groundwater recharge, several structures were directly used as surface water storage reservoir which helped in facilitating direct flow irrigation to the crop fields. For example, construction of a check dam in Barakatia Nala helped to provide flow irrigation to 20 ha area. These 20 ha area mainly covered paddy (15 ha) and vegetables (5 ha). Construction of two recharge tube wells in the village Sitarampur and Pithahkhia helped in augmenting groundwater resources by recharging excess rainwater in the area. These two wells were used as discharge wells also for irrigation purposes. On an average they irrigated 50 ha area each in *rabi* and summer and when required to *kharif* crops too. These tubewells mainly irrigate paddy crops and oilseed crops.

In the pre-treatment period, the total area cultivated was 928.2 ha out of which *kharif* paddy covered 700.4 ha (75.5%). Since, paddy is the staple food in the region and in *kharif* season there is abundant rainfall, farmers prefer to go for cultivating more paddy in the region. As shown in Table 3, area covered by other crops in the watershed is less. In *rabi* and summer seasons, the area receives scanty rainfall. The groundwater level is at deeper level and the watershed has no facility for canal irrigation. Hence, very less area is covered by crops in *rabi* and summer in 2011. However, after the imposition of different soil conservation measures, groundwater recharge increased which augmented the groundwater resources in the area. As a result more area came under irrigation and the cropped area increased from 928.2 ha in 2011 to 1006.5 ha in 2012 (8.43% more than 2011). Percentage area increased to 22.31 and 33.1 in 2013 and 2014. Thus, there was an additional 308 ha more crop area in 3 years period. Out of these 308 ha additional crop area, *kharif* paddy and *rabi* paddy accounted to 105.1 and 123.89 ha, respectively. Rest 79.1 ha was occupied by oil seeds and vegetables. Even, it is surprising that there was no sugarcane

in the study watershed but after increase of groundwater table some farmers started growing it. In 2014, 15 farmers in the watershed grew sugarcane in 5 ha area.

Productivity of different crops in the watershed also increased gradually due to application of frequent irrigation water (Table 3).

Yield of vegetables like potato, tomato, cabbage, cauliflower, radish, chili, and brinjal increased from 2.0 to 35.5%. Comparing the productivity of different crops in 2014 than 2011; the highest increase in yield was recorded for the crop sunflower (47.5%) followed by maize (45.6%). Thus the study reveals that construction of various soil and water conservation measures like recharge pit, recharge pond, recharge dug well, check dams and recharge tube wells helped in raising the ground water table through groundwater recharge and consequently enhancing cropped area, production and productivity of various crops in the watershed. It is expected that if the sustainability of the system continues, then in about 10 year's period, groundwater may come up by about 3 m and productivity of crops may increase by 50% in the watershed.

CONCLUSION

The comparison of water table in Barkatia watershed during 4 years of study period (2011 to 2014) shows that there is a trend of rising water table during different years after imposition of different soil and water conservation measures in the watershed. Average groundwater table came up by 0.27, 0.40 and 0.35 m during pre-monsoon, monsoon and post-monsoon periods in 3 years period after construction of various conservation measures with an average rise of 0.34 m. Groundwater recharge in the watershed helped in rising the groundwater level and increased the groundwater potential which helped in supplying more irrigation to different crops. Because of increased groundwater irrigation, the cropped area in the watershed increased by 308 ha in 3 years period. The productivity of different crops also increased. The yield of *kharif* and *rabi* paddy increased by 36.8 and 17.1% in 2014 as compared to the pre-treatment period i.e. 2011. The yield of other crops including vegetables also increased substantially. It is expected that if the sustainability of the system continues, then in about 10 year's period, groundwater may come up by about 3 m and productivity of crops may increase by 50% in the watershed. This will ultimately increase the livelihood status of the farmers in the watershed.

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Variations in some soil physical properties, micronutrient distribution and its stock under high density guava orchard ecosystem

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ABSTRACT

Long term orchard management may impact the soil properties over the period of orchard management. Estimating such variations is essentially important for evolving a strategic/sound nutrient management module. The present investigation was therefore aimed to assess the variations in some soil physical properties, micronutrients and its stock under long-term orchard ecosystem of guava cv. Lalit (555, 277 and 5000 plants ha^{-1}) with spacing of 3×6 m, 6×6 m and 2×1 m. Wide variations in soil properties were observed. Marginal variations in soil bulk density and water holding capacity as affected by different plantations was noted. Porosity of 39.49% was recorded under normal density of 277 plants ha^{-1} while 42.85 and 40.66 per cent in 555 and 5000 plants ha^{-1}. Mean water holding capacity was estimated as 21.44%. Higher DTPA-extractable micronutrients (Zn, Cu, Mn and Fe) were recorded in more densely populated system than normal density. The Zn stock of 2.28, 2.42 and 5.50 kg ha^{-1} was estimated under 277, 555 and 5000 plants ha^{-1}. A lower range of Cu stock (4.85 to 6.89 kg ha^{-1}) across systems was found. Similarly, the highest distribution of Mn stock (29.11 kg ha^{-1}) was found in the category 5000 plants ha^{-1} than 23.98 kg ha^{-1} in 555 plants ha^{-1}. Fe stock with maximum value of 54.96 kg ha^{-1} was estimated in the category of 5000 plants ha^{-1} followed by 39.06 kg ha^{-1} in 555 plants ha^{-1} and the lowest was recorded as 30.85 kg ha^{-1} (normal 277 plants ha^{-1}).

Key words: Different density guava system, micronutrient distribution and stock, physical properties, soil organic carbon, subtropical climate

INTRODUCTION

Soil properties within an orchard vary both in space and time scale (Ping *et al*., 2008). Such variations are a function of climatic factors, management options adopted, biogeochemical processes etc. occurring within the soil (Arora *et al*., 1992). Within-field variations of soil physiochemical and biological properties may arise under differential orchard ground floor management system or even adoption of a uniform management module (Zhou *et al*., 2012). Apart from farm operations, changes in rainfall events coupled with high temperature and evaporation rate make soil drier. Consequent processes like wetting and drying of soil impact significant variations in nutrient release pattern, enzymatic activities, compaction property, water holding capacities, porosity etc. Temporally dependent properties are also adding towards such variations. All these changes untimely contribute to yield variations within fruit orchard, impact quality also (Aggelopoulou *et al*., 2010). Knowledge on such variations of spatially and temporally dependent soil properties and its relationship with growth, development and ultimately yield is thus equally important for adopting site specific nutrient management (Lo´pez-Granados *et al*., 2002). Soil organic matter in turn soil organic carbon is an important soil factor because of its significant influence on physical, chemical and biological processes in soil. Differential SOC content under a given set of management in an orchard is different from different land use pattern i.e. forest ecosystem (Hughes *et al*., 1999), pasture (Kariuki *et al*., 2009), agricultural soils (Manna *et al*., 2013), fruit crops (Bernardi *et al*., 2007). Even such significant variations happened under different agroecological regions (Ayoubi *et al*., 2009). Adak *et al.* (2015) reported that SOC content significantly varied in different density mango plantation system. Volume and rate of decomposition of leaf litter, root dynamics within an ecosystem contributes to the SOC content and its storage in soil (Jha and Mohapatra, 2010). Furthermore vertical distribution

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in SOC content and its storage in soil are also associated with the climatic factors and related vegetation (Jobbagy and Jackson, 2000; Jiang *et al*., 2005). Distribution of soil nutrients i.e. macro or micronutrients under different land use system is also needed for proper nutrient management (Eneji *et al*., 2003).

Guava (*Psidium guajava* L.) is often considered as important economic fruit crop in India and recognized as nutritionally valuable fruit among consumers. It is widely grown even in marginal lands under both tropical and subtropical climatic conditions with wide range of soil management systems. It is normally planted in 6×6 m spacing having plant population of 277 plants ha^{-1}, however, increasing its population per unit area is gaining popularity among farmers (Kumawat *et al*., 2014). Thus, high density guava ecosystem is an important aspect to look into for nutrients variability, its contents and storage in soil. Dey and Singha (1998) investigated the nutritional status of citrus orchards for nutrient variability. Singh *et al.* (2003) reported approaches and strategies for precision farming in guava ecosystem under subtropical climatic condition. Lipiec *et al.* (2005) inferred variations in soil hydraulic and biological properties under long-term orchard management. Gucci *et al.* (2012) observed significantly higher soil macroporosity at the surface (0-10 cm) soil depth in high density olive orchards. Since, such types of information is lacking in high density guava ecosystem under subtropical climatic condition, the present study was thus undertaken.

MATERIALS AND METHODS

The study area is located in Central Institute for Sub-tropical Horticulture, Rehmankhera, Lucknow, Uttar Pradesh, India (Latitude of 26° 54′ N and Longitude of 80° 45′ E with an altitude of 127 m above mean sea level). Guava plants cv Lalit, was planted at a spacing of 3×6 m, 6×6 m and 2×1 m (555, 277 and 5000 plants ha^{-1}) respectively. The existing plantations are being maintained for more than 15 years. Each year uniform canopy management was performed. Crop protection measures were applied uniformly in the entire high density plantation system. Soil samples were collected randomly from ten different sites within each planting system from the root zone depth of 0-30 cm during 2013-15. Soil samples were then air dried and processed (< 2 mm) for chemical analysis. Available micronutrients (Zn, Cu Mn and Fe) were extracted with 0.005 M DTPA, and determined by atomic absorption spectrophotometer. Soil organic carbon content was estimated by chromic acid wet digestion method. For estimating soil physical properties like bulk density, particle density, water holding capacity and porosity, undisturbed core soil samples were collected from each plantation at 0-30 cm soil depth. Total porosity (TP) was calculated as TP (%) = $[\{1- (BD/\rho_s)\}*100]$ where BD is bulk density (g cm^{-3}) and ρ_s is the particle density (g cm^{-3}). DTPA-extractable soil micronutrient stock was estimated for the root zone (0-30 cm) soil depth and calculated as follows: $[M_s = \Sigma(M_c \times \rho \times d)/10]$. Where M_s - micronutrient stock (kg ha^{-1}), M_c - micronutrient concentration (g kg^{-1}), ρ - bulk density (g cm^{-3}), d - soil depth (cm). A descriptive statistical analysis of soil data involving mean value, standard deviations, coefficient of variation, standard error of mean and range across different plantation system was determined. Statistical analysis was performed using SPSS for windows version 12.0. Histograms were developed using SPSS software package. Required correlation graphs were generated using MS Excel software between SOC (%) and micronutrients.

RESULTS AND DISCUSSION

Climatic condition during the study period

The meteorological parameters for the study period are presented in table 1. Agroclimatic analysis indicated that monthly average maximum ambient temperatures varied from 18.6 to 39.4°C and corresponding values for minimum temperatures were 6.0 to 25.5°C. Maximum and minimum relative humidity ranged from 60.1 to 89.1 and 26.4 to 68.4 per cent respectively. The study area received a cumulative rainfall of 1021.8 and 746.7 mm (mean value of 884.3 mm). Majority of the rainfall is received from June to October; however unseasonal rainfall during January and February was also received. Bright sunshine of 3.4 to 9.9 h and pan evaporation of 2.0 to 10.0 mm per day was also recorded.

Dynamics on soil properties

The study indicated variations in soil physical properties under different guava plantation system. The bulk density varied between 1.41 and 1.56 g cm^{-3} while particle density ranged from 2.30 to 2.70 g cm^{-3} under different planting densities. However, pooled value had lower range of 2.43 to 2.53 g cm^{-3}. A porosity of 39.49% was calculated at normal density of 277 plants ha^{-1} while 42.85 and 40.66 per cent in 555 and 5000 plants ha^{-1}. Mean water holding

Table 1. Meteorological condition during the study period (2013-14) at Rehmankhera, Lucknow

Month	Mean Max Temperature (^{0}C)	Mean Min Temperature (^{0}C)	Mean Max. Relative humidity (%)	Mean Min. Relative humidity (%)	Bright Sunshine Hours (h)	Wind velocity (km/h)	Total Rainfall (mm)	Pan Evaporation (mm/day)
January	18.6	6.0	89.1	60.3	3.4	2.4	34.2	2.0
February	22.6	8.9	86.6	50.6	6.2	2.8	66.8	3.1
March	30.2	12.5	77.6	34.8	8.4	3.2	4.9	4.1
April	36.6	16.5	60.1	26.4	9.2	3.7	0.0	7.9
May	39.4	22.5	65.7	35.9	9.9	3.9	0.0	10.0
June	36.5	25.1	78.1	53.2	6.3	4.2	152.4	8.5
July	33.0	25.5	86.2	68.4	5.0	3.5	221.9	6.4
August	33.6	25.0	86.0	65.4	5.7	3.3	201.4	6.5
September	33.6	24.0	84.3	62.1	6.7	2.9	134.1	6.3
October	31.0	19.1	82.3	58.5	6.3	1.8	59.0	5.2
November	27.8	9.5	82.3	37.0	6.7	1.1	0.0	3.8
December	21.2	6.3	86.2	51.6	4.6	1.6	9.7	2.7

capacity was estimated as 21.44%. Of course a range of 19.72 to 23.08% water holding capacity was observed across these densities. Soil organic carbon (SOC) content varied from 0.33 to 0.47% having 277 plants ha^{-1} (normal density planting system) whereas 0.41 to 0.53% and 0.45 to 0.72% in 555 and 5000 plants ha^{-1} respectively (Fig. 2). The available P was 39.2±0.41, 20.18±0.36 and 16.75±0.55 ppm in 5000, 555 and 277 plants ha^{-1} respectively. Similarly higher available K content was recorded in high density system (139.79 and 78.88 ppm in 5000 and 555 plants ha^{-1}) as compared to normal density plantation (62.45 ppm in 277 plants ha^{-1}). Descriptive statistical analysis showed higher variability in porosity and water holding capacity in higher plantation systems (5000 plants ha^{-1}) as

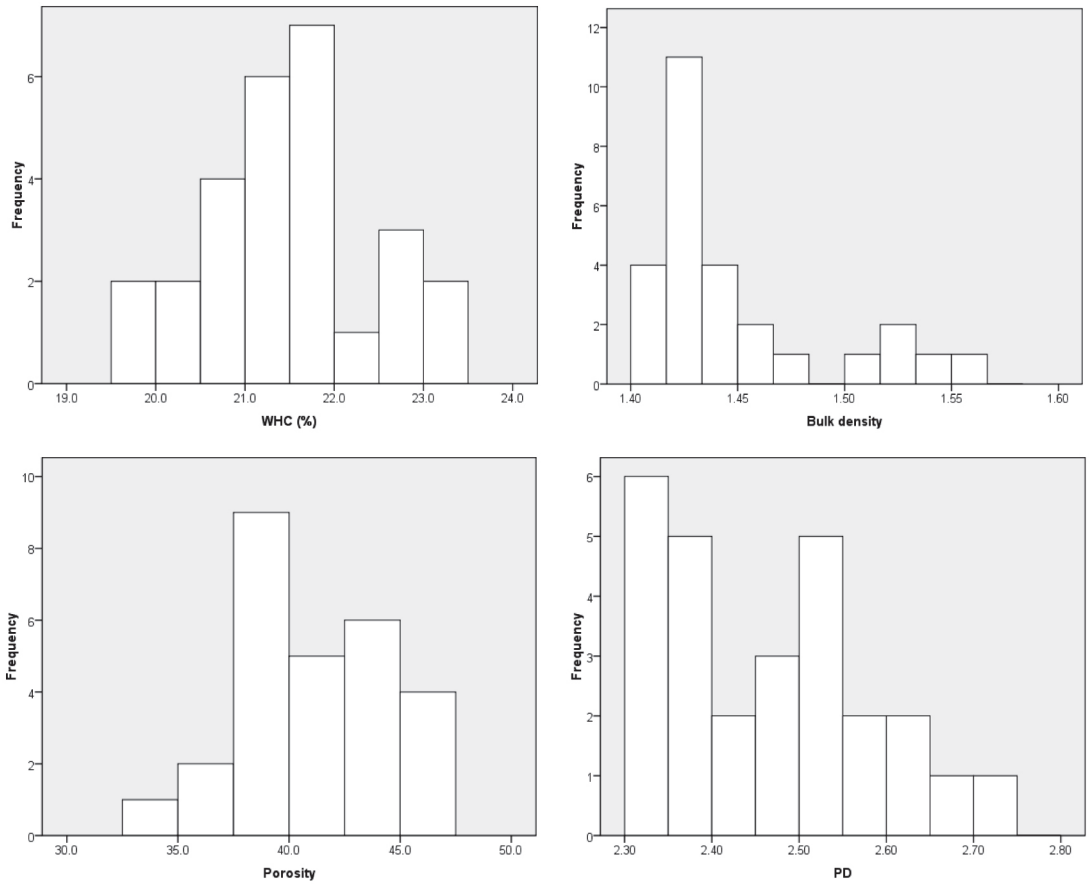

Fig. 1. Histographic distribution of soil physical properties in guava ecosystem

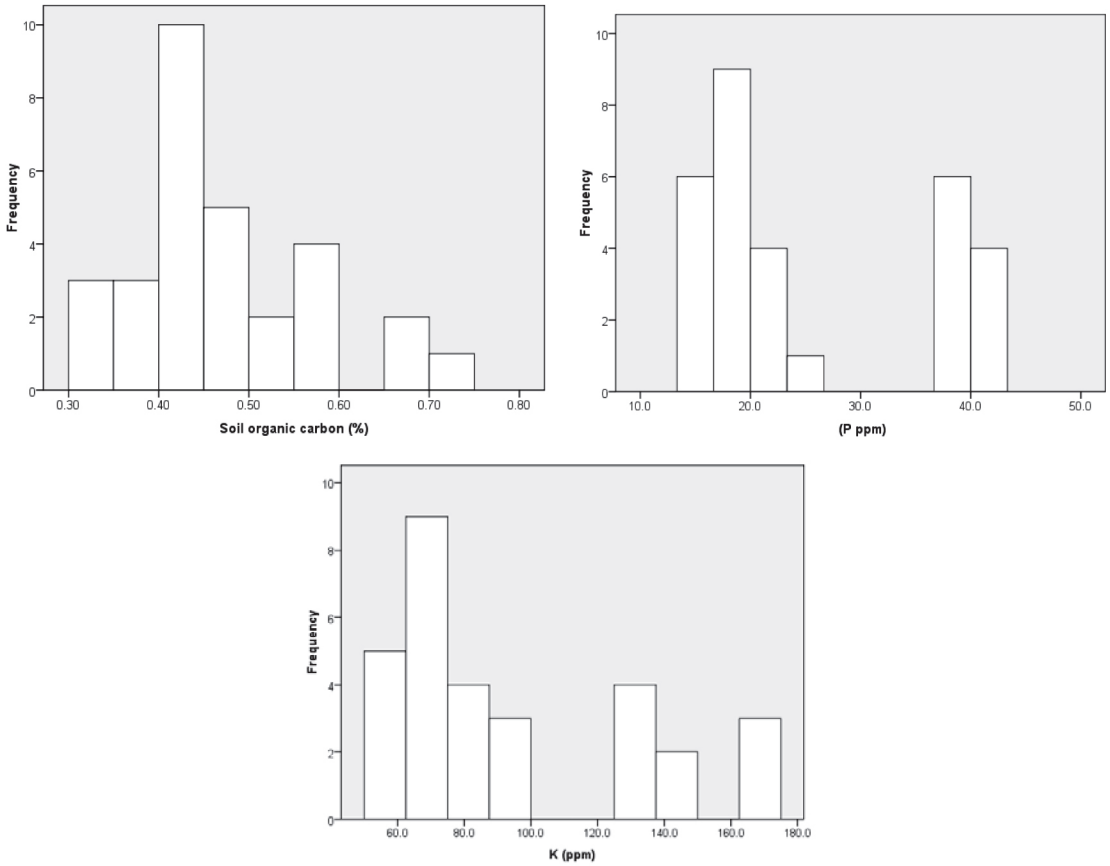

Fig. 2. Histographic distribution of soil organic carbon, P and K in guava ecosystem

compared to normal system (277 plants ha^{-1}). Further, histographic distribution showed variability in soil properties (Fig. 1 and 2).

Micronutrient availability

The present study indicated that planting density had strong impact on the micronutrient distribution and its storage in soil. The root zone micronutrient concentrations under different density guava systems had higher content in the densely populated plots (5000 plants ha^{-1}) with a tendency to decrease down with lower population density (277 plants ha^{-1}). Pooled data showed lower Zn content (0.52±0.0003 mg kg^{-1}) in 277 plants ha^{-1} while in other system, higher amount was recorded (0.57±0.001 mg kg^{-1} in 555 plants $ha^{-1}$and 1.25±0.003 mg kg^{-1} in 5000 plants ha^{-1}). Even, the range of variability of Zn content was also higher (0.50 to1.52 mg kg^{-1}) in those systems as compared to normal plantation (0.42-0.60 mg kg^{-1}) (Table 2). In case of Cu content, wider range of 0.78 to 1.98 mg kg^{-1} was recorded across different plantation systems with a higher content in densely plantation (1.56±0.01 mg kg^{-1}). A range of 4.06 to 9.86 mg kg^{-1} DTPA- Mn was estimated across different systems. Considering the critical limit of 4.0 mg kg^{-1}, it was inferred that all these plantations had sufficient Mn in the soil to support quality fruit production. DTPA- Fe concentration was highest in the density plantations with 5000 plants per hectare (12.48±0.53 mg kg^{-1}) followed by 9.17±0.42 mg kg^{-1} in 555 plants ha^{-1} and 7.04±0.14 mg kg^{-1} in 277 plants ha^{-1} (Table 2). Higher variability in the range of 5.88 to 16.48 mg kg^{-1} DTPA-Fe across the planting densities was observed. Considering the critical limit for Fe (2 mg kg^{-1}), soil samples had sufficient level of Fe concentration across different planting densities. The possible reasons for variations in micronutrients contents may be due to rhizospheric activities, higher microbial activities, litter fall, organic matter decomposition.

Micronutrient stock variations

Micronutrients stocks were estimated using the values of micronutrient concentrations, bulk densities and depth of soil layer. Micronutrients densities were significantly higher in high density systems as compared to normal density plantation. The Zn stock of 2.28, 2.42 and 5.50 kg ha^{-1} was estimated under 277, 555 and 5000 plants ha^{-1}. A lower range of Cu stock (4.85 to 6.89 kg ha^{-1}) across systems was found. Similarly, the highest distribution of Mn stock (29.11 kg ha^{-1}) was found in the category 5000 plants ha^{-1} than 23.98 kg ha^{-1}

Table 2. Descriptive statistical analysis of root zone (0-30 cm) micronutrients* and other soil properties under different density cv. Lalit guava plantation systems

Population Density (Plants ha^{-1})	Soil properties	Sd	CV (%)	Range	Soil properties	Sd	CV (%)	Range
	Zn (mg kg^{-1})				Cu (mg kg^{-1})			
277 (6×6 m)	0.52±0.0003	0.06	11	0.42-0.60	1.11± 0.01	0.26	24	0.80-1.62
555 (3×6 m)	0.57±0.001	0.08	13	0.50-0.72	1.20±0.01	0.28	23	0.78-1.66
5000(2×1m)	1.25±0.003	0.18	15	0.98-1.52	1.56±0.01	0.34	22	1.06-1.98
	Mn (mg kg^{-1})				Fe (mg kg^{-1})			
277 (6×6 m)	6.10±0.12	1.12	18	4.16-8.24	7.04±0.14	1.20	17	5.88-9.32
555 (3×6 m)	5.63±0.07	0.84	15	4.06-6.84	9.17±0.42	2.05	22	6.50-13.34
5000 (2×1m)	6.61±0.23	1.52	23	5.22-9.86	12.48±0.53	2.30	18	9.76-16.48
	P (mg kg^{-1})				K (mg kg^{-1})			
277 (6×6 m)	16.75±0.55	2.35	14	13.4-21.0	62.45±4.64	6.81	11	52.55-73.3
555 (3×6 m)	20.18±0.36	1.91	9	17.6-23.4	78.77±8.18	9.04	11	66.75-94.4
5000 (2×1m)	39.2±0.41	2.03	5	36.9-43.2	139.79±55.39	23.54	17	98.6-170.75
	WHC (%)				BD (g cm^{-3})			
277 (6×6 m)	21.02±0.07	0.44	2.11	19.92-21.98	1.47±0.001	0.05	3.29	1.42-1.54
555 (3×6 m)	22.30±0.16	0.70	3.12	21.18-23.08	1.42±0.0002	0.00	0.27	1.41-1.44
5000 (2×1m)	20.99±0.10	0.55	2.62	19.72-22.29	1.46±0.0003	0.03	2.21	1.41-1.56
	PD (g cm^{-3})				Porosity (%)			
277 (6×6 m)	2.43±0.0002	0.01	0.34	2.30-2.54	39.49±1.38	2.04	5.16	37.0-43.7
555 (3×6 m)	2.49±0.001	0.04	1.70	2.32-2.70	42.85±0.43	1.14	2.65	38.8-47.0
5000 (2×1m)	2.46±0.0003	0.00	0.14	2.30-2.69	40.66±0.62	1.36	3.34	33.9-46.1

*Mean ± standard error of mean

in 555 plants ha^{-1} (Fig. 3). Wide range of variability existed among the values of Fe stock with maximum value of 54.96 kg ha^{-1} was estimated in the category of 5000 plants ha^{-1} followed by 39.06 kg ha^{-1} in 555 plants ha^{-1} and the lowest was recorded as 30.85 kg ha^{-1} (normal 277 plants ha^{-1}). SOC content showed significant positive correlation with DTPA-Zn (r = 0.61**) (Fig. 4).

Estimating spatio-temporal variations in soil properties are essentially important in fruit orchard because of adopting a site specific precision horticultural management for quality fruit production. Such investigation would ensure if any nutrients are deficient in soils. Srivastava and Shyam (2006) reported diagnosis of nutrient constraints in citrus orchard soil under humid tropical Indian conditions. Zaman and Schuman (2006) developed an understanding on the variability of soil properties impacting citrus yield based on which a nutrient management zones were developed. Kirby and Potvin (2007) observed significant variability in soil among the agroforestry, pasture and forest land use system. They have reported that of course the soil organic carbon between depths of 0-10 and 30-40 cm marginally varied but its spatial variations within the same land use type was reported. The coefficient of variations in SOC% was 46, 40 and 25% for the three ecosystems respectively at 0-10 cm soil depth. It was estimated that Mango crop contributed 29.2% of carbon stock per ha. In the present study, the %CV in SOC content was observed as 8 to 15% among the three guava plantations system. Jimenez *et al.* (2007) observed higher soil bulk density in pasture as compared to tree species under different soil depths (0-10 and 40-50 cm). Moreover, average SOC concentration was significantly higher in tree species than pasture ecosystem, with concentration varied between 44.9 to 55.2 and 12.7 to 16.8 g kg^{-1} in 0-10 and 40-50 cm soil depth respectively. The changes in soil nutrients with depths and its storage under different land use system was studied by Jiang *et al.* (2006) and the study showed that the soil nutrients had a tendency to decrease down the depths. Tardaguila *et al.* (2011) observed variations in soil properties and its significant correlation with the vegetative growth and yield in grapevines. Singha *et al.* (2014) observed 0.22 to 0.65 per cent soil organic carbon in different density guava plantation and revealed positive and significant

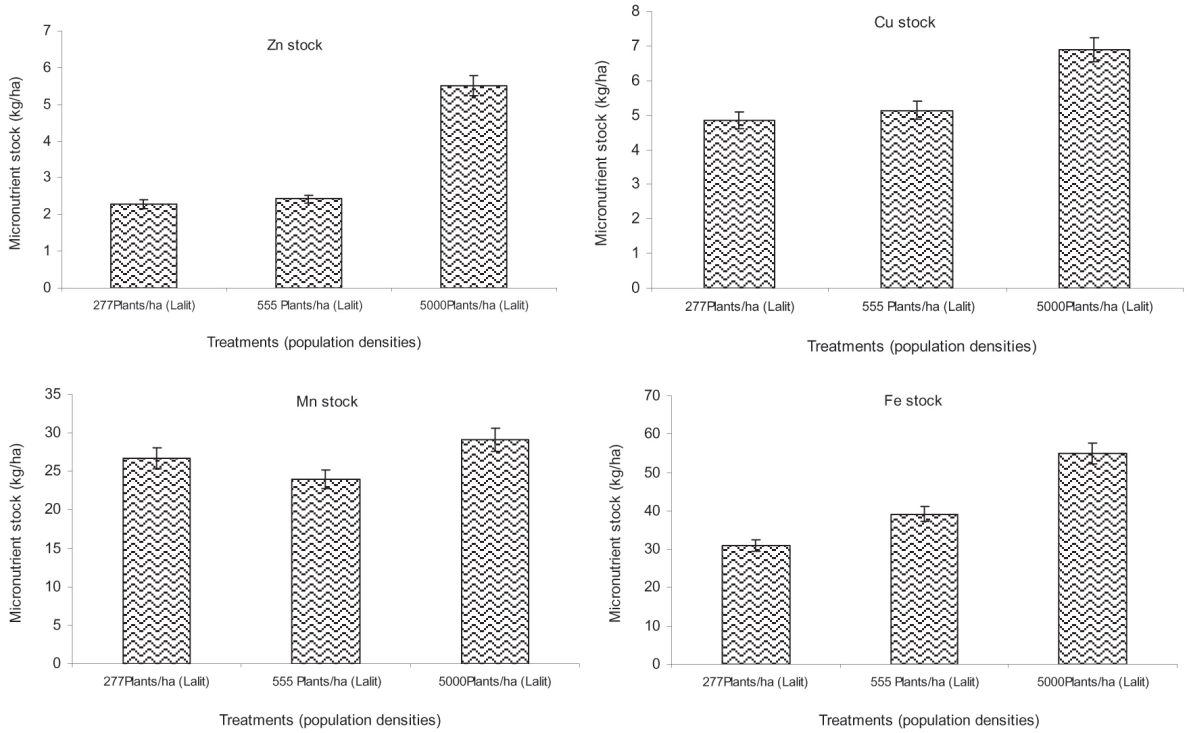

Fig. 3. Micronutrient stock (kg ha^{-1}) in different guava ecosystem

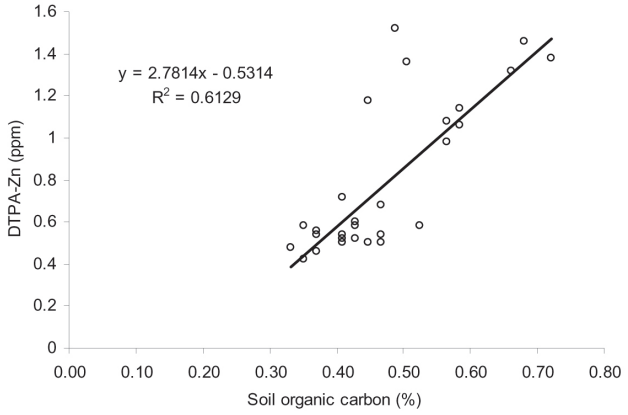

Fig. 4. Relationship between SOC (%) and DTPA-Zn in guava orchard

relationship between microbial activity and SOC. Gahlod *et al.* (2015) developed suitability of soils in for different orchards. All these study indicated the existence of variability in different soil properties. The changes in organic carbon content, soil nutrients in guava density system may be due to differential root amount volume, and its decomposition in high density as compared to normal density system (Balesdent and Balabane, 1996). Sometimes fine roots are also contributing to differential SOC content (Guo *et al.*, 2005). Sharma *et al.* (2003) inferred correlation between micronutrients and other soil properties. In this study also SOC had positive correlation with the Zn content.

CONCLUSIONS

The study indicated that indeed there was a variation in soil physical properties, micronutrient status and its distribution under long-term guava orchard management of different planting densities. Micronutrients densities were significantly higher in high density systems as compared to normal density plantation. SOC content showed significant positive correlation with the Zn content (r = 0.61**). The study also indicated that high density plantation showed wide variations in soil physical properties and greater micronutrient stock as compared to the normal density plantation in subtropical region. Precision nutrient management is thus needed to sustain the system.

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Enhancing productivity of wheat-maize cropping sequence on a sandy loam soil

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ABSTRACT

Sandy soils having low organic matter and low N content often result in low crop yields. There are socioeconomic constraints in adoption of balanced application of chemical fertilizers. Using biofertilizers can be a cheap alternative to fertilizer nitrogen. The present investigation was carried out on N management and biofertilizer application in wheat-maize cropping sequence during the year 2005-2006 and 2006-2007 in the research farm of Lakhaoti, western India to study the effect of biofertilizers and nitrogen on yield and N-use efficiency in wheat and maize on a sandy loam soil. Seed inoculation with biofertilizers significantly increased wheat plant height over control during both the years of study. However, no significant residual effects of biofertilizer inoculation were observed in terms of the maize plant height. Application of fertilizer nitrogen @ 60 and 120 kg ha^{-1}produced taller plants of both wheat and maize in comparison to control during both the seasons of study. LAI of the maize crop increased significantly with application of fertilizer nitrogen @ 60 as well as 120 kg ha^{-1} in comparison to control. Seed inoculation with *Rhizobacteria* and *Azotobacter* significantly increased the grain yield of wheat by 5.96 and 7.55%, respectively, over control. Nitrogen application @ 120 kg/ha enhanced grain yield, Agronomic N-use efficiency and N recovery efficiency in Wheat, however, the differences between 60 and 120 kg N/ha were not significant. *Rhizobacteria* and *Azotobacter* inoculation increased the straw yield by 9.23% and 7.27%, respectively over no inoculation. Nitrogen application up to 60 kg ha^{-1} significantly increased the straw yield of wheat over control during both the years. The stover yield of maize was significantly increased with each increase in direct applied N up to 120 kg/ha in both the years.

Key words: Nitrogen use efficiency, Wheat-maize, Biofertilizers, Sandy soils

INTRODUCTION

Coarse textured soils generally hold less nutrients in comparison to finer textured soils. This is generally due to the lower organic matter content as well as lower cation exchange capacity of the sandy soils. Moreover, sandy soils also have low water holding capacity, which further influence the productivity of these soils. Wheat-maize cropping sequence is a nutrient exhaustive cropping sequence, particularly with respect to potassium. Globally wheat (*Triticum aestivum* L.) is most widely cultivated field crop which is primarily grown in temperate region as well as in tropical and subtropical climates with moderate success (Klatt, 1988; Saunders and Hettel, 1994). In world wheat is grown an area of about 215.82 Mha with the production of 655.25 Mt and productivity of 3.04 t/ha keeping the first position among the cereals both in respect of area and production, however, In India, wheat is cultivated in 29.86 Mha with the production of 94.88 Mt having productivity 3.18 t/ha (Directorate of wheat research, Karnal 2013). In north-west India, late sowing of wheat is very common due to intensive cropping systems. The main constraints encountered in late sowing are initial low temperature resulting in slow germination and early growth of the seedlings. Secondly, the efficiency of nitrogen applied is also very low (Khan and Chatterjee, 1991). Among the *kharif* crops, maize (*Zea mays* L.) occupies a place of pride, because of its high production potential. In India, it also constitutes an important staple food and source of carbohydrate in areas inhabited by tribal and the rural poor. In recent years, it has also been gaining popularity as an industrial crop.

Deterioration of primary resources in agriculture and excessive use of agrochemicals has now become a threat to the environment. Despite

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technological advances such as improved cultivars, genetically modified organisms, precise irrigation systems and improved pest management, nutrient is still a key factor determining agricultural productivity. Fertilizer inputs constituting 55-60 per cent of the farmers' expenses are beyond the reach of small and marginal farmers. Continuous use of fertilizers results in decline in yield and soil fertility and increase in environmental pollution (Bhumbla, 1997). Hence, there is strong need for minimizing dependence on fertilizers by supplementing the plant nutrients with eco-friendly biofertilizers for enhanced productivity and sustainability. The importance of biofertilizers in conserving nutrients and to provide benefits to soil productivity through the favourable effects on the chemical and biological properties of soil is well known (Kannaiyan, 2000; Pradhan, 2001).

The information on the effect of biofertilizers (*Rhizobacteria* and *Azotobacter*) under differential N fertilization in late sown wheat-maize sequence is lacking. Therefore, it was deemed necessary to investigate the contribution of biofertilizer inoculation with and without N fertilization towards nitrogen nutrition of wheat and maize.

MATERIALS AND METHODS

A field experiment was conducted with biofertilizer in wheat-maize cropping sequence during *rabi* and *kharif* seasons of 2005-2006 and 2006-2007 in the research farm of Amar Singh College, Lakhaoti, Bulandshahr (28°4' N, 77°1' E and 228 m above mean sea level), Uttar Pradesh. The soil of the experimental site was sandy loam in texture (55% sand, 26% silt and 17% clay), slightly alkaline (pH 7.6), low in available N (174 kg ha^{-1}), but medium in available P (12.2 kg ha^{-1}) and K (179 kg ha^{-1}). The area received 600.5 and 586.1 mm rainfall throughout the growing seasons of 2005-06 and 2006-07 respectively.

The experiment was laid out in a factorial randomized block design with three replications and nine treatment combinations of three levels of nitrogen and three levels of biofertilizers as main plots during *rabi* season. The three levels of N were 0, 60 and 120 kg N ha^{-1} (N0, N1 and N2) and that of biofertilizers were no biofertilizer, *Rhizobacteria* (A combination of *Proteus vulgaris*, *Klebsiellap lanticola* and *Bacillus subtilis*) and *Azotobacter chroococcum* (B0, B1 and B2). In *kharif* season, the nine main plots were subdivided into three sub-plots in a split plot design which represented the fertility levels applied to the following maize crop. The sub-plot treatments were 0, 60 and 120 kg N ha^{-1} designated as F0, F1 and F2 for maize crop which were super imposed over the main plot treatments (N0, N1, N2 and B0, B1, B2) applied to wheat crop in the previous season.

Wheat variety Raj 3765 and maize variety Deccan 103 was used in the investigation with P and K application at the recommended dose. The wheat seeds treated with microbial inoculants were sown on 17 December, 2005 and 02 December, 2006 during the two years respectively at a row spacing of 23 cm with the seed rate of 140 kg ha^{-1}. The maize seeds were sown on 29 June, 2006 and 05 July, 2007 during the two years respectively in furrows with a seed rate of 15 kg ha^{-1} spaced 65 cm apart and two seeds per hole at 20 cm distance. Basal N, P_2O_5 and K_2O were applied and incorporated in all the treatments. Standard cultural practices were followed in crop management. Harvesting of wheat and maize crops was done on 30 April, 2006 and 16 April, 2007 and on 09 October, 2006 and 05 October, 2007, respectively during the two years.

Observations on grain yield and biomass yield were recorded. The N contents in grain and straw samples were estimated in the laboratory following micro-kjeldahl method as described by Jackson (1973). The N removal by the crop was then estimated by multiplying grain and straw yield with their respective N contents. For each treatment, the nitrogen use efficiency (NUE) of wheat such as agronomic N use efficiency (AEN), nitrogen recovery efficiency (REN), physiological N use efficiency (PEN), and nitrogen harvest index (NHI) and as described by Swain *et al*. (2006), Huang *et al*. (2008), and Singh *et al*. (2012) were computed as follows:

$$\text{AEN (kg kg}^{-1}\text{)} = \frac{\text{Grain yield in N fertilized plot, kg ha}^{-1} - \text{Grain yield in control plot, kg ha}^{-1}}{\text{Quantity of N fertilizer applied in fertilized plot, kg ha}^{-1}}$$

$$\text{REN (kg kg}^{-1}\text{)} = \frac{\text{Total N uptake in fertilized plot, kg ha}^{-1} - \text{Total N uptake in control plot, kg ha}^{-1}}{\text{Quantity of N fertilizer applied in fertilized plot, kg ha}^{-1}}$$

$$\text{PEN (kg kg}^{-1}\text{)} = \frac{\text{Grain yield in N fertilized plot, kg ha}^{-1} - \text{Grain yield in control plot, kg ha}^{-1}}{\text{Total N uptake in fertilized plot, kg ha}^{-1} - \text{Total N uptake in control plot, kg ha}^{-1}}$$

$$\text{NHI (\%)} = \frac{\text{Grain N uptake, kg ha}^{-1}}{\text{Total N uptake, kg ha}^{-1} \times 100}$$

A composite soil sample was collected (0-15 cm depth) from the experimental field before the start of the experiment. Soil samples from each plot were collected after harvesting of the second year's crop. All the soil samples were processed and analysed for organic carbon and available Nitrogen content. Organic carbon (OC) was determined following Walkey and Black method (Jackson, 1973) and available N by alkaline potassium permanganate method (Subbiah and Asija, 1956). The data were statistically analyzed by standard analysis of variance technique for randomized block design suggested by Cochran and Cox (1985). Wherever treatment difference was found significant based on results of F-test, least significant difference (LSD) was calculated at 5% level of probability.

RESULTS AND DISCUSSION

Seed inoculation with biofertilizers significantly increased wheat plant height over control during both the years of study. However, no significant residual effects of biofertilizer inoculation were observed in terms of the maize plant height. Application of fertilizer nitrogen @ 60 and 120 kg ha^{-1} produced taller plants of both wheat and maize in comparison to control during both the seasons of study (Table 1 & 2). Seed inoculation with biofertilizers did not increase the LAI of wheat and maize crops during both the years. Application of fertilizer nitrogen was also not found to influence the leaf area index of wheat. However, LAI of the maize crop increased significantly with application of fertilizer nitrogen @ 60 as well as 120 kg ha^{-1} in comparison to control. Residual effect of biofertilizers could not exhibit any beneficial effect either on growth parameters in the present investigation, but markedly improved by residual nitrogen only at 120 kg Nha^{-1}. This was indeed a consequence of residual fertility left behind by preceding crop which caused a substantial improvement in grain and Stover yield of maize. Similar observations were also made by Kumar and Ahlawat, (2004) and Singh (2005). Successive increase in N level up to 120 kg Nha^{-1} significantly increased the plant height and leaf area index at all the stages of crop growth (Table 1). This might be due to easy and greater availability of nitrogen in fertilized plots. Since nitrogen plays an important role as a constituent of chlorophyll and also present in many other compounds of physiological importance in plant metabolism.

Table 1. Plant height, LAI, grain and straw yields of wheat as influenced by biofertilizer application and N levels (pooled over two years)

Treatment	Plant height (at 120 DAS)	LAI (at 120 DAS)	Grain Yield (q ha^{-1})	Straw Yield (q ha^{-1})
Biofertilizers				
No biofertilizer	58.85	0.19	38.94	58.34
Rhizobacteria	65.16	0.21	41.87	63.71
Azotobacter	63.56	0.20	41.25	62.57
SEm(±)	1.37	0.06	0.66	1.08
CD (P=0.05)	4.63	NS	1.78	3.95
N(kg/ha)				
0	54.40	0.18	33.77	54.93
60	65.75	0.20	43.13	63.07
120	67.42	0.21	45.16	65.56
SEm(±)	1.38	0.06	0.66	1.08
CD (P=0.05)	4.63	NS	1.78	3.95

DAS = Days after sowing; NS = Non-significant; SEm = Standard error of mean; CD = Critical difference

Table 2. Plant height, LAI, grain and Stover yields of maize as influenced by biofertilizers and N levels (pooled over two years)

Treatments	Plant height (at 90 DAS)	LAI (at 90 DAS)	Grain Yield (q ha^{-1})	Stover Yield (q ha^{-1})
Biofertilizers				
No biofertilizer	164.3	2.16	37.98	65.83
Rhizobacteria	166.8	2.17	38.91	67.03
Azotobacter	166.3	2.16	38.43	66.35
SEm(±)	3.7	0.06	0.64	0.97
CD (P= 0.05)	NS	NS	NS	NS
N (kg/ha)				
0	161.6	2.06	37.13	64.69
60	166.5	2.17	38.30	66.21
120	169.4	2.26	39.88	68.21
SEm(±)	3.7	0.06	0.64	0.97
CD (P= 0.05)	6.9	0.10	1.82	2.84
Fertilizer N (kg/ha) to maize				
0	151.4	1.83	29.73	58.48
60	170.1	2.23	40.04	68.89
120	176.0	2.43	45.55	71.84
SEm(±)	2.2	0.04	0.48	0.70
CD (P= 0.05)	6.1	0.11	1.39	2.00

DAS = Days after sowing; NS = Non-significant; SEm = Standard error of mean; CD = Critical difference

The nitrogen application rates and biofertilizer application had a significant effect on grain and straw yield of wheat (Table 1 & 2). Biofertilizer inoculation resulted in a marked increase in grain and straw yields as compared to control (7.55% and 5.96% increase in grain yield snad 9.23% and 7.27%, increase in straw yield over the two years, in the same order). The grain yield of wheat was significantly increased by application of N in both the years. Nitrogen application up to 60 kg ha^{-1} significantly increased the straw yield of wheat over control during both the years as well as in pooled data. There was no significant effect of further increase in nitrogen level up to 120 kg N/ha. Over the years, 60 and 120 kg N ha^{-1} increased the straw yield by 16.68% and 19.40%, respectively over no nitrogen. Interaction effect between nitrogen and biofertilizers was not significant. Such favourable response of biofertilizers in yield was the result of increased availability of nutrients which in turn must have improved synthesis and translocation of metabolites to various reproductive structures of the plant. Similar increases in yield of wheat due to *Azotobacter* (Tomar et al., 1995) and *Rhizobacteria* (Singh and Panwar, 1997) inoculation have been reported. Similar response of both the micro-organism in the present investigation has shown that both are equally efficient under the situations of this experiment. In earlier studies also, similar behaviour of these micro-organisms was noticed by Singh *et al.* (2000). The increase in yield could be attributed to better plant growth and development of yield attributes. Maize grain yield was not affected by biofertilizer inoculation in preceding wheat crop during both the years and in pooled data. The residual nitrogen of wheat significantly increased the grain yield of maize in both the years and in pooled data. Application of 120 kg $Nha^{-1}$was being on par with 60 kg Nha^{-1} recorded higher maize yield than no nitrogen (Table 2). There was a significant increase in grain yield of maize with each successive increment in N up to 120 kg/ha in both the years and in pooled data. The maximum grain yield 44.60 and 45.50 q ha^{-1} was recorded at 120 kg Nha^{-1} in 2006 and 2007, respectively. The interaction effects were not significant. Biofertilizer inoculation of preceding wheat failed to affect the stover yield of maize in both the years and in pooled data. The residual nitrogen of wheat had a marked influence on stover yield of maize. 120 kg N/ha being on par with 60 kg Nha^{-1}, recorded markedly higher stover yield over no nitrogen (Table 2). The stover yield of maize was significantly increased with each increase in direct applied N up to 120 kg/ha in both the years. The maximum stover yield of 70.62 and 73.06 q ha^{-1} was produced with an application of 120 kg N ha^{-1} in 2006 and 2007, respectively. The interaction effects were not significant in both the seasons. The improvement in yield of the wheat crop with increasing rates up to 120 kg N/ha reflects on its requirement for growth and development. Similar, increase in yield and yield attributes by nitrogen have been reported by many workers Kumar and Ahlawat, 2004). An increase in growth parameters by nitrogen application has also been reported by many workers (Sharma *et al*., 2000, Kumar and Ahlawat, 2004 and Dixit *et al*., 2005).Application of nitrogen to maize exercised a favourable influence on grain yield. The cumulative beneficial effect of yield attributing characters was finally reflected in grain yield, which increased with increasing levels of N up to 120 kg Nha^{-1}. These findings are in agreement with those of Parmar and Sharma (2001), Kumar and Ahlawat, (2004) and Kaushik and Shaktawat (2005). The increase in stover yield with the applied nitrogen was the outcome of improvement in the general vigour of the plants in terms of plant height, dry matter production and crop canopy. Similar results were also reported by Kumar and Ahlawat (2004).

The AEN was the highest (15.02 and 16.19 kg kg^{-1} during 2005-06 and 2006-07, respectively) with 60 kg N/ha and thereafter decreased significantly with higher level of N (120 kg ha^{-1}). The maximum recovery of applied N (43.46% and 48.70%) was observed with the application of 60 kg N/ha during 2005-06 and 2006-07, respectively and it tended to decline with increasing level of N (120 kg ha^{-1}).PEN in wheat was not influenced by levels of nitrogen during both the seasons. The effect of nitrogen was marked on NHI during both the years of study. Increasing the level of N up to 120 kg ha^{-1} in 2005-06 significantly increased the NHI. Based on average of two years, 75-77% of the total uptake of nitrogen was retained in the economic product i.e. grain. The maximum NHI and PEN were recorded under uninoculated control during the investigation.AEN was significantly higher at lower level of N (60 kg ha^{-1}) in both the years and thereafter a significant decrease was recorded at 120 kg N/ha. This may be due to the fact that the magnitude of increase in kg grain per kg applied N was more under 60 kg N ha^{-1} as compared to 120 kg N ha^{-1} (Table 3). However, AEN and REN decreased with an increase level of N in wheat. The maximum REN was obtained with the application of 60 kg N ha^{-1}. However, recovery of applied N

Table 3. Agronomic N use efficiency, N recovery efficiency, physiological N use efficiency, N harvest index, soil organic carbon and available nitrogen after harvest of wheat as influenced by biofertilizers and N levels (pooled over two years)

Treatment	Agronomic N-use efficiency (kg kg^{-1})	N recovery efficiency (kg kg^{-1})	Physiological N use efficiency (kg kg^{-1})	Nitrogen harvest index (%)	Organic carbon (%)	Available N (kg ha^{-1})
Biofertilizers						
No biofertilizer	9.39	26.99	23.78	77.49	0.39	968
Rhizobacteria	7.52	22.97	21.98	75.58	0.41	1009
Azotobacter	8.19	24.00	22.77	75.67	0.41	1005
SEm(+)	0.98	3.12	0.41	0.04	0.01	13
CD (P=0.05)	NS	NS	0.96	0.13	0.02	39
N(kg/ha)						
0	-	-	-	76.00	0.38	963
60	15.61	46.08	34.19	76.28	0.41	1004
120	9.44	27.87	34.33	76.46	0.42	1016
SEm(+)	0.98	3.12	0.41	0.04	0.01	13
CD (P=0.05)	2.92	9.34	NS	0.13	0.02	39

NS = Non-significant; SEm = Standard error of mean; CD = Critical difference

decreased with increase in level of N during both the years. The magnitude of increase in N content was more between 0 and 60 kg N ha^{-1}. The proportionately greater N uptake at 60 kg Nha^{-1} than 120 kg Nha^{-1} than 120 kg Nha^{-1} was probably responsible for higher REN. The results are in close conformity to Singh and Shivay (2003), Kumar and Ahlawat, 2004 and Kachroo and Rajdan (2006). Residual effect of biofertilizers and nitrogen could not exhibit any beneficial effect on AEN and NHI of maize during the study. However, REN and PEN were significantly differed by residual nitrogen (60 and 120 kg Nha^{-1}) over no N during 2007 and 2006, respectively. Direct application of nitrogen to maize had a favourable influence on recoveries of applied N viz. AEN, REN, PEN and NHI during both the years. The AEN was the highest with 60 kg Nha^{-1} and thereafter declined with increased N level up to 120 kg ha^{-1} (Table 4) and similar trends in REN were also observed. However, AEN and REN decreased with an increase in level of N in maize. Nitrogen application had significant influence on PEN, the application of 60 kg N ha^{-1} recorded the highest PEN. NHI differed significantly up to 120 kg N/ha, as the rate of N application was increased the N harvest index increased. These results were supported by the finding of Singh and Shivay (2003) and Kumar and Ahlawat (2004).

The residual biofertilizer of wheat did not influence the AEN, REN, PEN and NHI of maize in either of the two years of study (Table 4). However, PEN in maize was significantly influenced by residual fertility in 2006 only, where application of 120 kg N ha^{-1} resulted in the highest PEN, being significantly more than other levels of N. REN was also significantly decreased with each successive increase in N level up to 120 kg Nha^{-1}.N levels applied to maize had significant influence on AEN during both the seasons. Application of 60 kg Nha^{-1} recorded higher AEN and it declined with higher level (120 kg N ha^{-1}). Nitrogen application to maize had significant influence on REN during both the years. Application of 60 kg N/ha resulted in the PEN of 34.12 and 30.85 kg grain per kg N uptake in 2006 and 2007, respectively, being significantly higher than that obtained with 20 kg Nha^{-1}. The levels of N had significant influence on NHI in maize in both the years of study. The maximum NHI of 61.95% and 61.07% was recorded at 120 kg Nha^{-1} in 2006 and 2007, respectively. Based on average of two years, 59.62% of the total N taken up by maize plant was retained in the grain.

Biofertilizer inoculation of wheat markedly increased the organic carbon in soil over uninoculated control after wheat crop in both the years of study. The N application rate at 60 and 120 kgha^{-1} recorded similar organic carbon content. The interaction effect between biofertilizer and N was not significant in both the seasons (Table 3). However, *Rhizobacteria* and *Azotobacter* proved equally efficient in enhancing the total N content of soil. The increasing levels of N up to 120 kg ha^{-1} increased the total N status of soil after wheat crop.

Table 4. Agronomic N use efficiency, N recovery efficiency, physiological N use efficiency, N harvest index, soil organic carbon and soil available nitrogen after harvest of maize as influenced by residual effect of biofertilizers and N levels of preceding wheat and direct N application to maize (pooled over two years)

Treatments	Agronomic N-use efficiency (kg kg^{-1})	N recovery efficiency (kg kg^{-1})	Physiological N use efficiency (kg kg^{-1})	Nitrogen harvest index (%)	Organic carbon (%)	Available N (kg ha^{-1})
Biofertilizers						
No biofertilizer	10.08	31.63	21.36	59.85	0.42	972
Rhizobacteria	10.19	32.43	21.02	59.85	0.43	999
Azotobacter	10.03	31.25	21.32	59.89	0.42	998
SEm ±	0.39	0.86	0.26	0.12	0.007	13
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
N (kg/ha)						
0	10.14	32.70	20.57	59.97	0.41	968
60	10.33	32.73	21.16	59.77	0.42	998
120	9.83	29.88	21.98	59.85	0.43	1006
SEm ±	0.39	0.86	0.26	0.12	0.007	13
CD (P = 0.05)	NS	2.51	0.77	NS	NS	NS
Fertilizer N (kg/ha) to maize						
0	-	-	-	58.18	0.40	958
60	17.03	52.78	32.49	59.90	0.43	998
120	13.27	42.51	31.20	61.51	0.44	1014
SEm ±	0.68	1.93	0.28	0.12	0.006	13
CD (P = 0.05)	1.95	5.55	0.78	0.34	0.017	38

NS = Non-significant; SEm = Standard error of mean; CD = Critical difference

Data on organic carbon content in soil after harvesting maize crop indicated that biofertilizer inoculation and nitrogen fertilizer applied to preceding wheat had no significant effect in both the years of study (Table 4). Organic carbon content in soil significantly increased by direct application of N up to 120 kg ha^{-1} in maize over no nitrogen in both the seasons and over 60 kg N ha^{-1} in 2006. Application of 60 kg Nha^{-1} also recorded higher soil organic carbon over no nitrogen in both the seasons. The data on available soil N status (Table 4) revealed that biofertilizers inoculation in preceding wheat did not affect the available soil N content after maize in both the seasons. The available N status of soil after maize remained unaffected by residual nitrogen in both the seasons. Data on available soil N status after maize harvest indicated that application of 60 and 120 kg N ha^{-1} to maize being at par recorded markedly higher available soil Nitrogen over no nitrogen in both the years. Direct application of nitrogen to maize also did not influence the bulk density of soil after harvest of maize in both years of experimentation.

A greater build up of available soil N was noticed at higher level of N (120 kg ha^{-1}) (Table 3). The improvement in soil N might have resulted owing to extensive root residues left in the soil and the higher amount of N fixed in the soil by micro-organisms. These results are in agreement with those of Hedge and Katyal (1999) and Kumar (2003). However, residual fertility due to biofertilizer and nitrogen had no effect on soil physico-chemical properties under wheat-maize sequence. The maximum organic carbon (0.45%) was noticed with 120 kg Nha^{-1} after maize harvest. It was observed that both total N in soil than its initial status after maize harvest (Table 4). The beneficial effect of fertilizer nitrogen on soil properties might be accrued due to better root development in fertilized plots, which on harvest of the crop added more biomass to the soil. These results are in conformity with those reported by Kumar (2003).

CONCLUSIONS

Blanket recommendations of fertilizer may serve well for achieving the optimum yield, but lead to poor N use efficiency and cannot maintain the environmental sustainability. Biofertilizers are seen as a resource conserving option for realizing higher productivity and nitrogen use efficiency. Biofertilizer (*Rhizobacteria* or *Azotobacter*)

inoculation and N application at 120 kg N/ha gave higher yield and net returns. The maize crop responded favourably to 120 kg residual and direct applied N in terms of productivity and net returns. It may be concluded that both crops in wheat-maize sequence should receive 120 kg N/ha in addition to seed inoculation of wheat with *Rhizobacteria* or *Azotobacter* for realizing higher productivity and conserving the resources.

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Potential climate change impacts on water resources in Jammu

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ABSTRACT

While studying the climatic change scenario of Jammu region, it was revealed that during the period between 1985 and 1995, the rise in temperature in Jammu district was 0.046°C per year, while as during the period from 1996 to 2004 the temperature increase was found to be 0.155°C per year. If the trend persists in similar manner, the temperature would rise above 3°C in another 20 years. The rise in temperature will have a profound effect on crop water demand and ultimately water resources. Crop water demand was determined under different temperature scenario with the help of FAO CROPWAT model, window version 4.2 (FAO, 1995) assuming other meteorological parameters as normal. The investigation revealed that with an increase in annual mean temperature by 0.5°C, the crop water demand increases by 1.1% and it may go as high as 7.8% if the temperature rose by 3°C.

Key words: Climate change, Evapotranspiration, Crop water demand, Water resource planning, Jammu

INTRODUCTION

Himalayas are a source of inspiration and recreation for world as it serves as the 'Water Towers of the World'. With a growing emphasis globally on water resource issues, its function is crucial for human being living in its domain. Water resource is driven by environmental factors like temperature and rainfall. During the latter half of the past century, air temperature has shown slow increase in all the countries of South Asia. An estimate reported a significant warming of 0.4°C/ 100 years in the mean annual temperature during 1901 and 1982 for India (Hingane *et al.*, 1985). The most modern prophecy is for an increase of 2° to 6°C at global level by the year 2100 (Bind and Howden, 2004). This increase in temperature is expected to increase evapotranspiration rates, reduce water availability and thereby altering the hydrological cycle. To assess the interacting impacts of augmented temperature and of their consequences at all relevant scales on the regional water resources, a study has been conducted on the likely change in evapotranspiration demand taking in to account the climatic data of Jammu.

MATERIALS AND METHODS

The investigation carried is confined to Jammu district between 32° 27′ and 33°50′ North latitude and 74°19′ to 75°20′ East longitude covering an area of 3201.3 km^2. In the north it is surrounded by district Udhampur, northwest by district Rajouri, northeast by district Kathua and in the south it shares its international boundary with Pakistan. Administratively the Jammu district of J&K state comprises of five tehsils namely Jammu, Akhnoor, R.S.Pura, Bishnah and Samba. (Fig.1)

Daily meteorological data collected from India Meteorological Department Pune, for Jammu, from the period between 1985 and 2004 was used for this study. The data was put to statistical analysis for deriving out mean for visualizing the normal character of distribution of temperature. The daily and monthly normals of crop water requirement were calculated using FAO CROPWAT model, window version 4.2 (FAO, 1995). Evapo-transpiration was also estimated under different temperature regimes assuming the other meteorological factors constant. The total annual water loss has been calculated from the annual evapotranspiration for different tehsils of Jammu district by multiplying it with the total area of the tehsil concerned. The mapping has been done with the help of survey of India toposheets on the scale of 1:50,000 through Geo-spatial tool. The contour lines are manually traced, scanned and later with the help of Arc view GIS 9.0 (Eval.CD), the contour

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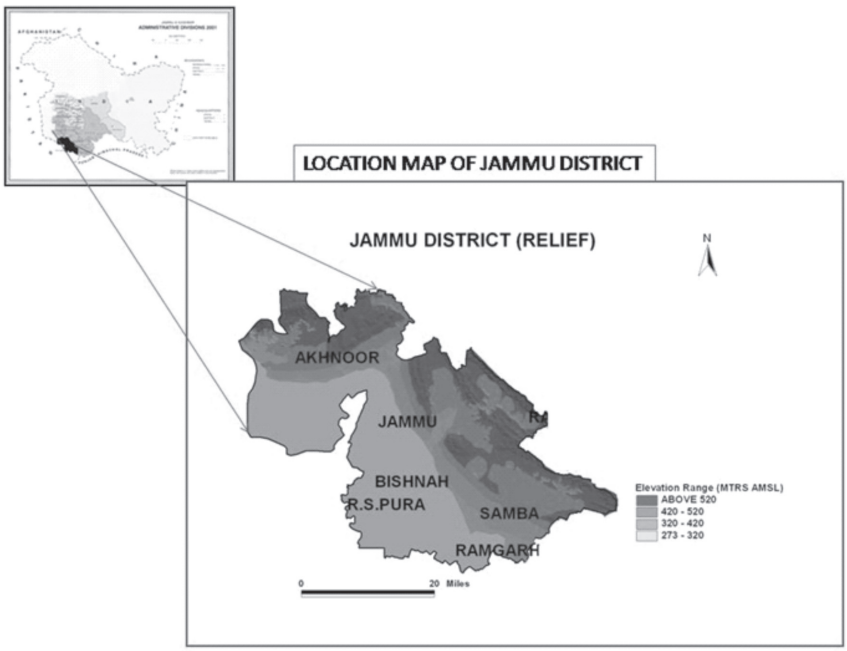

Fig. 1. Location map of Jammu district

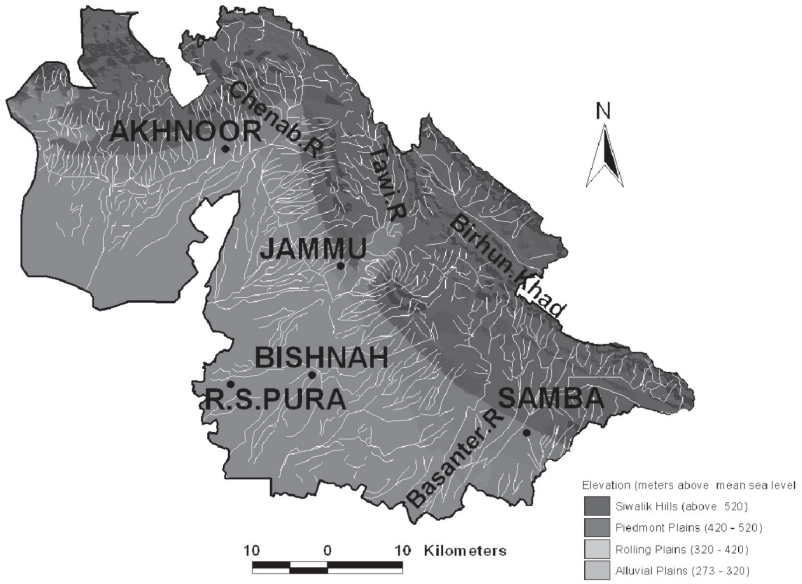

Fig. 2. Physical set up of Jammu district

lines were digitized and assigned an ID value representing height. The physiographic/altitudinal units have been classed from a tin generated from the contour lines.

RESULTS AND DISCUSSION

Perusal of Fig. 2 reveals that Jammu district displays a general rise in the elevation from 273 m southeast to 1675 m northwest which has been conveniently divided in to alluvial plains (273-320 m), rolling plains (320-420 m), piedmont plains (420-520 m) and Siwaliks hills (above 520 m). The low hills of Siwaliks with slopes foot striping into plains are intersected by deep meandering ravines of the transverse streams-surface features. These ravines debouching from Siwaliks on to the wide open plains have developed on number of alluvial fans which coalesce to form a piedmont zone representing plain with a gently rolling slope. Towards the south of this zone, there are gently sloping, small dry hillocks irregularly broken by ravines and made up of boulder mass known as rolling plains (*Kandi* belt), which terminates into the alluvial plains. The alluvial plains, primarily flood plains of Tawi river system and partly of Chenab, have a flat outline owing their origin to fluvial action under reduced velocity and heavy load concentration in the penultimate stage of river deposition. The area receives far more energy being confined in low altitude sub-tropical zone. The climate is moist sub-humid megathermal with an annual average temperature of about 24°C and

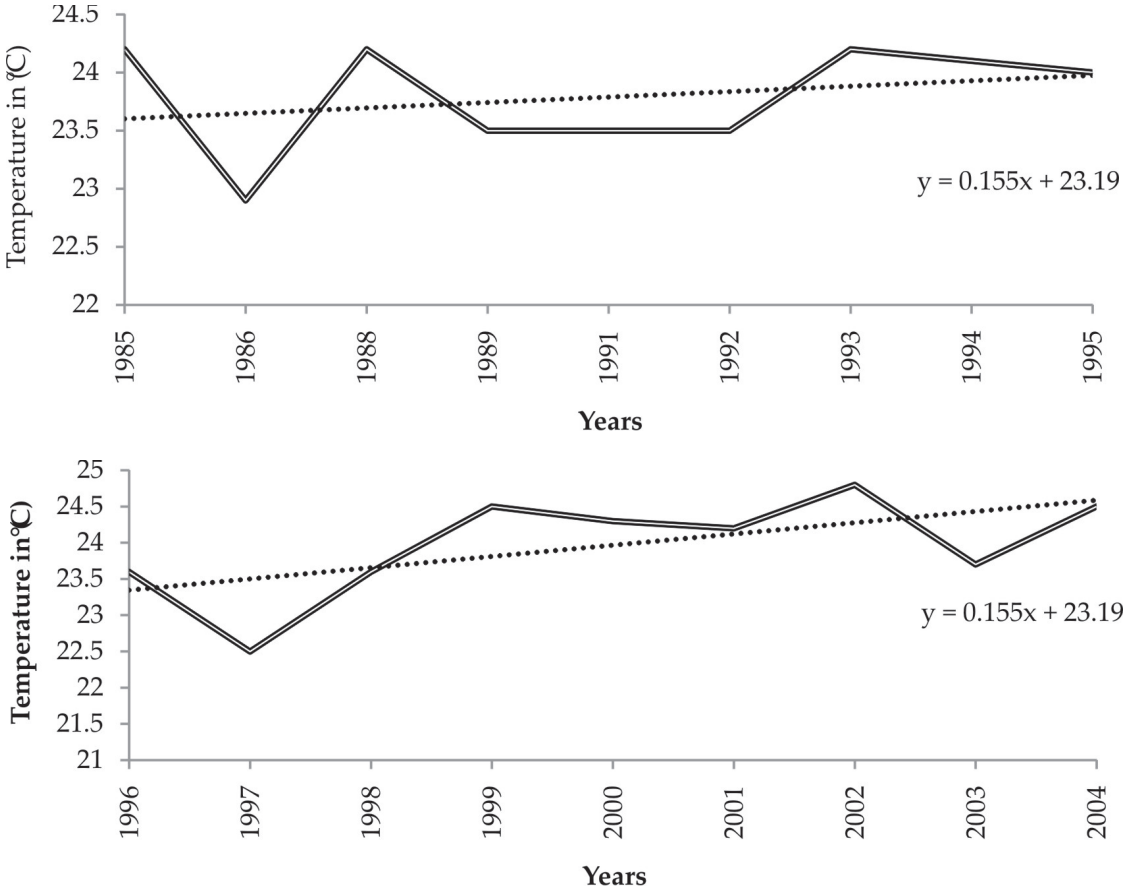

Fig. 3. Mean Temperature (°C)

Table 1. Daily and Monthly crop water demand (mm) of Jammu station

Months	Tmax. (°C)	Tmin. (°C)	Relative Humidity (%)	Bright Sunshine hours	Daily crop water demand (mm)	Monthly crop water demand (mm)
January	18.3	8.3	0.87	54	1.65	51.15
February	21.1	10.6	0.96	54	2.27	63.56
March	26.3	14.8	1.12	53	3.33	103.23
April	33	20.5	1.24	64	4.84	145.2
May	39	25.7	1.37	63	5.86	181.66
June	40.4	27.7	1.87	64	6.26	187.8
July	35.4	26	2.75	32	4.48	138.88
August	33.2	25.1	2.88	32	3.88	120.28
September	33.2	23.8	2.41	64	4.27	128.1
October	31.3	19.3	1.49	83	3.56	110.36
November	26.2	13.3	0.98	76	2.39	71.7
December	21.1	9.3	0.87	54	1.73	53.63
Annual	29.88	18.7	1.6	57.75	44.5	1355.6

average annual rainfall of 1150mm, 65-70 percent of which is received during monsoon months. The mean relative humidity is maximum (2.41-2.88%) during monsoonal months and lowest (0.87-0.96%) during the winter period (Table 1.).

The soils are sandy loam to clay loam in texture and the former dominate over an altitude of 320m. The water holding capacity in the alluvial plains are high (above 40%), whereas it is low (20-25%) over the rolling plains, piedmont and Siwaliks hills (Rashid, 2008). The study area is phyto-geographically, most complex and diverse. The subtropical dry deciduous scrub is mainly confined between an altitude of 320 and 520 m by reason of

Table 2. Water loss (Billion litres) for Jammu district at different rise of temperatures.

		Water Loss (Billion Litres)						
Tehsil	Area (ha)	At normal temperature	At 0.5°C rise	At 1°C rise	At 1.5°C rise	At 2°C rise	At 2.5°C rise	At 3°C rise
Jammu	95751.3	1298	1312	1326	1340	1354	1385	1399(7.8%)
Samba	83418.8	1131	1143	1155	1167	1179	1207	1219(7.8%)
Akhnoor	101346.5	1374	1388	1403	1418	1433	1466	1481(7.8%)
R.S. Pura	24504.4	332	336	339	343	346	355	358(7.8%)
Bishnah	15105.4	205	207	209	211	214	219	221(7.8%)
Total	320126	4340	4386 (1.1%)	4432 (2.1%)	4479 (3.2%)	4526 (4.3%)	4632 (6.7%)	4678 (7.8%)

its lithology (boulders, gravels with ferruginous material), which has resulted in deep water table and vis-à-vis xeric conditions, whereas, exceeding the altitude of 520m, some scattered Chir-pine forests are found (Rashid and Arora, 2007). Agriculture is the main stay of the people of Jammu district, as 70 to 75 percent of the land is the net area sown in alluvial plains, 20 to 23 percent in Kandi plains and 13 to 21 percent in Siwaliks hills.

The analysis of the temperature data for the period from 1985 to1995 indicate that the rate of rise in temperature was merely 0.046°C per year, which has increased to 0.155°C during the period from 1996 to 2004 (Fig. 3). The impulsive increase in the temperature can be attributed to rapid industrialization, increase in the number of vehicles, number of households and population. The number of small scale industrial units was merely 1838 in the year 1981, which has increased to 5849 and 9871 for year 1991 and 2005, respectively (Anon., 2007). The number of vehicles plying on the roads of Jammu has also increased from 28,995(1982) to 45,965 (2001) and 2, 95,790 in the year 2005(Anon., 2009). During 1981 census it was reported that the total population and number of households in Jammu district were 943395 and 162992, but the 2001 census has revealed that they have increased to 1588772 and 296953, respectively (Anon., 1981, 2001).

Based on the trend in the increase of temperature from 1996 to 2005, it is expected that a rise of 3°C can occur in another 20 years (Fig. 3). In that case, the water losses will be much more since the evapotranspiration rate will increase. Perusal of Table 2 reveals that at normal temperature the water loss in whole of the district Jammu is 4340(billion liters) as crop water demand. However, with an increase in temperature by 0.5°C annually, the crop water requirement would rise by 1.1 percent thereby total water loss of district would be to 4386 (billion liters). The result indicated that crop water demand increase with increase in temperature above normal and water loss can be as high as 7.79% with increase in temperature by 3°C with the result total water loss would increase to 4678(billion liters). The water losses are more in tehsil Akhnoor, Jammu and Samba by virtue of their having more area as compared to R.S.Pura and Bishnah. The increase in water loss would aggravate the situation in the region, as major part of these tehsils fall in the *Kandi* belt and Siwalik hills having coarse textured soils with low water holding capacity, deep seated water table, lack of assured irrigation and sparse vegetation. The water losses in tehsil R.S.Pura and Bishnah, which being a part of alluvial plains, can be compensated up to some extent through nexus of canal derived from Tawi river system. However, the area is agriculturally highly efficient and high water loss can affect the agricultural production.

The rise in the temperature coupled with water losses will likely have a profound effect on agriculture. It is the high time for planners/users to think in terms of expected change in the water requirement due to global climate change while planning for the development of future water resources.

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Digital knowledge management in agricultural research and development

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ABSTRACT

Communicating agricultural knowledge is utmost important not only for the benefit of researchers but it is more important for the overall agricultural growth of the country. Technologies developed by the researchers after long dedicated and hard work should be known to the farmers, researchers, policymakers and stakeholders so that the research can be applied for the growth of their productivity. The farmers are to be informed about the benefits of the technologies in a very simple, understandable language so that the new innovations are widely acceptable. Communicating research is an essential part of disseminating knowledge to the concerned people in a systematic manner through a right platform at the right time for the ultimate impact. 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.

Key words: E-agriculture, ICT, e-product, e-media, e-publication, agropedia, e-learning, repository, e-choupal, Portal, knowledge innovative, mKrishi, Web-mail

INTRODUCTION

The emergence of Information and Communication Technologies (ICT) in the last decade has opened new avenues in knowledge management that could play important roles in meeting the prevailing challenges related to sharing, exchanging and disseminating knowledge and technologies. ICT allows capitalizing to a greater extent on the wealth of information and knowledge available for Agriculture Knowledge, Science and Technology Knowledge and information have become the major drivers of social and economic transformation in the world. They are of even higher significance in agriculture, which sustains the food and livelihood security as well as economic growth. Presently, the agriculture across the globe is facing challenges in the wake of increasing climatic variability, biotic stresses, and competitive global market; declining base of production resources; growing essentiality of application of hi-tech and precision farming for adaptation and increasing need for matching the pace of technological advancements and knowledge explosion. Generation and dissemination of market oriented information is very essential for making agriculture profitable and sustainable. There is need to tap the large reservoir of farmers' tacit knowledge to consider their perspective and for blending with the scientific findings to develop applicable knowledge and appropriate technologies. Promotion of mobile networks along with community radios may enhance the knowledge management at grassroots level. Various Content Management tools used in different portals may be adapted for extension systems. Knowledge Portals may be developed with vernacular language content to meet out local needs. More focus should be given to farmers'

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success stories through print media and ICT tools. Market Information Systems should be integrated with KVK system so that knowledge is provided along with market information.

The Indian Council of Agricultural Research comprises of more than 100 research institutes under it's own establishment and further coordinates the research and education at the apex level with agricultural universities and several international organizations. The Council has adopted Open Access Policy and Open Data. The information sharing is very strong and to further enhance the outreach to all stakeholders a number of portals, websites and social media initiatives have been initiated as the cyber connectivity is growing at a very fast pace in the country and the Government is laying emphasis on digital India. India has more than 24 crore Internet users accounting for more than one fifth of the total population. Through internet we have immediate space in the international arena having presence of around 40% of the world population and growing at 8% per annum. ICAR laid special emphasis on use of ICT for dissemination of agriculture information and knowledge through World Bank funded National Agriculture Innovation Project.

SELECTED PORTALS AND WEBSITES IN AGRICULTURE

A. ICAR website (http://icar.org.in)

ICAR website has more than 10,000 pages and it is visited by over 2,50,000 visitors every month. Success stories on how scientific agriculture has been adopted by different farmers to raise the productivity and profitability are covered as case studies and posted on the home page. News items on various events across ICAR institutes are regularly uploaded. News on capacity building and trainings are covered under a separate subhead. ICAR is also using the social media platforms i.e. Facebook page, launched on 27 February 2013 and YouTube channel launched in 2012

B. Wheat (http://www.iasri.res.in/wheat)

EXOWHEM is a web based Expert System that provides complete information about the Wheat Crop Management in the country. It advises wheat varieties on the basis of area, cultural and climatic conditions and other characteristics of farmer's interest. It also suggests the appropriate cultural practices like field preparation, fertilizer application, schedule of irrigation etc. It guides them in protecting the crop from insects/diseases/ weeds etc. It also provides solution to the problems faced by the farmers through online queries.

C. Seed Spices(http://www.iasri.res.in/exps/)

Expert system on seed spices is a web based expert system developed on seed spices. It provides the complete information about seed spice production management. The system covers altogether 10 seed spices namely cumin, fenugreek, coriander, fennel, nigella, dill, ajowain. It helps farmers by providing information on selection of seed spice varieties on the basis of area, cultural and climatic conditions and other characteristics of farmer's interest. It also suggests the appropriate cultural practices like field preparation, fertilizer application, schedule of irrigation etc. It guides them in protecting the Seed crop from insects/ diseases/weeds etc. It also features online help to answer famer's queries regarding problems faced by them.

D. Rice Knowledge Management Portal (www.rkm.co.in)

It is an exclusive portal on rice which aims to serve as an information highway for sharing rice knowledge through latest ICT tools including mobile telephony. Built on web 2.0 standards, this portal caters to location specific information needs of many stakeholders through IP based customization on 24X7 bases. Another feature of this portal is providing content in local language.

The portal provides the short term weather forecast to render timely information to the farmers and extension agents for real time decision making. The day to day Mandi prices of rice prevailing in the various national markets are channeled into this portal for better decisions for better remuneration to the rice farmers.

E. KRISHI-Data portal of ICAR (http://krishi.icar.gov.in/)

Knowledge based Resources Information Systems Hub for Innovations in agriculture, is an initiative of Indian Council of Agricultural Research (ICAR) to bring its knowledge resources for all stakeholders at one place. The portal is being developed as a centralized data repository system of ICAR consisting of technology, data generated through experiments/ surveys/ observational studies, geo-spatial data, publications, learning resources etc.

F. E-Learning Portal of ICAR

An exclusive portal for the e-learning in agriculture has been made available at http://ecourses.iasri.res.in The portal hosts e-Courses for the degree level programmes in seven disciplines namely; Agriculture, Fisheries Science, Dairy Science, Veterinary and Animal Husbandry, Horticulture, Home Science and Agricultural Engineering with 1107 credits and 15820 lessons have been developed as per ICAR approved syllabus. This portal provides 24/7 services for online access to all the teachers and students learners in the field of agricultural education. For remote area institutions/ faculty/ students, free download facility is provided for using the e-Courseware contents offline. A total of 118880 downloads across 71 universities have been registered up to 5th January, 2016.

G. Institutional Repositories

The institute repositories are being developed by different institutes under the ICAR. Some of the institutes have full-fledged repositories. Eprints@CMFRI is the Open Access Institutional Repository of Central Marine Fisheries Research Institute. Research outputs of CMFRI - journal papers, conference papers, reports, theses, patents etc. are uploaded. Users can freely download from institute repository and also from internet search engines. Research outputs of CMFRI - journal papers, conference papers, reports, theses, patents etc. - are uploaded/self-archived by CMFRI scientists who do research on fisheries and related areas. Interested users can freely download and use documents as most of them are directly accessible and full-text downloadable. The repository holds full text research papers, theses, books, proceedings, images and videos etc. as given below. More than 96% of the items are 100% open access. The metadata is searchable by year, author, subject or type of document and since 2010 more than 16.80 lakhs of downloads have been registered in all.

H. Krishikosh (http://krishikosh.egranth.ac.in/)

Digital library and information management under NARS has been strengthened through "Krishikosh" available at http://krishikosh.egranth.ac.in/. The portal provides digital access to library resources of 38 partner institutions of National Agriculture Research and Education System. These resources include important institutional repositories, rare books and old journals, which were made publically accessible over the internet. Introduction of AgriCat, (http://www.egranth.ac.in), as a sub-set of the WorldCat, a first of its first kind in agriculture, provides a visualization of the visit to a library. Implementation of KOHA, the open access software for library management was initiated as a strong platform for integration of libraries of NARS and knowledge tagging in the digital era has been achieved. This repository has 16 million digitized pages in 50,000 digital items like old books, old journals, and reports including theses from KrishiPrabha.

I. Agropedia(http://agropedia.iitk.ac.in/)

AGROPEDIA is an open-ended online knowledge sharing platform that makes agriculture information available to scientists, researchers, extension personnel and the agricultural community and allows them to search and make contributions to the knowledge base. AGROPEDIA comprises a repository of knowledge models. With the aid of agricultural Experts developed the following models:

- A standard map, acting as top level foundation crop ontology.
- Specific maps on different crops.
- This space of AGROPEDIA portal deals with the certified contents added to the portal mainly by the agricultural scientists of the consortium partners of the project in the form of 'Library' content, 'Voice Messages', ' Text Messages', 'Package of Practices', 'Crop Calendar' or 'Dos and Don'ts' on the different crops. AGROPEDIA provides different features like blog, forum, chat, wiki to share and learn agricultural information and experiences

J. E-Publication(http://epubs.icar.org.in/ejournal/)

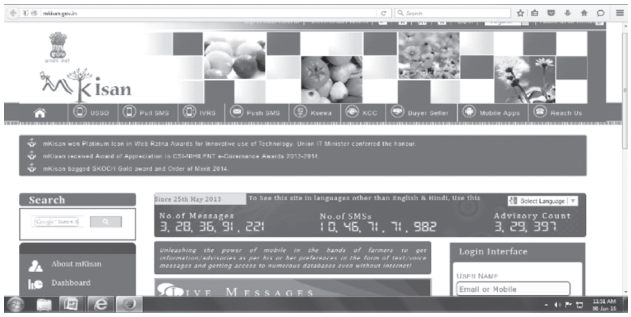
A web based e-publishing and knowledge system in agricultural research (EPKSAR) system for publishing of scientific journals covering the entire life cycle of research paper publishing and online production was created and successfully implemented. The portal provides role based access to users including authors, reviewers, editorial staff and readers. The system is being used for 24 scientific journals including ICAR journals (3), semi-technical journals (2) and scientific society journals of NARS (19). Due to the Open Access Policy in ICAR, these ICAR journals are being accessed online from 192 countries globally, and 82 cities nationally. The numbers of online readers of

e-journals increased by 2-3 folds and their impact factors also improved significantly.

SELECTED E-RESOURCES IN INDIAN AGRICULTURE

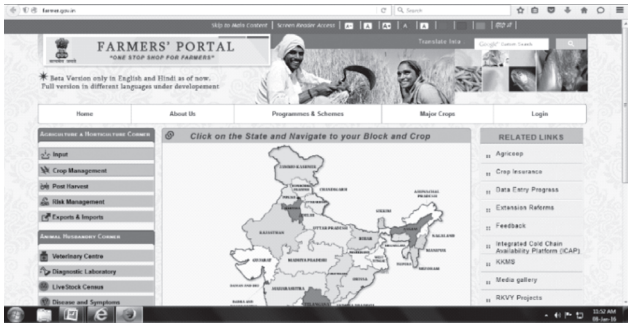
A. mKISAN (URL:http//mkisan.gov.in)

MKisanSMS multipurpose portal is conceptualized, designed and developed in-house within the Department of Agriculture & Cooperation, Government of India. As part of agricultural extension (extending research from lab to the field), under the National e-Governance Plan - Agriculture (NEGP-A), various modes of delivery of services have been envisaged. Farmers can register themselves for receiving these messages on their mobiles as per their specific needs & relevance at a particular point of time. All applications and services listed in the Portal are accessible on any kind of mobile phone including basic feature phone. This portal interaction with mobile telephony (with or without internet) is the most potent and omnipresent tool of agricultural extension.



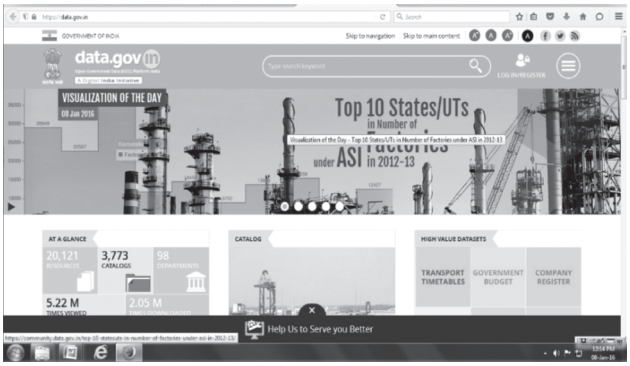
B. Farmers Portal (URL:http//farmer.gov.in)

This is the Official website of Department of Agriculture & Cooperation, Ministry of Agriculture Government of India, designed, developed and hosted by National Informatics Centre (NIC). With the help of this portal a farmer will be able to get all relevant information on specific subjects around his village/block /district or state. This information will be delivered in the form of text, SMS, email and audio/video in the various languages. These levels can be easily reached through the Map of India placed on the Home page. Farmers will also be able to ask specific queries as well as give valuable feedback through the Feedback module specially developed for the purpose.



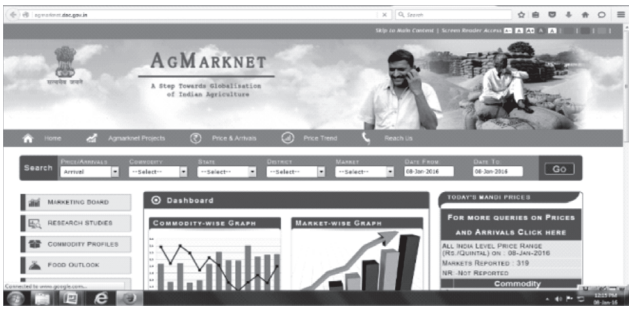
C. Open Government Data (URL:http//data.gov.in/)

Open Government Data (OGD) is a platform for supporting Open Data initiative of Government of India. The portal publish datasets, documents, services, tools and applications collected by them for public use. It intends to increase transparency in the functioning of Government and also open avenues for many more innovative uses of Government Data to give different perspective. The base Open Government Data Platform India is a joint initiative of Government of India and US Government. Open Government Data Platform India is also packaged as a product and made available in open source for implementation by countries globally.



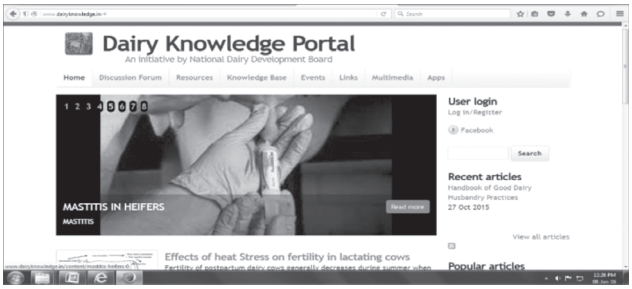
D. AGMARKNET (URL:http//agmarknet.nic.in/)

The AGMARKNET portal also serves as a single window for assessing websites of various organization concerned with Agricultural Marketing. It also provides weekly price trend report for important markets in respect of major agricultural commodities. It is linked with the online exchange portals for providing spot and future prices for important commodities. International price trends of various agricultural commodities are also accessible through this portal.



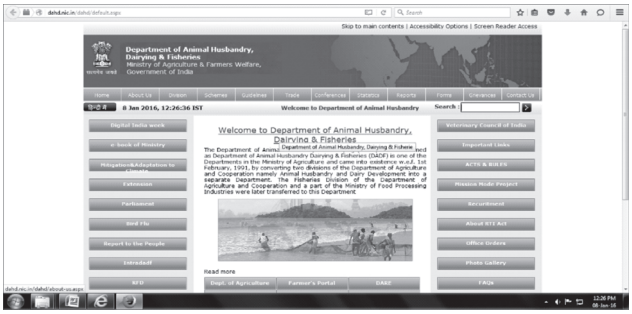
E. Dairy Knowledge Portal (URL:www.dairy knowledge.in)

Dairy Knowledge Portal is an initiative by National Dairy Development Board. This portals deals with the various Dairy related issues as, animal health, breeding, fodder, nutrition, milk quality and other products, dairy technology and apps on basic guide to good animal husbandry practices, PashuPoshan, Story of Milk A Cow's Tale (English, Hindi), has sections on Dairy Federation, cooperative, producers, company, government agencies, educational institution etc.



F. DADF Department of Animal Husbandry Dairying & Fisherries (URL:http://dahd.nic.in/dahd/default.aspx)

This website is developed by the Department of Animal Husbandry Dairying & Fisheries (DADF). The Department advises State Governments/Union Territories in the formulation of policies and programs in the field of animal husbandry, dairy development and fisheries. This website contains section on related Departments and Divisions, topics on extension, technology, training, scheme, guidance, education, related e-books, diseases and reports etc.

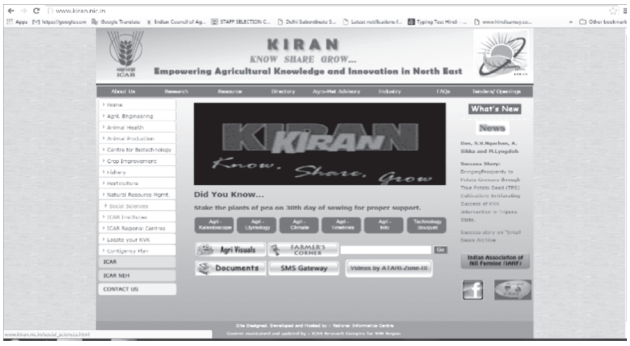


G. aAqua (URL:http://aaqua.persistent.co.in/aaqua/forum/index)

aAquaeAgriService is a problem-solving system dedicated to find solutions to problems posed by Indian farmers - small and large. Answers to your agri-related queries are sent in 24 to 72 hours depending on the difficulty. Experts are employees of their respective organizations and serve without charge. This multi-purpose portal has been developed to deliver the query related to agriculture from all over the India about various issues like, corps, oilseeds, irrigation, fertilizer etc. The question asked by the farmers from all over the country on various topics is answered on this portal with the help of agri-experts. Portal also deals with market information, farmer's schemes and related discussions etc.

H. KIRAN (Knowledge Innovative Repository of Agriculture in North East) (URL:www.kiran.nic.in/)

KIRAN (Knowledge Innovative Repository of Agriculture in North East) portal provides information on technology, reliable agricultural data, applicable knowledge, innovative solutions, Farming system, single window arrangement for obtaining technological consultancy and innovative solutions. This portal also promotes utilization strategies through partnership and convergence etc., provides various topics related to North East agricultural growth, initiation, framework etc.



CONCLUSION

E-agriculture is an emerging field focusing on the enhancement of agricultural and rural development through improved information and communication processes. More specifically, e-agriculture involves the conceptualization, design, development, evaluation and application of innovative ways to use these information and communication technologies (ICT) in the rural domain, with a primary focus on agriculture. The

Internet is increasing communication and business opportunities within the agricultural community, which previously operated in the relative isolation of rural areas. Farmers, agricultural researchers, cooperatives, suppliers and buyers use the Internet to exchange ideas and information. The work of preservation and documentation of agricultural knowledge were started during Veda period and after the establishments of Indian Council of Agricultural Research, the activity of bringing out Agricultural Information Products are still continue in a organize way by the ICAR and its institutes. The present paper describes the type of print publications, e-product, and web based information resources developed by the Indian Council of Agricultural Research and other agriculture department in the country.

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NICRA (National Innovationsin Climate Resilient Agriculture) (http://www.nicra icar.in/nicrarevised/)

KIRAN (Knowledge Innovative Repository of Agriculture in North East) (URL:www.kiran.nic.in/)

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Delineation and estimation of unsaturated aquifer and saturated aquifer of Faridabad district, Haryana, India

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ABSTRACT

India in general and Faridabad in particular is facing a serious water resource problem and as trends suggest, it is expected to become 'water stressed' by 2025 and 'water scarce' by 2050 (IDSA, 2010). The Faridabad district is critically reliant on groundwater for both drinking water and non–potable uses. The area comprises both rural and urban area. Better understanding of groundwater flow, identification of recharge and discharge area will ensure sustainability of groundwater resources. ArcGIS (ESRI, USA) is a geographic information system (GIS) for working with maps and geographic information. It is used for creating and using maps; compiling geographic data; analyzing spatial information and managing database in GIS platform. It is used for making DEM, water table contour map interpolation, spatial analysis and raster analysis etc. This has resulted in increased groundwater draft for construction purpose and further leading to decline of water level. The close inspection of four hydrographs reveals that there is distinct pattern in hydrograph behaviour. Ballabhgarh and Bhoapni indicates sharp decline in water level because these monitoring wells lies in urban area. Whereas Kabulpur and Sikri water level is almost constant as these two well fall in rural/agricultural area. In urabn area paved area restricts recharge whereas in rural area return flow from irrigation recharge the aquifer. In order to assess the aquifer volume available for recharge GIS based analysis was carried out. Post Monsoon water level is used to estimate unsaturated thickness of aquifer which is available for recharge. Water level more than 3 meter has been considered as maximum water level for recharge above this it will create water logging condition.

Key words: GIS, DEM, Pre and Post Monsoon, Water level, Setellite Image

INTRODUCTION

Water is a fundamental human need and a critical national asset. It is the key to socio-economic development and quality of life. As the pressures of population and economic activities converge on water requirement, the water sector will increasingly face the challenge of bridging the demand-supply gap. India in general and Faridabad in particular is facing a serious water resource problem and as trends suggest, it is expected to become 'water stressed' by 2025 and 'water scarce' by 2050 (IDSA, 2010). Groundwater is under stress in almost all parts of India due to rapid development in agricultural activities, industrialization, urbanization, education, improved sanitation and increase in population. These scarcities of water make groundwater more precious. Faridabad district is also marred by off and on water crisis.

In the densely populated semiarid territory in and around Faridabad (India), the water demand is rising continuously, while the surface- and groundwater resources are threatened by contamination and overexploitation. This is a typical scenario in many newly industrialising and developing countries, where new approaches for a responsible water management have to be found. Industrialization and urbanization are major threat to water quality. Groundwater, unless contaminated, is generally of better quality than surface water and can be developed incrementally in close proximity to needs, thus avoiding the need for large-scale storage, treatment, and distribution systems (Dapaah-Siakwan and Gyau- Boakye, 2000; Odai and Dugbantey, 2003). In an effort to provide the population with safe, adequate, and sustainable water supply, the significant groundwater resources, which are contained in the sedimentary sequence of the basin, have increasingly been exploited.

Increasing urbanization results into decline in water level. Rapid population growth, and increasing urbanisation of Faridabad and Greater Faridabad has added considerable stress on the region's water resource. The impacts of less rainfall

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and increasing water demand have been evident as declining stores of surface water and groundwater within the Faridabad district for the past several decades. All the hydrographs of Ground Water Monitoring stations of Central ground Water Board in the district reveals continuous decline of limited fresh ground water resources and needs immediate remedial measures.

Need of the study

The literature survey reveal that very limited work has been done to understand groundwater flow regime and its sustainability. The Faridabad district is critically reliant on groundwater for both drinking water and non–potable uses. The area comprises both rural and urban area. The study area is facing multiple groundwater related problems like declining water level, water quality issues (geogenic, anthropogenic contamination and salinity). Urbanization has an adverse impact on groundwater. This leads to declining water level due to decreased recharge and increased groundwater draft. Therefore, it is necessary to evaluate the aquifer potential to artificial recharge and sustainability of groundwater resources in the district. Enhancing groundwater storage in the aquifer system through artificial recharge is both a practical and necessary strategy for achieving water security. Artificial recharge is defined as any engineered system designed to introduce and store water in aquifer.

Purpose and Scope

The major source of domestic and irrigation water is from ground water resources in Faridabad District. However, this water resource is facing problems of declining water level. To arrest declining ground water level it is imperative to take up artificial recharge intervention. In order to that aquifer potential and feasibility need to be assessed. Better understanding of groundwater flow, identification of recharge and discharge area will ensure sustainability of groundwater resources. So far this information for the study area very limited.

Objective

The purpose of this study was to assess the hydraulic feasibility of artiûcial recharge of the superûcial aquifer across the Faridabad region by developing a quantitative method to estimate aquifer response to various recharge rates. Speciûc tasks that would be undertaken includes:

1. To delineate and estimate of unsaturated aquifer and saturated aquifer.
2. To develop a quantitative procedure for simulating aquifer responses to artiûcial recharge , including well injection and basin inûltration, which has to be applied spatially across the study area,
3. To prepare a suitable spatial datasets of aquifer properties and hydrological conditions across the Faridabad district for modelling of aquifer response.

MATERIALS AND METHODS

Location and extent of Study Area

Faridabad is situated on the Delhi – Mathura National Highway No.-2 at a distance of 32 km. from Delhi, at 28° 25' 16" north latitude and 77° 18' 28" east longitude. The town is bounded on the north by Delhi State, on the east by Agra and the Gurgaon canals and on the west by the Aravali Hills (Fig. 1). The Yamuna flows on the eastern side from north to south.

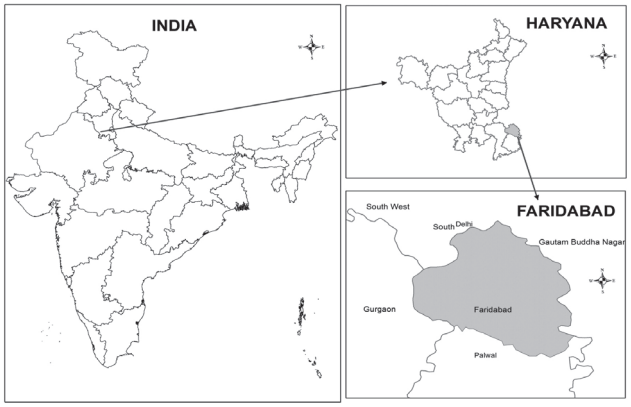

Fig. 1. Index map of study area

Demography

According to the 2011 census Faridabad district has a population of 1,798,954 i.e. about 7.10 percent of the state population. Almost 80% population of the District is urbanized. This gives it a ranking of 266th in India (out of a total of 640). The district has a population density of 2,298 inhabitants per square kilometre. Its population growth rate over the decade 2001–2011 was 31.75%.

Physiographic and Drainage

The Faridabad district is occupied by the surface exposure of hard rock measuring about 99 square kilometres in the western part comprising of localities like Kot, Ankhir , Badkal and Surajkund

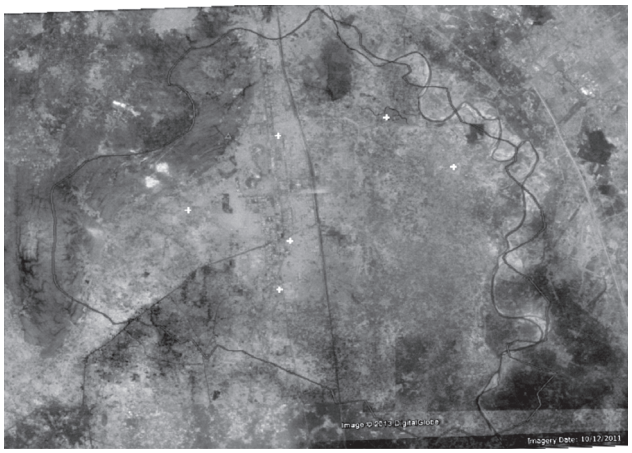

Fig. 2. Satellite Image of the study area

etc. (Fig. 2). Besides the hard rock areas, the other parts of the district are occupied by mainly alluvial to fluvio-aeolian deposits.

The depth to bedrock/ basement topography is defined by steep escarpment at the margin of the hard rock area (where the depth of bed rock follows a steep gradient) and a mild undulation in the rest of the district, where depth to bed rock is found in the range of 300-400 *meters below ground level* (mbgl).The highest value of the topographic contour is found in the range of 317 *meters above mean sea level* (mamsl) in the NW part of the area at Manger village. The hard rock areas slopes steeply in SE direction and has a steeper slope towards east and west direction (Fig. 3). On approaching the alluvium the lowest elevation is found at Bagpur kalan 180 mamsl. The general gradient of the alluvium is towards the SW and NE. The area is drained mainly by the Yamuna River which enters the district near Chak Basantpur, flows southwards and exits at Bagpur kalan.

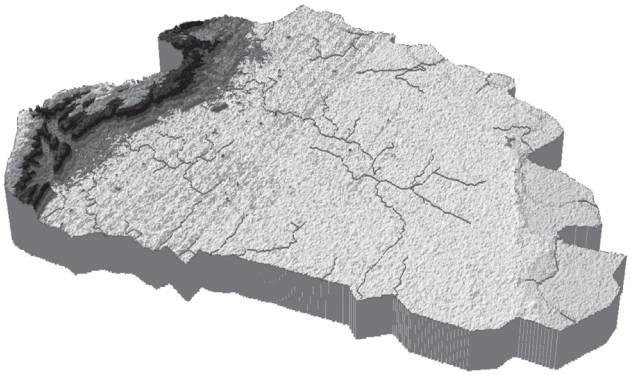

Fig. 3. Digital elevation model showing physiography

Climate and Rainfall

The area has semi-arid type of climate. There are three well defined seasons. The cold season begins in November and extends to the middle of March. Winters are usually very cold and icy winds are common feature.

Table 1. Rainfall and temperature data of Faridabad

Rainfall (mm)		Temperature (°C)		Normal
Normal Annual	Normal Monsoon	Mean Maximum	Mean Minimum	Rainy days
542	460	41 (May & June)	8 (Jan)	27

Agriculture and Irrigation

As per the census of 2011, the district has total of 52 villages. The Faridabad district is having of 20% rural population. Groundwater is the main source of irrigation, on account of absence of canal irrigation in the area. Besides the normal rabi and kharif crops, vegetable crops are one of the important crops in the area.

Soils

Soils of Faridabad district are classified as tropical and brown soils, existing in major parts of the district. They are moderately to well drained. In Hathin block the organic content of soils ranging from 0.41 to 0.75 percent which is of medium category. In rest of the area organic contents is 0.2 to 0.4 percent and falls in Low category. The average conductivity of the soil is not more than 0.80 μ mhos /cm and the average pH of the soil is between 6.5 and 8.7.

Geology

The Faridabad comprises of quartzetic hard rock area in the western part measuring about 99 sq. km. The western fringes of the hard rock have steep gradient when it comes in contact with the alluvium and the depth to basement increased from west to east. The quartzites are interbedded with mica schist and slates and belongs to Faridabad Supergroup. The rocks are uncomfortably overlain by unconsolidated quaternary to recent sediments. The general stratigraphic profile of the region is given in Table 2.

The Alwar quartzites form the hard rock formation of the area. They are massive gray to buff coloured with brown to reddish brown ferrugenously leached surfaces. The phenomenon of spheroidal weathering is very common in these rocks with reddish brown concentric layers peeling off the surface. Thin argillaceous intercalations metamorphosed to schistose grade exhibiting layers

Table 2. The General Stratigraphic Profile of Faridabad region

Period	Formation	Description
Quaternary	Fluovio Aeolian deposits	Consists of unconsolidated interbedded, interfringing deposits of sand, clay, gravel and kankar, moderately sorted with alternation of fluvial fine sediments.
Pre Cambrian	Alwar quartzites	Massive gray coloured with buff to brown frequently leached surfaces at places, highly fractured and jointed. It is intruded locally by pegmatites and quart/, veins and is interbedded with mica schist at places.

of mica schist is common in these rocks. The rock is highly fractured and jointed. They are locally intruded by pegmatites and quartz veins at places. The schist band and the pegmatites are highly weathered. The general strike of the bedding unit in the Alwar quartzites is NNE and NE to SSW and SW, the bedding unit dips towards SE and NW in the range of 40° to 60° giving an impression of the presence of mega anticline and syncline in the area. The quartzites are traversed by many faults tending NE-SW and NW-SE at different scales.

Fig. 4. Geological of Faridabad District

Exploratory drilling and geomorphic study at the CGWB have brought out the fact that the sedimentary deposits are of the fluvio aeolian character. The fluvial bands are common and occur in random orientation. The aeolian deposits are mainly loam, silty loam and sandy loam. They are fine grain in size having flakes of muscovite and kankar nodules. Lenses and bands of medium to fine sand/silt alternating with clay and kankar deposit is common The thickness of the silt, sand and kankar zone is significant near the hard rock ridge. The older alluvium of Pleistocene age occurs extensively in the area and generally consists of sand, silt, clay and kankar mixed in varying proportions. The sediments are fine to medium grained with moderate sorting.

The phenomenon of weathering giving rise to boulder, gravels, Badarpur sand and the permeable fracture is on account of the seepage of water along the joints and fractures mentioned above. The joints and fractures in their spatial orientation mentioned above forms an important control to the movement and occurrence of ground water in the hard rock areas. When properly analyzed in the perspective of yielding fractures, they could be used as geo-indicators for the occurrence and movement of groundwater in the hard rock terrain of Faridabad.

Numerous faults have been observed in the area. These faults trend NE-SW and NW-SE. There are many small faults which are parallel in orientation to each other. The eastern and the western fringe of the Faridabad ridge is bound by faults , and along the fringes, many fault escarpments have been mapped by earlier workers. Similar escarpment like feature is observed in the Faridabad district where the steep gradient of the quartzitic rock on the fringes in the cross section and the depth to bedrock map suggests at the possibility of a fault on the eastern fringes of the Alwar quartzite. The fault forms and important tectonic control on the occurrence of fresh groundwater.

During the study , spatial model parameters and spatio-temporal data were acquired and processed using remote sensing and GIS to use as in-outs for the groundwater recharge evaluation and flow model. Synoptic view of the methodologies adopted in the study is shown in Flow chart (Fig. 6).

The data required for aquifer evaluation and groundwater modeling study can broadly classified in physical and hydrological framework (Table 3).

Table 3. Data required for aquifer evaluation and groundwater modeling

S. No	Physical framework	S. No	Hydrological stress
1	Topography-Elevation using SRTM data	1	Water table elevation
2	Geological map	2	Delineation and rate of recharge and discharge areas
3	Types of aquifers-Unconfined /confined	3	Groundwater draft from tubewells
4	Aquifer thickness and lateral extent- from litholog		
5	Aquifer boundaries		
6	Lithological variations , within the aquifer		
7	Aquifer characteristics (Hydraulic conductivity, Specific storage, specific yield etc.)- from Pumping test data		

Physical framework

i. Topography-Elevation using SRTM data

The SRTM (Shuttle Radar Topography Mission) elevation data having 90m resolution is used to prepare topographic elevation and digital elevation model after processing in ArcGIS software. This data is utilized for preparation of water table contour map. Location of streams, divides, ponds and so on are derived from Satellite Imagery-Google Earth.

ii. Geological map

Geological map on 1:50,000 scale has been acquired from Geological Survey of India.

iii. Aquifer type, Aquifer Geometry and parameters –

Based on basic data reports of CGWB reports, analysis and interpretation of borehole lithologs, pumping test data are utilized to know aquifer geometry, aquifer parameters and aquifer type.

Hydrological stress

i. Water table elevation- A discretized projected spatial dataset, representing the water table depth below ground surface in Post Monsoon, 2013, was constructed by subtracting the Post Monsoon, depth to water level for November, 2013 from the ground surface elevation model.

ii. Delineation/ rate of recharge and discharge areas – Water table contour map, satellite image and field survey have been used to delineate/ rate of recharge and discharge areas.

Evaluation of Aquifer Recharge Potential

Post Monsoon water level is used to estimate unsaturated thickness of aquifer which is available for recharge. Water level more than 3 meter has been considered as maximum water level for recharge above this it will create water logging condition. This may be explained as if water level is 4 mbl it means unsaturated thickness is only 1 meter (4mbgl water level-3 meter need to be minus from ground surface to avoid water logging=1). Thus map produced by this method was discretized using Spatial Analyst of ArcGIS. Further, specific yield of aquifer is used to know the available volume of aquifer. The grid size considered for unsaturated thickness is 500 meters x500 meters. The formula is used to estimate available volume of Unsaturated aquifer for recharge is

= *Area* x *Unsaturated thickness of Aquifer* x *Specific yield* …*(Eq. 1)*

Estimation of Artificial recharge

Various studies on the subject of artificial recharge of groundwater through surface spreading have been reported by Glover (1961), Marmion (1962), Marino (1967, 1974), Hantush (1967), Bianchi and Muckel (1970), Rao and Sarma (1983), and Latinopoulos (1986). Most of these solutions are based on the assumption of a constant rate of recharge applied continuously or periodically. Common to all these solutions are the assumptions that percolation moves vertically downward until it joins the main groundwater body and that the flow of groundwater takes place in a homogeneous, isotropic, unconfined aquifer having hydraulic properties that remain constant with both time and space.

Hantush (1967) solves the general two-dimensional groundwater flow equation by making assumptions to create boundary conditions that allow the use of a Laplace transform with respect to time and the Fourier cosine transform with respect to x and then y to derive an integral that

can be solved. The resulting equation is

$$h^2 - h_i^2 = (w/2k)(vt)\left\{S^*\left(\frac{1+x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{1+x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right) + S^*\left(\frac{1-x}{\sqrt{4vt}}, \frac{a+y}{\sqrt{4vt}}\right) + S^*\left(\frac{1-x}{\sqrt{4vt}}, \frac{a-y}{\sqrt{4vt}}\right)\right\}$$

where $S^*(\alpha, \beta) = \int_0^1 erf\left(\frac{\alpha}{\sqrt{t}}\right) erf\left(\frac{\beta}{\sqrt{t}}\right) dt$ …(Eq. 2)

h = head at a given time after recharge begins;
hi = initial head (height of the water table above the base of the aquifer);
w = recharge (infiltration) rate;
K = horizontal hydraulic conductivity;
v = diffusivity, where v = Kb/Sy;
b = average aquifer thickness;
Sy = specific yield;
t = time elapsed since recharge began;
l = half-length of the recharge basin;
a = half-width of the recharge basin;
x = distance from the center of the recharge basin in the x direction;
y = distance from the center of the recharge basin in the y direction;

$$\alpha = \frac{l+x}{\sqrt{4vt}} \text{ or } \frac{l-x}{\sqrt{4vt}};$$

$$\beta = \frac{a+y}{\sqrt{4vt}} \text{ or } \frac{a-y}{\sqrt{4vt}}$$

Infiltration from a recharge basin produces a groundwater mound above the original water table as shown schematically in Figure 12. The dimensions of the mound are governed by the basin size and shape, recharge rate and aquifer characteristics. The shape of a mound beneath a rectangular recharge area, expressed by h-ho, is the mound height in function of time and space, depending upon the artificial recharge flux, the storage coefficient and transmissivity of the aquifer.

ArcGIS

ArcGIS (ESRI, USA) is a geographic information system (GIS) for working with maps and geographic information. It is used for creating and using maps; compiling geographic data; analyzing spatial information and managing database in GIS platform. It is used for making DEM, water table contour map interpolation, spatial analysis and raster analysis etc.

RESULTS AND DISCUSSION

The groundwater in South West district of Faridabad occurs in broadly two types of formations namely the hard rock areas of the eastern side and the alluvium in the rest of the district . The hard rock areas are characterized by the fractures which serve as conduit for recharge to ground water and a route for the flow of groundwater to the water abstraction structures. The groundwater occurs in semi-confined to confined condition in the hard rocks. The pressure of the groundwater is represented by the piezometric head or pressure head. . In the alluvium and fluvio-aeolian areas, the ground water occurs in unconfined condition in the top sandy horizon and semi-confined to confined condition in the lenticular sandy layers occurring at depths. Where ever the percentage of Kankar in clay and silt is high, they form very good aquifers for ground water development. But very often these aquifers are filled with saline ground water resources which restricts its development. The top sandy horizons

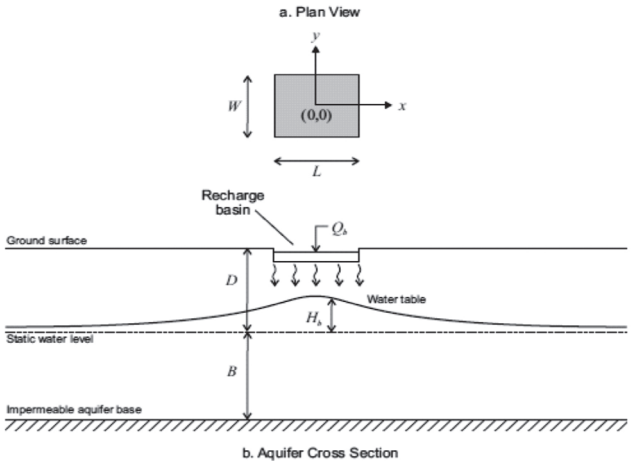

Fig. 5. Groundwater mounding due to recharge from infiltration basin

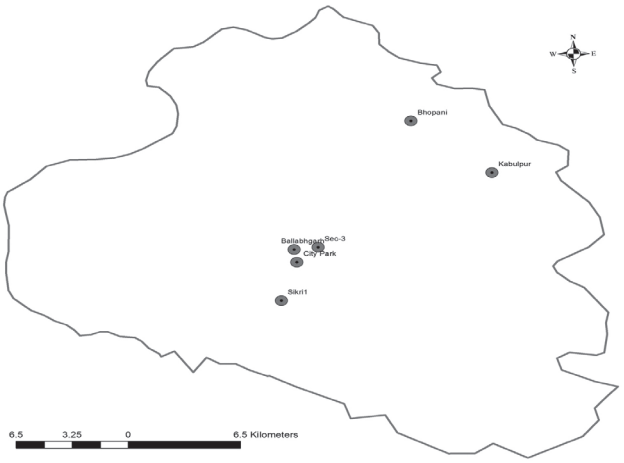

Fig. 6. Location of monitoring wells, Faridabad

mixed with Kankar and silt forms potential aquifer zone in the area.

The Depth to Groundwater Levels

Pre Monsoon May 2013

The deepest groundwater levels are observed in the hard rock areas at the higher elevations and the areas adjacent to it. The western part of the area shows deepest ground water levels more than 20 meters below ground level and Shallow groundwater level have been observed in southern eastern part of the district.

There is a wide variation in the pre monsoon depth to water level in the district in the range of 6-30 meters below ground level (mbgl). The south eastern part of the district comprising of Atrena, Mohna, Mohiapur and Pahladpur areas (Fig. 7) have shallow depth to ground water levels in the range of 6-10 mbgl. The area to the north of the above mentioned zone comprising of localities like Digh, Maojpur,, Walipur and Panehra have depth to water level in the range of 11-15 meters below ground level. The zone bordering Yamuna river and eastern part of the district comprising of localities like Kurali, Dadsia, Lalpur , Faizpur Khadar, Sotai, Sagarpur and Sikri etc (Fig. 7) have depth to water level in the range of 16-20 meters below ground level. There is another zone to the Western part of the district comprising villages like Pali , Mangar, Kot, Nimka, Sirohi, Kabul pur, Faridabad, Tilpat and Bhatola having depth to water level of more than 20 meters below ground level.

In a broader perspective the deepest groundwater levels to the west of Yamuna River is found towards central part of the area and further north of it. While the depth to ground water levels in the region to the east of the Hilly Area occupied by hard rock shows an increasing trend on moving from west to south east towards the Yamuna River area and towards the direction of decrease in elevation. It is an observation that as gradually the elevation decreases from west to southeast direction, the depth to water level also decreases. The urban area is marked by deeper water level which is attributed to heavy groundwater abstraction.

Groundwater draft is a major controlling factor in the spatial variation of the depth to water level zones. But the fact that the area of recharge in the hard rock domain shows deeper groundwater levels is also established.

Post Monsoon November 2013

The post monsoon observation of the depth to water level in the district shows a similar spatial orientation as that of the pre monsoon observations. There is no significant change in the zones of depth to water level and its trend (Fig. 8). The areas adjoin to Hills shows a shrinking in the region having depth to water level in the range of > 20 meters below ground level (mbgl). At Pali, Bajri, Gazipur, Samaipur and Karnera water levels have come up after Monsoon and having depth to water level 16-20 from >20 mbgl during Pre-monsoon. The region with the depth to water level in the range of 6-10 and 11-15 mbgl have slightly widened (Fig. 8). There is no other very significant change in the post monsoon depth to water level observed in the district. It indicates towards the fact that the change in water level was mostly due to rain fall recharge. There was no significant recharge observed in the area to the east of Yamuna River. While the area to the west of the Yamuna River showed some recharge to the groundwater after monsoon Showers.

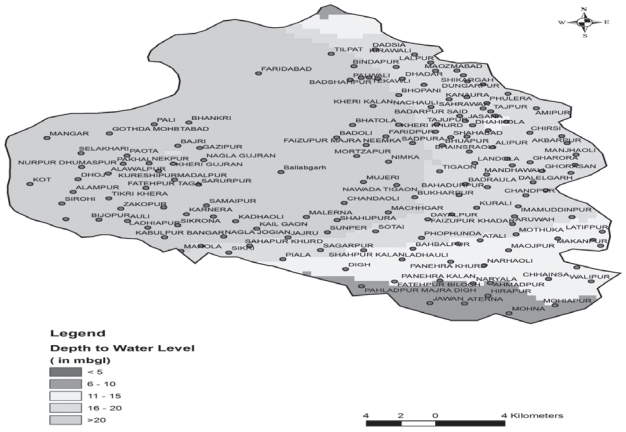

Fig. 7. Depth to water level map (Pre-Monsoon, 2013)

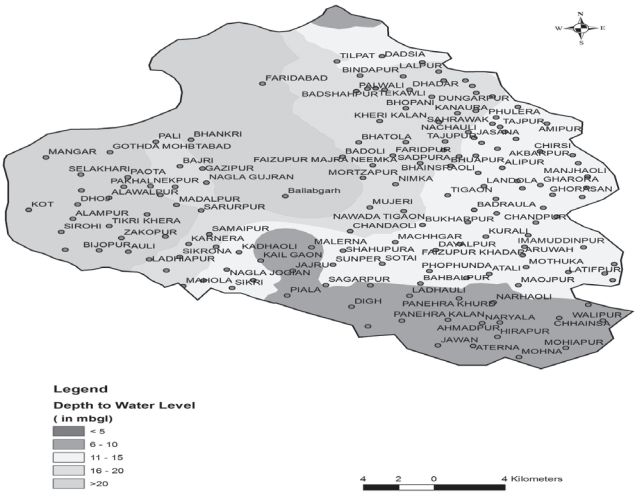

Fig. 8. Depth to water level map (Post-Monsoon, 2013)

Seasonal Fluctuation in Water Levels (Pre and Post Monsoon)

The depth to water levels during the monitoring of the key wells in post monsoon period of the year 2013 was compared to the depth to water level values monitored during the pre-monsoon period of the year 2013. The point values for the fluctuation in the water level was noted and plotted on a map to obtain the water level fluctuation map of the district for the pre and post monsoon period of year 2013 (Fig. 9). The post monsoon observation of the depth to water level with respect to that of the pre monsoon for the year 2013 shows rise in the water level throughout the district. Maximum rise in water. While the area adjoining to Yamuna River have minimum rise within the range of 0-5 meters (Fig. 9).

The small area around north of Faridabad town showing post monsoon rise in water level to the tune of 16-29 meters (Fig. 9) could be on the account of localized recharge the surrounding areas and the natural recharge from the numerous stone quarries in the region around Pali, Mangar and Ankhir area. The area covered in the above zone is barren with very little habitation. The analysis of the water table contour map shows convergence of the ground water flow to the areas showing significant post monsoon rise in the water levels (Fig. 9). As regards to the narrow strip along the Yamuna River and its tributaries showing post monsoon rise in the water levels ,the causative factor could be recharge from the water flowing through the Yamuna River system.

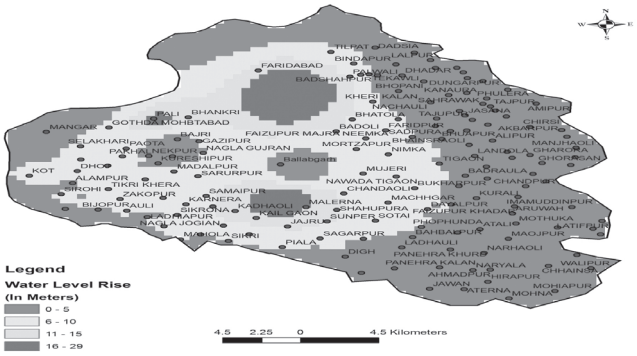

Fig. 9. Groundwater level Fluctuation (Pre-Post Monsoon, 2013)

Groundwater flow

The water table contour map of the district has been prepared for the pre monsoon season of the year 2013 (Figure 10). An analysis of the water table contour and the flow directions brings out the basic groundwater flow direction in the district. The region to the west of the Yamuna River have major cone of depression around Faridabad city area. Groundwater flows into this zone from the surrounding areas. This is caused by heavy abstraction for domestic use, it attracts groundwater flow towards it. The hydraulic gradient is comparatively steep in these depressions on the account of them being mostly in sweet water belt and on the fringes of the hard rock areas. The elevated ridge in the Ankhir area and further western has emerged out as major areas of recharge with ground water flowing in the North East and East directions from it. The presence of depressions near Pali village located at western boundary of the district attracts groundwater flow in to these depressions (Fig. 10).

The another cone of depression in Tekwali area (Fig. 10) developed on account of heavy discharge from agricultural and farmhouses activity, attracts groundwater flow from all directions towards it.

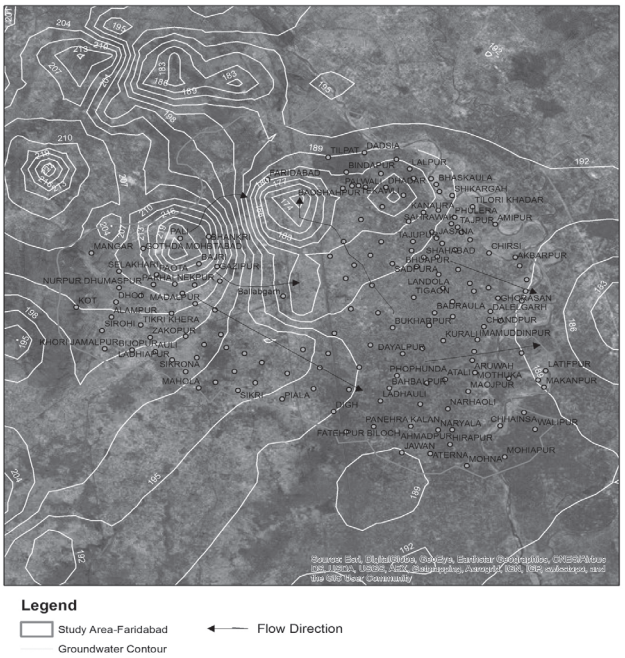

Fig. 10. Water Table Elevation contour, Faridabad district

Hydrograph

The ground water level monitoring data for Ballabhgarh monitoring station is available for last 20 years. The hydrograph analysis of this monitoring station (Fig. 11a) shows that decline in ground water level is continuous phenomenon. In the last 20 years there is a decline of 12 meters. This decline is directly linked with increase in groundwater draft due to increase in population. Similarly, Bhopani hydrogrpah (Fig. 11b) decline of 7 meters in last 12 years. Landuse around Bhopani has changed from agriculture to urban

area. This has resulted in increased groundwater draft for construction purpose and further leading to decline of water level.

The close inspection of four hydrographs reveals that there is distinct pattern in hydrograph behaviour. Ballabhgarh and Bhoapni indicates sharp decline in water level because these monitoring wells lies in urban area. Whereas Kabulpur and Sikri water level is almost constant as these two well fall in rural/agricultural area. In urabn area paved area restricts recharge whereas in rural area return flow from irrigation recharge the aquifer.

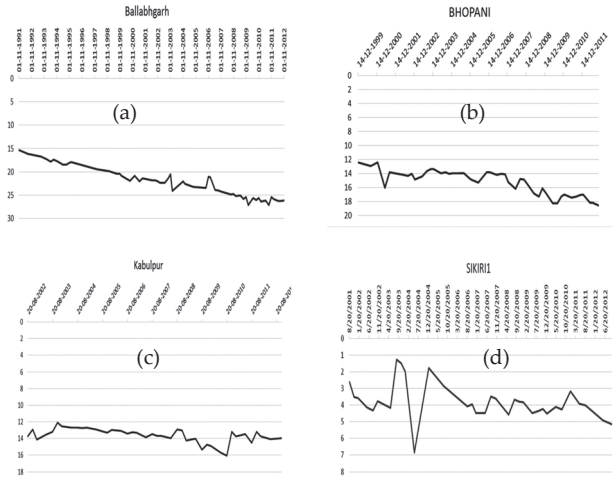

Fig. 11. Hydrograph of groundwater monitoring station

Estimating the volume of unsaturated aquifer

Post Monsoon water level is used to estimate unsaturated thickness of aquifer which is available for recharge. Water level more than 3 meter has been considered as maximum water level for recharge above this it will create water logging condition. Thus map produced by this method is discretized using Spatial Analyst of ArcGIS (Fig. 12). Further, specific yield of aquifer is used to know the available volume of aquifer (Figure 13). The grid size considered for unsaturated thickness is 500 meters x 500 meters. The formula has been used to estimate available volume of Unsaturated aquifer for recharge is

= *Area* x *Unsaturated thickness of Aquifer* x *Specific yield.*

Fig. 12. Thickness of unsaturated aquifer

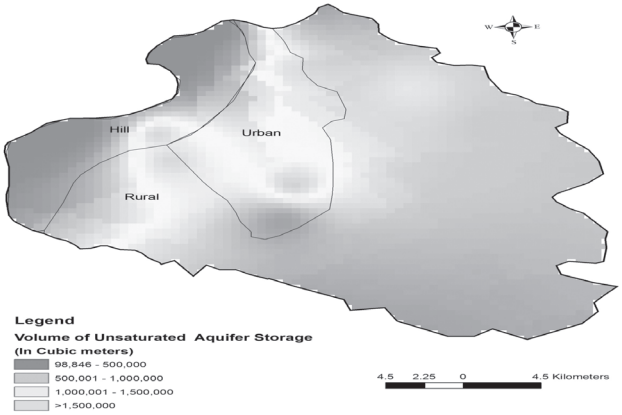

Fig. 13. Volume of Unsaturated Aquifer Storage Available for Artificial Recharge

Figure 13 reveals that rural area which is covered mostly by alluvium is having better prospect for artificial recharge. The light green and dark green color in map legend indicates that colume of unsaturated aquifer storage is high in these area. Further, Table 4 shows that a total of 2561 MCM of volume is available for recharge during Pre Monsoon. During Post Monsoon the volume is available for recharge is about 1839 MCM of. Thus, the total volume of natural recharge in the district is 722 MCM annually. About 978 MCM volume of unsaturated aquifer storage is available for recharge in rural area.

Thus there is sufficient volume of unsaturated aquifer storage is available for recharge.

Evaluation of Aquifer Response in Response to Artificial Recharge Measures

In unconfined aquifer two basic techniques Well injection and Basin Infiltration are commonly used for artificial recharge.

Table 4. Volume of Unsaturated aquifer storage available for recharge

	Volume Available for Recharge			In MCM
	Hill	Rural	Urban	Grand Total
Pre Monsoon	612.39	1376.10	573.31	2561.81
Post Monsoon	512.85	978.47	347.710	1839.04
Volume Filled	99.54	397.62	225.60	722.76
Increase in %	16.25	28.89	39.35	28.21

Table 5. Site suitability criteria for basin infiltration

Favourable conditions	Unfavourable conditions
Unconfined aquifer with sufficiently thick unsaturated aquifer	Aquifers in which the basin bottom cannot be excavated into permeable strata.
unsaturated aquifer with large hydraulic conductivity and absence of clayey layers.	Existence of layers with small hydraulic conductivity within the unsaturated aquifer zone.
Adequate areal extent of permeable soils. Sufficient aquifer transmissivity to prevent excessive water table mounding, e.g., deep, wide conductive layers.	Small aquifer transmissivity leading to excessive water table mounding.
Source water that is chemically compatible with the receiving groundwater.	Pollutant in the source water or unsaturated aquifer zone
Source water and vadose zone that are free of pollutants.	Shortage or inhibitive expense of land area.

Well injection requires external energy source to inject water into the aquifers. Moreover, source water should be clean and without any impurity to avoid clogging problems of aquifers. The intake capacity of wells can decline rapidly when the source water contains suspended materials that clog the injection well screen, well–pack or the aquifer formation. This causes high operational cost and maintenance. So this method is not suitable in the context of Faridabad.

Surface infiltration is generally a more cost–effective method of artificial recharge, provided that adequate land is available and the unsaturated zone hydrogeology is favourable for vertical percolation. Criteria for site suitability for basin infiltration is given in Table 13. Most large scale artificial recharge structures use surface infiltration. The infiltration rate will depend on the depth of recharge water, hydraulic conductivity, unsaturated zone, and clogging of the filtration surface due to physical sedimentation, bacteriological activity. Regular desiltation and drying up of infiltration is required for proper recharge of aquifers.

In the following section efficacy of infiltration basin shall be assessed using analytical and numerical modelling.

Analytical solution

Simple analytic models of basin infiltration is applied in the study area to predict the vertical and lateral growth of recharge mounds in response to variable recharge rates. The models involve a number of simplifying assumptions that are reasonable for a regional scale feasibility assessment. A minimum depth to groundwater of 3 m has been considered to identify potential areas suitable for artificial recharge. On the basis that this depth would allow greater time for percolation to the water table and attenuation of pollutants present in treated wastewater, if any.

The analytical solution provided by Hantush (1967) to predict mounding beneath a rectangular infiltration basin has been applied. The data required are recharge rate, specific yield, horizontal hydraulic conductivity, basin width and length, and duration of recharge, and the spreadsheet calculates using Hantush formula (Eq. 2) the maximum height of groundwater mounding and the mounding at user-specified distances from the centre of the mound.

SUMMARY

It has been observed that there is significant continuous decline in the groundwater levels in most part of the district except a small patch at Kabulpur near Yamuna river area.The maximum decline of 12 meters in the last twenty years at the rate of have been observed in the Faridabad urban areas. It is to be noted that the area showing maximum decline rate is also the areas having maximum depth to pre monsoon water levels. Moving from the Yamuna River to west direction the rate of decline increases in the direction of the increase in elevation of the surface topography.

Hydrograph interpretation of groundwater monitoring wells in the alluvium has demonstrated that the alluvial aquifer in the District of Faridabad is subject to large variations in groundwater levels, which can be directly correlated to recharge and indirectly correlated to irrigation use. Water levels in monitoring wells adjacent to the Yamuna River respond to small amounts of rainfall and these wells also display a rapid response to a flood event. Analysis of hydrograph of urban and rural areas shows distinct pattern. Monitoring wells falling in urban area shows declining trend and response to rainfall recharge is delayed whereas in rural areas water level bounces back due to open uncovered land and return flow from irrigation. Fall in water level in rural areas is not as sharp as in urban areas.

CONCLUSION

The outcomes of this study are as follows:

Faridabad district is highly industrialized and urbanized. The groundwater is the only source to meet the drinking water requirement. Due to this groundwater resources of the study area is under stress and leading to decline in groundwater levels. Decline in groundwater level is more pronounced in urban area due to heavy withdrawal of groundwater. This is reflected in hydrograph analysis of long term historical water level data. The western part of the Yamuna River have major cone of depression around Faridabad urban area (Secttor-21, 30 and 45) area. Groundwater flows into this zone from the surrounding areas. The presence of depressions near Secttor-21, 30 and 45 area attracts groundwater flow in to these depressions. The another cone of depression in Badshapur area developed on account of heavy discharge due to change in landuse pattern from agriculture to urbanization activity, attracts groundwater flow from all directions towards it. The elevated ridge in the western area near Khot, Mangar , Bhankri and Gazipur has emerged out as major areas of recharge with ground water flowing in the East and North East directions from it.

To arrest the declining groundwater resources it is necessary to replenish the groundwater resources. In order to assess the aquifer volume available for recharge GIS based analysis was carried out. Post Monsoon water level is used to estimate unsaturated thickness of aquifer which is available for recharge. Water level more than 3 meter has been considered as maximum water level for recharge above this it will create water logging condition. The spatial analysis reveals that a total of 2561 MCM of volume is available for recharge during Pre Monsoon. During Post Monsoon the volume is available for recharge is about 1839 MCM of. Thus, the total volume of natural recharge in the district is 722 MCM annually. About 978 MCM volume of unsaturated aquifer storage is available for recharge in rural area.

To avoid future water scarcity and water conflicts among citizen it is imminent to ensure water security by carefully utilizing treated waste water generated from Sewage Treatment Plants as a source water for infiltration basin. The total volume annually recharge would be 17 MCM using treated waste water.

The rapid urbanization of the study area will aggravate dwindling groundwater resources and its sustainability. The future of the district vis-a vis fresh ground water availability is bleak. The need of the hour is sustainable and eco-friendly management of the fresh ground water resources available.

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Ecology, soil and crop management for livelihoods in Ladakh region: An Overview

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ABSTRACT

The Ladakh region is the cold arid region of Jammu and Kashmir state in north India where agriculture is the main occupation. The soils of the region are alkaline, poor in fertility and prone to erosion. The low temperature of the area during most part of the year accompanied with scanty rainfall, low humidity, more evaporation transpiration and soil erosion hazards pose obstacles for agricultural production. The glacial erosion is quite predominant in the cold arid region of Ladakh. Application of organic manures, compost and biofertilizer can improve soil health. Livestock management has great scope for livelihood security. Plantation of agroforestry, medicinal plants, fruits and vegetables can help in management of wastelands and restoration of poor agricultural lands. Soil and water conservation including rainwater harvesting, agronomic measures such as crop rotation, mulching and integrated nutrient management, especially green manuring and mixed use of FYM and fertilizers, are useful in management of soil and water resources for sustaining agricultural production vis-à-vis economic upliftment of the farmers in the region.

Key words: soil conservation, water management, cold arid zone, high altitude

INTRODUCTION

Ladakh, a Trans-Himalayan Region of Jammu and Kashmir State, situated between 32° and 25'N-Latitude to 75-80° E-longitude is versatile in altitude ranging from 2400 to 4500m. It harvours great variation in geography and climate from arctic to cold desert with land of high passes and rugged topography and as such is known as one of the "Cold Arid Zone" or "Cold Desert Zone" of India (Fig. 1).

Fig. 1. Ladakh region of Jammu & Kashmir, India

This region possesses an area of 96,701km^2 which is all mountainous barren and nude except for its 235 villages. Villages always remain separated by weeks rather months together owing to intense winter cold. The only tow highways ice-sealed from the world about seven months in a year. A thin scattered population of 2,90,492 souls (2011 Census) somehow manages to dwell. This is what Ladakh is! Barring a few soils of Sindh valley all are highly alkaline in soil reaction. Very low of temperature of the area during most part of the year accompanied with scanty rainfall, low humidity, more evaporation transpiration and soil erosion hazards pose obstacles for the growth of wide flora in this cold arid region as well as agricultural production.

Agriculture in Ladakh

In spite of the rugged topography and mountainous area accompanied with suffering from heavy soil erosion during melting of the snow as well as landslides, the most of the land of Ladakh Region has been made suitable for cultivation. Agriculture, in fact, constitutes the main livelihood of the people of the region to bear the self sufficiency. The villages are generally located near

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the patches of land with well levelled ground and irrigation facilities where cultivation becomes, thereby a doable practice.

In order to upgrade and increase irrigation facilities in the state a considerable thrust has been given to boost up this sector for which various projects have been launched (Anonymous, 2008). Under these irrigation projects by the Planning Commission of India, Leh irrigation schemes has already been completed at a cost of Rs 90.40 crore for providing irrigation facilities to the farming communities of Leh. Mixed farming is the main practice, consisting of growing of food crops, vegetables, and fruit trees and rearing of livestock.

Cultivation of food crops

In Ladakh region most of the agricultural area is single cropped because of long severe winter and short cropping season. Double cropping is possible in areas having altitude less than 3000 m, where field pea, lentil and French bean can be grown as leguminous crop. Other field crops grown in cold Arid Region are barley, wheat, mustard and smaller millet. Actually, the low summer temperature in Ladakh makes it possible to cultivate the winter (Rabi) crops grown in rest of the country. As cold arid region of Ladakh is a remote area by virtue of its location amid the inaccessible peaks of Higher Himalayas so agricultural developed is in isolation and it is marked by relatively less diversity of agricultural flora. However in changed scenario of agro-climatic dimensions through solar green houses in Ladakh accompanied with more financial and technical, know how, it has now become appropriate to exploit the prospects and potential dimensions through solar green houses in Ladakh accompanied with more financial and technical of new crops like vegetables and fruit crops.

It is worth mentioning that hulled barley is used to prepare a drink like beer which is called chang.- C hang is a must commodity at all exuberant occasions of the region. Infect, naked barley (*Hordeum vulgare* L) also known as grim, is an ancient form of domesticated barley with an easier to remove hull. From this kind of barley tsampoa, the staple food in Ladakh is made (Anonymous, 2011).

Vegetables production

According to Dolma (2009) a green revolution of all sorts was knocking at the doors of barren landscape of Ladakh, where even a blade of grass was a rare sight. People who used to survive on herbs like nettle, are now producing more than 6 varieties of vegetables, consisting both of tuber and leafy in summer and have brought great change in the area. Farmers are now growing cabbage and cauliflowers of different varieties. Apart from this poly green house technologies had also been a successful attempt to produce seeds of onion, tomato, radish, carrot, brinjal, capsicum, green chili, broccoli etc. Cultivation of several new vegetables like parsley, celery, chenopodium and sweet turnip are also being grown in poly green houses. This has ensured the supply of vegetables to towns and cities during off season and further opened up a new arena for the farmers not only towards their own self sufficiency but also for export of seed outside the region. Scientists of Defense Institute of High Altitude of Research, a unit of DRDO (Defense Research and Development organization) in Leh have produced some exotic vegetables such as Sennel, Asparagus, leek, Pakenoi, brussen sprout, bhallot, Cherry- tomatoes, which are now being successfully grown by the farmers of Ladakh also. Some progressive farmers of central Ladakh are now growing garlic commercially. The commercial green house technology has also been adopted by the Army for promoting it among the farmers in Ladakh under operation "Sadbhavana".

Ladakh Autonomous Hill Development Council provides subsidy of Rs 80,000 to the farmers to establish green houses on their land. With the help of commercial green houses, vegetables are locally available. One of the main benefits is the extension of the vegetable availability a month before in autumn and advancement by one month in spring. While the open field vegetables survive only up to September. Tuber vegetables are available in July and August.

Fruit crop production

The fruit trees grown in Ladakh region consist of pome fruit (apple and pear), stone fruits (apricots, peach, plum, cherry, almond) and nut fruit (Walnut), aggregate (mulberry) berry (grape and etaerio of Achenes (strawberry).Unlike other crops, fruit trees are mostly perennial in nature, restricting, thereby, the diversification in fruit plants, except the few which have acclimatized in the cold arid region. It is remarkable to note that though the fruit crop production is limited to a few temperate fruits yet the fruits produced are sweeter and better coloured then in many parts of the state (Mir, 2000).

Apricot (*Prunus armenica*) locally known as "Chulli" is one of the most nutritive, delicious and commercially important fruit crops of Ladakh (Dorjey and Rinchen, 2012). It has a wide range of distribution in different parts of Ladakh including Dhaattanu, Garkhon Skurbuchan, Domkhar, Wanla, Khaltse and Timosgang. Apricot in Ladakh is believed to have been introduced a century back either from China or Central Asia. Since then this fruit has become one of the most preferred and commercially cultivated fruit crop of Ladakh and now has become an integral part of the people there. There are many varieties of apricot grown in Ladakh which differ from one another in taste (sweet, bitter, sour) size, shape and physical appearance. Some of these varieties include Halman, Laktse karpo, safaida, Khanteh etc. Halman and Laktse karpo are the most preferred ones for commercial purposes. From the commercial point of view apricot has been major the source of income for many Ladakhis who are engaged in cultivation and marketing of this fruit. Halman, Laktse karpo are with sweet kernel which is consumed as dry fruit and make a good market price of Rs. 100-150 per kg, while the seed with bitter kernel is used for oil extraction. The apricot oil (locally called tseghumar) is multipurpose oil with a peculiar apricot flavour and is sold at a remarkable price of Rs. 300-500/L.

Cultivation of medicinal plants

There are number of medicinal plants which can be grown in the cold arid zone of Ladakh. They have rare properties of curing human ailments. List of medicinal plants which stand used Amchies in Ladakh have been detailed elsewhere (Anonymous, 2003-2013). Like Siwaliks of Jammu region, Ladakh region of Jammu and Kashmir was also once an abode of medicinal plants (Sharma and Mir, 2000). There were about 500 plants in cold arid region of Ladakh having rare properties of curing human ailments but now some of them have become endangered dues to their indiscriminate collection by Pharmaceutial agencies vis-a-vis of their overgrazing by the animals. Some among most of the species locally known are as burtse, yulang, tata known, longze etc.

Growing of poplars

Owing to scarcity of forest tree species in cold arid region of Ladakh, growing of various species of poplars hold a great promise to meet the future demands of the people in respect of fuel wood, timber and fodder requirement for the livestock. The methodology of planting of the poplars is as follows:

Unlike other tree species the poplars are propagated through cuttings. Prior to breaking dormancy in the trees (during March-April) when day temperature starts rising, branch cutting of about 150 cm size are prepared from the tree branches. These can be then planted directly in small pits about 30×30×30 cm capacity. However, to get good sprouting, the branch cuttings should be soaked in water for about fortnight. With advancement of the season when the dry temperature rises to 25 ^{o}C by ending May, the new shoots begin to sprout. Up to end of August, the planted cuttings must be watered vigorously to combat high rate of water loss through evaporation/ transpiration as well as leaching out of salts, the accumulation of which otherwise hinders their root development.

As poplar are also planted on field bunds or borders of canal areas other than enclosed patches of lands, these must be protected against animals especially goats and donkeys. This can be done by providing the shelters of the thorny shrub (*Hippophae rhaniods*) around the saplings. Wrapping of gunny bags or placing of used tins around the saplings is another method which can be used for protecting the planted poplars against the attack of animals (Gupta *et al*., 2007). On an average, the survival rate of the planted poplars by this method is more than 60 percent. The saplings are planted only at those places where the water supply is assured. The trees shed their leaves on the onset of winter season i.e during the end of October and enter in dormancy of period. The leaves are lopped during summer and used for natural fall, leaves are collected stored and used either as fodder or fuel during winter.

Economics of growing poplars

To work out the economics of growing poplars, a distance of 3m x 2m was adopted having 1666 number of trees per hectare (ha). Over a period of nine years the poplar trees attained a girth of 70 cm at breast height which is the desirable seize for felling down the tree for commercial purposes and other uses. It is the point worth mentioning that for working of the returns only 84 percent of the trees have been assumed to be fit for the marketing purposes. The price escalation over a period of nine years was assumed to be neutralized with the interest amount on the working capital, hence was

Table 1. Cost of production of poplar/hectare in Ladakh
Nine year gestation at 3m × 2m Distance

Operation	Cost (Rs.)
Fencing for one hectare of land	40,000
Partial leveling of land, ploughing and construction of Irrigation channels	6,000
Digging of 1666 pits @Rs. 2 per pit	3,332
Cost of 1666 cuttings @ Rs. 3 per cutting	4,998
Cost of plantation @ Rs. 1 per cutting	1,666
Gap filling due to causalities in 2nd and 3rd year (approx. 1000 Nos.)	6,000
Cost of FYM/fertilizers for 9 years	3,000
Irrigation and watch and ward for 9 years	15,000
Pruning of trees	
3rd year @ 10 plant/labor day	8,330
6th year @ 5 plant/labor day	16,660
9th year @ 5 plant/labor day	16,660
Miscellaneous unseen expenditure	30,000
Total	1,51,646

not considered in both income and expenditure, respectively. Cost of production of poplars and net profit per ha are shown in the Table 1 & 2.

Rearing of livestock

Rearing of livestock mainly comprises of yaks, cows, goats, sheep, asses, and horses, jersey cows yak cow hybrids (Dzomo). Yak, jersey cow, yak cow hybrids and goats serve as the milch animals, whereas yak, ox, horse, donkey, and double hemp camel are utilized as draught animals. Sheep goats and yak are the main animals used for producing meat. Pashmina goats provide a special type of wool known as pashm which is used for making pashmina both fine and rough. The fine pashm is obtained from undercoat of the small sized goats, rearing at the higher altitudes ranging from 3,600-4,500 m. In due course of time, only finer outer coat drops, leaving merely outer tough coat available. The pashm obtained from outer rough coat is used in making ropes, coarse carpets and other rough materials. Apart from the animals reared for the above said purposes such as milk, meat, wool and social status and a draught power, they are used for preparing manure and compost. It is remarkable to note that the cold a rid region possesses exclusive potential of rearing pashmina goats, especially Changthang area.

Pashmina goats and pastures in Changthang

As already mentioned, Ladakh region of Jammu and Kashmir state, is not only the land of many passes and gompas but also alpine meadows, which constitute the grazing grounds for "pashmina goats". Changthang area is one of the glaring examples in this respect (Gupta, 2006; Gupta, 2009). The people of Changthang are called as "Changpas" – an old tribe of Ladakh.

Traditionally, the Changpas have been rearing "Pashmina goats" from time immoral to obtain raw wool locally known as "pasham" which is used for making time and superior quality Kashmiri shawals. Although changthang sprawls over an area of 2,200 km yet 80-85 percent of its land is unproductive and barren. Despite restricted real grazing meadows land (15-20% of the total), the livelihood of Changpas is live stocks rearing like other Ladakhis. Besides pashmina goats, they also rear sheep, cows, horses and yaks. As most of the land of the area is practically unproductive, most of the Changpas are nomads. They frequently move from one place to another in search of meadows for their livestock feeding. But it is alas! That these meadows are now getting extinct due to their exploitation of overgrazing and tourist influx. If proper measures are not taken well in time, the changpas will be in trouble as out of the 2 lakh

Table 2. Gross and net income of poplar plantation/hectare in ladakh
Nine Year Gestation

Particulars	Cost (Rs.)
Firewood (twigs) received in three pruning (3rd year, 6th year and 9th year) @ Rs. 50 per tree in tree life of 9 years	83,300
Poplar cutting fit for propagation received through pruning @20 cuttings/tree during 6th year and 30 cuttings/tree during 9th year	2,49,900
Cost of 1400 nos. of grown up trees sold in situ @ 700/=per tree (assuming only 84% fit to fell)	9,80,000
Gross turn	13,13,200
Gross expenditure for 9 years	1,51,646
Net return	11,61,554
Average net income for 1 year	1,29,061

pashmina goats in Ladakh around 1.5 lakh feed only on Changthang meadows. These pashmina wool worth crore of rupees, is removed from the pashmina goats during the month of May when due to higher temperature, pasham starts shedding. So combing out operations being in month of May and go up to July and August. The quality of pashmina is determined on the quantity of coarse outer coat that it contains. Pashmina having 20-30 % outer hairy coat is of good quality. On an average, there is about 250-350 g yield of pashmina per goat and yield of hairy coat varies from 50-750 g per goat. After combing spinning and weaving the pashm, the Changpas get pashmina cloth. They then sell to the dealers from Leh and Srinagar at suitable rate. There is also barter system for sale and purchase of goods. In exchange of pashmina, they purchase food grains, sugar, kerosene oil etc.

Although Changthang region in Ladakh produces about 80% of the country's pashmina fetching Rs 3,000 per kilogram, yet it was marred by the stench of death of 25,000 pashmina goat's during February-March 2013 (Gupta, 2013). Several reasons have been given with regards to death of these goats. According to government officials in Leh and residents, most of the goats have died due to starvation. There were very little rains last summer due to which there were not enough pastures. Heavy snowfall to the extent of 121 cm cut off the region from the outside, causing delay in the fodder supply from the government. Whatever pastures available were buried under snow, making grazing impossible. Mostly old and young goats were died.

Changpas use horse and yaks for transport. Old persons and children usually ride on yaks whereas young ones utilize horses. Sometimes they have to go on foot long distances. They also depend upon many army vehicles which carry them. They have very good contact with army personnels who safeguard the India borders both from China and Pakistan.

Causes of Shrinking of Changthang Meadows

Indo-China border conflict - The wandering of the traditionally nomadic Ladakhi changpas across the Changthang, the Tibetan Plateau extending from Tibet to the Eastern Ladakh, border since 1962 war fought between China and India the Limited Plateau has now become poorer grazing grounds for the herds of pashmina goats and flocks of sheep reared by the Changpas.

Capturing of pastures

The traditional pastures have considerably shrunk after forcibly capturing some very important winter pasture reserves in Skagzhungin Kuyul border area by the China. The post Chinese episode also saw large number of Tibetan refugee, nomads settling in the Eastern Ladakh further along-with the locals. No doubt, the resulting conflicts over sharing the pastures were somehow resolved recently. But it was no use as the destruction caused by 50 years of overgrazing of the pasture in Changthang range had already become tremendously.

Various projects with regard to construction of roads and buildings as well as other development activities in Rupsho Smad Kharnak to other nomadic areas in Changthang would replace lot of forage range.

Impact of tourism

In just over 20 years of tourist influx in Changthang that commenced in 1994, the number of visitors and their impact has wreaked havoc on its fragile grassland ecosystem. Besides causing severe damage to the grazing lands led on by about 1,17,266 livestock from Karzok, Samad and Kharnak nomads agricultural lands are also affected. Number of the tourists from couple of hundreds in 1996 became few thousand in 2000 and 2001, which stood in a number of thousands in 2013 and 2014. Seasonality of the tourism to Changthang (June to September, peak season being middle July to ending August) further compounds the impact.

Camping in the pastures or near the feeding and breeding grounds of birds, driving off roads, washing of vehicles in the lakes, are a few of the several worth mentioning tourists activities. These activities have created disturbance to the wildlife and produce pollution also besides degradation of pastures. Hundreds of tourists during summer along with guides cooks, assistants and pack animals at the time of germination of the grasses go on trampling over the pastures. This results in the decay of grass species causing there by an acute shortage of forage. Trampling renders the soil compact which increases soil erosion. Not only have this pack animals of tourist groups eaten up the grasses of the pastures reserved for winter.

Soils of Ladakh Region and Their Problems

As most of the soils of Ladakh region are skeletal so they are shallow overlying the

weathered parent material. Due to unfavorable climatic condition, soli development is limited. At most of the places soil cover is very much affected by the wind erosion. The soil beds are exposed to wind erosion due to which not only land is robbed of its richest soil but also crops are either blown away or left to die with roots exposed or are covered by the drifting debris. The abrasive action of the wind erosion results in some detachment of tiny soils particles. These are transported by bounces along the surface of the ground or creep along the surface. It has been found that the soil losses are the highest in the bare fallow land and least under grass cover.

It is not only the wind erosion which affects the cold arid region but it is affected by glacial erosion also. It is quite prevalent in the area with wide spread slow moving surfacial processes like periglacial soliflucation and wind deflection. The glacial erosion is characterized by furrowing, cutting and scouring of the land is also very common in the area. The flash floods owing to enormous snow melt carry away a large amount of debris after causing great damage to their beds and side gullies.

The glacial erosion is quite predominant in the cold arid region of Ladakh. It is because the area has a large number of peaks which remain under perennial snow or receive snow for most of the time during winter months. Whenever there is movement of large mass glacier down slope, it brings with huge debris causing lot of soil erosion. Topographical variation also accelerates the sheet and gully erosion. The cold arid zone of Ladakh also suffers from land slide erosion. The land slide activity along the highway in Ladakh not only posses threat to the vehicular traffic but also carries a lot of debris.

The soils are predominantly sandy derived from weathered debris of the rocks and are subject to the great diurnal as well as seasonal alteration of temperature which leads to a mechanical disintegration of the rocks, producing an abundance of loose debris and as such there is no chemical or organic matter (Humus) action to convert it into the soil cap. Because of scarcity of vegetation, it plays but only a minor role in the soil formation in the Ladakh region. As there is low rainfall so chemical weathering is slow and mineral resources are often high. Physical weathering is intense in the region because of temperature variation. The penetration of rainwater downwards through cracks in boulders also accelerate weathering.

Most of the soils of Ladakh region are coarse textured with sand content ranging from 97 to 51 percent and clay content from 14.8 to 1.2 percent. However, the sand content in the soils of Kargil (Khurbathang Plateau) is relatively less with sandy loam as predominant surface texture. Most of the soils are neutral to moderately alkaline in soil reaction with pH ranging from 7.4 to 8.9 (sometimes as high as 9.5). They are characterized by low content in available N. The available P and K contents varied from medium to high respectively. Most of the soils of Ladakh region are found to be deficient in available Zn whereas the amount of the micronutrients like Cu, Fe and Mn is sufficient.

Reclamation of wastelands

In reclaiming the wastelands in Ladakh, the main objective must be restore the life support system especially soil ecosystem and to restore the integrated agro pastoral systems of rural ecosystem. Since the soils of Ladakh region are less matured and as such coarse in texture. Coarse textured soils are characterized by gravelly/stony, sandy and silty type which is always poor in soil fertility and productivity. These soils are, therefore required to have more FYM, compost and night soil compost. Hence which ever quantity of organic manure is available with the farmers, they must add to these soils.

Rejuvenation of lands and creating awareness

As there is an acute storage of fodder so Lucerne which is perennial leguminous forage crop, especially for irrigated areas so, it must be sown during April after melting snow. It not only provides the fodder but also enriches the fertility/ productivity of soil by fixing atmospheric nitrogen.

There is dire need to educate the farmers to make use of right kind of seeds, species of plants and other inputs like manures and their preparation in the nice way as well as right time of their application.

In proper management of land it would be much better if an emphasis is laid banking the women folk for proper utilization of barren or unproductive at higher altitudes in Ladakh Himalayas. It is because women of Ladakh are involved not only in various agricultural activities but also in certain generating activities like weaving, knitting and sewing.

To improve the animal health for getting more milk and meat, they must be fed with heavy feeds. For this purpose, wherever it becomes possible, the grasslands should be developed with growing of white clover.

Promotion of agro-forestry

As poplar tree holds an ideal combination for agro-forestry system under Ladakh region, hence its plantation should be practised as companion among cultivated crop like barley, wheat, peas and other vegetables.

Appropriate cultural practices for raising poplar nursery and plantation techniques are required to be developed to shorten the growth period of the poplars. Jammu and Kashmir Government must provide subsidy on transportation in providing the seed of potatoes and cereals to the farmers. Discourage the use of chemical fertilizer, while the use of organic fertilizers like vermin compost, use of *Rhizobium* culture for leguminous crops be encouraged. Azotobacter culture is another biofertilizer which can be used for growing vegetables and wheat/ barley.

Growing of medicinal plants

As majority of the medicinal flora of Ladakh have become rare, endangered and threatened to extinct due to their unscientific exploitation, overgrazing of the pastures, uprooting for fuel and natural disaster. In the light of the above, there is a dire need to grow medicinal plants.

Develop package of practices of medicinal plants to popularize their commercial cultivation. To achieve this objective herbal gardens are required to be developed. Some of the rare and endangered medicinal plant species of Ladakh cold arid region are: *Aconitum heterophyllum*, *Aconitun violaceum*, *Acanthalimon lycopodiolides*, *Anaphalis contorta*, *Aster tibeticus*, *Dianthus angulatus*, *Podophyllum hexandrum*, *Sassurea costus*, *Sassurea bracteale*, *Ulmus wallichiana*.

Water management

As the rainfall during summer is quite scanty and inadequate to support to higher plant productivity. Hence, to produce more fodder in the pastures, it is inevitable to develop suitable water conservational and utilization method. Moisture conservation in soils of Ladakh can be achieved by compost mulch which will prevent evaporation losses. Drip irrigation, pitcher irrigation or sprinkle irrigation should be used where it is possible. It would be much better if all the fore said methods of irrigation need to be experimented to assess their usefulness in cold arid region.

Adoption of soil and water conservation measures

Adoption of soil and water conservation measures or resources conservation technologies for efficient utilization of land, water, vegetation and human resources, approach is the only solution in the present climate change dynamism. Generally, there are three kinds of measures which can be adopted to control soil and water. They may involve use of agronomic measures, biological measures and mechanical or engineering measures.

Bench terracing or land leveling of all sloping cultivated land is found to be the most suitable practice for soil and water conservation (Bali, 2014). Build up soil fertility after fresh bench terracing/ land leveling by green manuring if possible or by using FYM/vermicompost. Adopting conservation agronomic measures such as crop rotation, mulching and integrated nutrient management, especially green manuring and mixed use of FYM and fertilizers, are useful in the region.

Afforestation/grassland development/ horticulture of village common lands be done on priority in collaboration with Panchayats. Choose the tree and grass species in consultation with local villagers so that the planted vegetation may be useful for them especially to meet fodder and fuel wood needs as well as for consumption of fruits. Suitable grass species are required to be planted, especially in the overgrazing pastures and deforested areas.

A good pastures species in high grazed environment should have the following physio-morphological characteristics

a) High speed production and germinability
b) Seed viability persists in the soil for many years so that unfavorable seasons are efficiently tide over.
c) Capabilities to disperse seed over long distance.
d) Sprouting is fast following grazing or harvesting.
e) Fast seeding establishment and perennial growth habit.
f) Palatable and nutritious to animals.

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Farmer's Organization: Lessons Learned from East Java Province, Indonesia

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ABSTRACT

The number of Indonesian cooperatives approximately 192450 units, East Java is known as a barometer and locomotive cooperative movement in Indonesia as one of the co-operative namely Citizens Cooperative of Gresik was ranked 233 in the list of co-operative world in 2013 at the International Cooperative Alliance Global Conference and General assembly (ICA) in Capetown, South Africa. The number of cooperatives in East Java 30,741 units with members 7,248,543. This success spawned many breakthroughs that produced the cooperative movement in East Java, which later became a national program. East Java Province is the center of animal husbandry area where nearly 40% of all cattle in Indonesia in East Java. Currently there were 119 cooperative farms, which consist of 35 cooperative beef cattle, 66 dairy cooperatives, 13 goats and 5 cooperative breeder chicken farm cooperatives. Besides, East Java also has a sizable fishing potential, the current number of cooperatives engaged in the fisheries sector as much as 132 cooperatives, with 113 cooperatives in the fishery business, 15 inland fisheries cooperatives and the cooperative efforts of seaweed. Indonesia is looking for a form of organization of farmers to increase their profits; therefore in the fiscal year 2014 has been carried out a research to assess a lesson learned for the development of cooperatives in various other parts of Indonesia. The study was conducted in 5 core cooperatives in East Java namely: 1). Cooperative Citizens Semen Gresik (KWSG) engaged in providing capital for farming in Gresik Province. 2). Cooperation in the field of rice production in Banyuwangi Province. 3). Cooperation in the field of production of rice in Tulungagung Province. 4). Cooperative fisheries in Malang Province and 5). Cooperative of dairy cow in Tulungagung. The result indicates that the cooperative has had a total of a legal entity, formed through decades of struggle, has diversified units and qualified administrators. The implications of these findings are farmers'organizations should have the legality of the law so as to ensure the clarity of the status of its members in striving to obtain optimal benefits.

Key words: Cooperatives, East Java, rice farmers, Tulungagung Province

INTRODUCTION

There are two classifications of farmer's organization namely farmer's groups (*kelompok tani or Poktan*) and the union of farmers' groups (*Gabungan Kelompok Tani or Gapoktan*) and farmers' economic organizations such as cooperatives, PT, CV and association (*Badan Penyuluhan dan Pengembangan Sumber Daya Manusia Pertanian* or The Agency for Agricultural Extension and Human Resource Development, Ministry of Agriculture, 2014). It has something to do with the legality of the group formation. The farmer's group is approved by the agricultural technical service office while the economics organizations approved by a notary, completed with a number of legal entities. The number of legal entity is very important for farmer's organization in terms of net working to get accessed for capital, especially with banks and established companies.

In response to the fact that capital is one of the problems faced by farmers in developing their farming, the government had been implementing various programs to help farmers in capital. In 2008, a program providing seed capital (IDR 100 million) called Rural Agribusiness Development Program (*Pengembangan Usaha Agribisnis Pedesaan* or PUAP) were given to *Gapoktan* in 35,710 villages (50%) of total villages in Indonesia (Pasaribu *et al*., 2011). The fund is expected to be use for productive economic activities leading to the developement of micro agribusiness finance institution *or lembaga keuangan mikro agribusiness (LKM-A*) serving the farmers in terms of credit. The LKM-A is designed to be established in the third year which is able to solve the problem of financing the micro farmers and farm workers through a simple and rapid procedure without any collateral, timely and in accordance with the character of farmers as

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customers (*Direktorat Pembiayaan Pertanian, Ditjen Prasarana dan sarana Pertanian* or Directorate of Agricultural Finance, DG Agricultural Infrastructure, 2013). The evaluation report on the program showed that the established LKMA only found in about 20 percent of the beneficiaries, which was mostly found in East Java, some in North Sumatra and the least is in Nusa Tenggara Province (Pasaribu *et al*., 2011). It was not a good results as expected, therefore efforts to improve the farmer's organization continued to be done by the government through the release of some legislations such as Act No. 19 in 2013 on the Empowerment and Protection of Farmers; Act No. 16 of 2006 on the Extension System for Agriculture, Fisheries and Forestry especially and Act No. 17 / 2012 on Cooperatives in which farmer groups and *Gapoktan* were suggested to have "*Badan Usaha Milik Petani*" (*BUMP)* or their owned organization such as Cooperative, CV, PT and associations (Republic of Indonesia, 2013). These policies provide limited opportunities for the farmer's organizations because they are too general and not sensitive in terms of farmer's characteristics differences, therefore information on good performance characteristics in management process of farmer's organizations are necessary as references or lessons learned.

This paper describes process of management and performance of *Gapoktan* within PUAP program, new cooperatives and famous cooperatives for comparation. The information will be very significant as lessons learned for the base of policies to promote or improve the ideal farmer's economic organization.

METHODOLOGY

Organization is a term that is very widely recognized, both in the government and in academic, that has a broad meaning and diverse, ranging from tight to loose one (Lawrence *et al*., 2009). This paper implements the Creswell (2007) theory on qualitative research methodology in reviewing the success of farmer's organizations which qualitative parameters such as: (1) the creation or process of management in maintaining the organization, and (2) the performance of the organization. The study site was chosen purposively namely East Java Province, which has very good record in the performance of farmer's organization.

Primary data were collected from group interviewed represented by leaders and some respresentative members based on structures quesioner involving seven *Gapoktans* three emerging cooperatives suggested by the office of agriculture dan secundary data from five famous agriculture cooperatives as source of comparation and related agencies.

RESULTS AND DISCUSSION

Gapoktan or Union of Farmer's Group

In East Java, there were 2,007 units of *Gapoktan* in 2010 having loan and saving activities, which is originally of PUAP. The PUAP performance were clasified in to five grade which are : (1) >15% very good, (2) good 10-15% (= evolve towards a LKM-A), (3) almost good 5-10%, (4) moderate 0-5% and (5) poor < 5%. The *Gapoktans* in East Java consisted of 24% poor, 37% moderate, 24% alamost good (those were in the progress of being an LKM-A) and the other 15% good, which already had LKM-A) Assessment Institute of Agricultural Technology/ AIAT, 2010). The reason why there was a low percentage of the good class others as the following: (1) the amount of the seed capital was considered too small as compared to the farmer's needs; (2) there were many miscommunication between the *Gapoktan* and the technology sources in applying the introduced technology; (3) the program was not adequately socialized/well informed (Pasaribu *et al*., 2011). However, these problem were not considered as the major matter for the following *Gapoktans* (Table 1) which showed that the seed capital increased in the range of 15-25% and got 0 non-performed loan (NPL).

The success was supported by the local governments that fully implemented the general guidelines for the implementation of the programs refered to The Minister of Agriculture, Act. No. 16/ Permentan/OT.140/ 3/2009). The essence of the rule was that *Gapoktan* who received the program must have a viable business scheme which provide benefit at the least of 30 percent. Besides, the beneficieries of the PUAP were prioritized to *Gapoktan* that had good performance in the previous program they received such as Small Farmer's Income Improvement Program. The most important requirement for the beneficieries is the good personality and managerial capacity of the leaders. Table 1 presents criteria of the leader showing that honesty and willing to be a leader were the most important characteristics.

An example on how a *Gapoktan* managed the seed capital in a good manner is reported by *Gapoktan* Klotok in Gresik District which use the

Table 1. The Process of Management and the Performance of *Gapoktan*

No.	Process	*Gapoktan* (N=7)
1.	Established	2006-2010
2.	Member of groups	3-5
3.	Member of farmers (people)	112-503
4.	Coverage area of the organizations	Village-Sub-district
5.	Facilities	No office
6.	Main activities	Savings and loan and fertilizer procurement
7.	Comodities	Paddy
8.	Organization's structure	complete
9.	Leadership: 1. Management period; 2. Turn of the leader 3. Criteria of leader	1. 3-5 years 2. Not yet 3. Honest, ready to lead (be the chairman)
10.	Kinds of assistance / government program received	1. PUAP = 100% 2. Food security and energy credits = 50% 3. Agribusiness credit=50%
	Performance	
11.	Performance government program	
	1. PUAP 2. Food security and energy credits. 3. Agribusiness credit	1. Growing 15-25% 2. 100% Success 3. 100%
12.	Championship	A *Gapoktan* is the best in 2013 for province level
13.	Perception on ideal organization for farmers	Cooperative

seed capital for providing fertilizer to members. *Gapoktan* buy fertilizer at the sub-district agent then sold it to the group (a *Gapoktan* consisted of 5 unit *Poktan*) at the same price. The chairman of each farmer's group then again sold it to individual member with an addition price of one thousand rupiah/Kg. This price was a lot cheaper as compared the price if farmer purchased fertilezer individually not to mention it would also consume additional transportation cost, time and energy. However, only farmers who have cash could buy fertilizer from the group. Collected money as profit of this business is used to increase the group's capital and for operational costs including remuneration for the group's chairman (0.5%). Of the five *Poktan* under *Gapoktan Klotok* who received the program only one *Poktan* who had no increase in the capital, the other four *Poktan* increase the capital by 5%, 45%, 15% and 10% respectively. These additional income (profit) were used for *savings-loans* activities, which program was very appreciated and by farmers and expect to transform the *Gapoktan* to a cooperative which could utilize the services of banking. Similar findings reported by Syahyuti *et. al.* (2014) that *Gapoktans*' activities such as fertilizer dealers were also found in West Java and West Sumatra.

Another example is *Gapoktan* Makmur in Malang District who has reached the development of PUAP funds by 24% in two years. Other successful credit scheme in this *Gapoktan* is from *Kredit Ketahanan Pangan dan Energy (KKPE)* or Credit Scheme Program for Food and Energy Security that amounted of IDR two billions through Bank of Indonesian People (BRI), although it has not yet got a legal entity. The *Gapoktan* got the credit, most likely due to honesty and thoughtfulness of the Chairman's. Funds from KKPE program was distributed as loans for 47 members who already paid the registration fee of IDR 10,000 and a monthly mandatory fee of IDR 50,000. Each member received loan for about IDR 40 million which was used to buy some fattening cows. After being raised for 6 months the farmers earned money from sold cows around IDR 60 millions.

Emerging Cooperatives

The number of cooperatives in Indonesia is approximately 192,450 units. East Java Province is known as a barometer and locomotive of cooperative movement in Indonesia. One of the cooperatives there namely Cooperative of Cement Gresik Citizens or *Koperasi Warga Semen Gresik (KWSG)* was ranked for 233 in the list of world best cooperatives in 2013 at the International Cooperative Alliance (ICA) Global Conference and General Assembly in Capetown, South Africa. East Java has 30,741 units of cooperatives with members

7,248,543 people. This success spawned many breakthroughs that produced the cooperative movement in East Java, which later became a national program.

Results obtained from the interviews with the Head of Agency for Agricultural Extension of Gresik District showed that cooperative socializations were conducted through monthly meeting initiated by the Agency for Agricultural extension of Gresik District since 2011. The total meeting was 10 times/year since the other two meetings were held at the same events of "*Safari Ramadan*" and *Hari Krida Pertanian* (Agriculture Day. The meetings were attended by all *Satuan Kerja Perangkat Daerah* (SKPD) or district level technical service office, which was directly commanded by the Head of the District (Bupati) and attended by about 600-1000 people even reached 2000 people. The meeting was conducted in rotation in each sub-district and broadcast by East Java Television (JTV) and called *Sambung Rasa* or feed back discussion, some are named *tilik deso* or back to village and Partners Meeting. The above strategy reported to be very effective as a development strategy since the entire SKPDs present and directly hear the problems faced by farmers and society. All of the problems reported by the public are recorded and immediately solved by the SKPD before the next meeting. Other strategy in promoting the cooperative are through competitions and popularizing the jargon of the head of Regent to work in the "togetherness" that requires the coordination, sincere and honest" and integration of institutions namely cooperatives, agriculture, family planning, environmental and economic.

Result of socialization can be seen by the many emerging cooperative, including the following three examples of cooperatives (Table 2), as there is a cooperative established in 2014 reflecting that cooperatives continue to emerge.

Famous Agriculture Cooperatives

Currently there were 808 farm cooperatives and 119 husbandry cooperatives which consists of 35 of beef cattle, 66 dairy cooperatives, 13 goats and 5

Table 2. The process and Performance of Emerging Cooperatives

No.	Process	Cooperative 1	Cooperative 2	Cooperative 3
1	Established	2014	1975	2011
2	Address	Sekar melati (Woman Cooperative) Gresik	Pakisaji, Malang	Sri Rejeki (Woman Cooperative) Malang
2	Member of groups	1 (family welfare education)	26= sugar cane 35= paddy	3
3	Member of farmers (people)	25	1200	102
4	Coverage area of the organizations	Sub-Village	Sub-district	Sub-Village
5	Organization's structure	Complate	Complate	Complate
6	Facilities	No office (village office)	No office (Leaders' house)	No office (Leaders' house)
7	Main activities	1. Procurement of fertilizer for vegetable = 30%. 2. Procurement of fertilizer for rice field = 30%. 3. Home industry = 20% 4. Trade saple food = 20%	1. Savings and loan 2. Provide of fertilizer 3. Saple food stall	1. Savings and loan 2. Provide organic fertilizer and vegetable
8	Commodities	Vegetable, Rice, Crackers, staple food	Paddy and sugar cane	VegetableOrganic fertilizer
9	Government program received			
	1. Agricultural office	No	No	Yes=2012=50 millions (IDR)
	2. Cooperative office	Yes = 2014 = 25 millions (IDR)	Yes= 2014 = 65 millions (IDR)	No
	Performance	Seed capital increase from the interest (10%)	Achievement 1,2 billion (IDR), target only 800 million IDR)	Produce organic vegetable with high price, seeling vegetable seed. 10% of member have income 3-5 millions (IDR) in 2014

Table 3. The Process and Performance of Famous Cooperatives

Characteristics	Established and well-known Cooperatives				
Name	Koperasi Warga Semen Gresik Gresik	KUD Dwi Karya Banyuwangi	Syariah Baitul Maal Tulungagung	KUD Mina Jaya Sumbermanjing Malang	Koperasi Tani Wilis Tulungagung
Process					
Establish	1963	1973	1998	1983	1981
Initial bussines	Vegetable	Rice	Rice	Fish	Dairy
Member of people	5 954	2012= 6.335 (Youth=60%)	200 - 319		1 389
Principal savings		25 000 IDR	1000 000 IDR	100 000 IDR	
Compulsory savings /mth)		2 000 IDR	10 000 IDR	10 000 IDR	
Performance					
Branch	60	-	5	-	-
Assets (Billion)	621 550	12	330	30	
Coverage area	Indonesia	Other island	District	Japan and Australia	District
Expantion of bussines (units)	Tailoring, photo copy, catering services, general trading and building materials.	Saving & loan Rice=411.268 ton in 2013, Tofu n soybean cake industry = 20%, 50%= griculture farm shop and transportation = 30%	Saving & loan Agriculture, husbandry, Aqua, convection, pilgrim, high school banking	Fuel Filling Station), ice blocks, drinking water, transport services, *savings-loans*, shops, payment of electricity.	Loans for basic goods and cattle fodder.

cooperative breeder chicken farm in East Java (Department of cooperatives and small and medium enterprises in East Java province, 2013). East Java also has fishing potential, the current number of cooperatives engaged in the fisheries sector as much as 132 cooperatives, with 113 cooperatives in the fishery business, 15 inland fisheries cooperatives and three (3) cooperative in seaweed processing. Tabel 3 showed that cooperative has existed since 1963 and demonstrated success that recognized by the community, therefore the government did not hesitate to promote cooperative although many opinions considered that promoting cooperatives like a wake of dead bodies.

In 2008 the Department of Cooperatives in East Java Province established the Cooperative Clinic and had 150 rounds of training products with the number of participants in 5333, IT training 50 times with, 040 participants, and 46 times of managerial training with 981 participants. Until 2013 people who visit the clinic to consult 6955 people. Besides providing services free of charge consultation the clinic also provide short courses, business consulting, business information, advocacy or assistance, product marketing access, access to finance intrepreneur library center, mobile clinic services, IT services and TV enterpreneurs.

East Java province is the only province in Indonesia that have a cooperative-based entrepreneurship module for students, result of collaboration between the Department of Cooperatives and Industry with 23 public universities and private universities. This module became a hand book for the teaching of entrepreneurship in all faculties at universities in East Java. As the results of these efforts, cooperative institutions increasingly demanding namely in the Department of Cooperatives in Mojokerto regency average of 90 filings/ month. While the number of cooperatives in the district as of July 2014, there were 813 units, with 181,127 members with assets value up to IDR 430 billions to IDR 418 billions.

Process: Cooperative of Semen Gresik employees (KWSG), began with the trade of vegetables to meet the needs of employees. Furthermore, growing the businesses in tailoring, photo copy, catering services and general trading, so that in 1991 became the Cooperative of Semen Gresik Citizens (KWSG). Then growing rapidly as a distributor of building materials industry engaged in Gresik cement and other building products. While Cooperative "Dwi Karya" begins with only 20 people with main activities in post harvest process of paddy since there are 3 times harvesting in a year which 411 268 tonnes of paddy in 2013. The paddy was

processed in milled rice, packed into the brand "*Beras punel Mahkota*" and sold in Banyuwangi region shops. The cooperative manage by a leader choosen by members with turnover lasted 3 years, asisted by 5 board 5 and 2 supervisors and more than 6 000 members, in which 60% are young members meaning they are already owned cooperatives awareness today. This shows how important to introduce and motivate the youth on enterpreunership since Indonesia has only 2% enterpreuners of the total population, while Malaysia, for example, has already got 8% (Ministry of Cooperative and SME, 2013).

In this cooperative, the unit of "savings-loans" is dominant with the main capital from savings of the members of IDR 25 thousand and compulsory IDR 2 thousand per month. Members who want to borrow money must be willing to do a feseability survey similar to the banking system and the loan must adhere for business. About 50% of the capital is for businesses related to agriculture, 30% for trade, 20% for business such as producers of soybean cake and tofu. Similar processed found in Dairy Cooperative of Tani Wilis which relying on the dairy business and dairy cattle fodder since there are dairy cattle breeders scattered in 11 villages with 5000 cattles of which 2400 are lactation. The members of the KUD given services such as loans for basic goods to meet farmer's daily needs while for the livestock are given cattle fodder in balanced feed with repayment done after the member receives payment from the dairy cooperatives.

The established of *BMT Ar Rohman* were not directly in agriculture sector but serve small traders with capital requirements for IDR 100 000 per person now the cooperative provide of loan for businesses in agriculture, livestock and small businesses sector. Members are must pay IDR 1 million for principal savings and mandatory savings IDR 10 000/month. In order to expand the services, Cooperative BMT Ar Rohman operate 5 branches at the district level supported by 24 employees. However, the need for loans geting higher during the Eidul Fitri and new school year therefore doing partnership with Bank of East Java to borrow funds amounting to IDR 2 billion.

Fish Cooperative of Minajaya established with full support from the government with main activity of the fish auction with strict requirements for members. Members must pay of principal IDR 100 thousand and compulsory IDR 10 thousand/ month while the bidders must be a member of KUD Mina Jaya and put guarantees to cooperatives in the form of certificates of house, land, or a four-wheeled vehicle. Every day during the fishing season, the cooperative auctioning 50 to 70 tons of fish, especially tuna, including baby tuna every day dielang from 500 kg to 1 ton to which is exported to Japan and Australia.

Performance: At age of 50 years the KWSG cooperative has assets of IDR 621.55 billion, net income after tax in 2012 reached USD 47.73 billion and has 60 outlets spreading all over Indonesia. In 2013, Dwi Karya cooperative was able to provide loan of IDR 150 millions/ to members of 6,335 people with seven business units such as, Rice Milling, *Savings-loans*, stationary, Farm Shops, Transport Services and Electricity Service Payments. This cooperative has been able to provide a loan of 150 million to its members. While the Cooperative of BMT Ar Rohman has developed the business of rice trade between the island and refill drinking water for the shops. Besides the success on the material aspect also motivate students to begin familiar with banking transactions through opened the branch in high school *Madrasah Aliyah Negri* (MAN) 2 or Islamic public school which has 1,200 students. The famous cooperative of KUD Mina Jaya, besides provide the fish auction services, also has seven bussines unit, namely fuel, ice blocks, drinking water supply, transport services, *savings-loans*, shops, and electricity payment. Units of savings-loans and shops were less encouraging because members only borrow but never have savings. Now *KUD Mina Jaya* reached omzet IDR of 3 billions and in 2012 to share as much as IDR 35 millions net profit.

The dairy cooperative *KUD Tani Wilis* now supported the savings and loan business with turnover IDR 375, million/month and stores 150 million/month dan electricity bill payment services in the amount 1,000 subscribers. By running the business units according to the needs of members, the KUD last year was able to get net income of IDR 208 million 10% target to come. However revenue from fresh dairy business and fodder production is dominant, where the two business units was recorded monthly average turnover IDR 5.9 billions. Among IDR 4.6 billions from the average milk supply of 744,000 liters to PT Nestle Indonesia and IDR of 1.3 billion from feed products to the farmers on average 550 tons.

CONCLUSIONS

The *Gapoktan's* success is supported by a strict implementation and selection of the beneficiaries.

The growth of cooperatives supported by socialization, consulation and seed capital from the government. All *Gapoktans* were eager to transform into legal economic organization such as cooperative. Although the women cooperatives are newly established, they showed really good performances. It exhibits that the provincial program to boost woman cooperatives is finally got succeed. In the future, the program will be continously scaled up.

The famous cooperatives achieved their succcess because the bussines based on the needs of the members, which is supported by the potential of natural resources and local governments. The time period to achieve success and prominence of the cooperative at least in 15 years. Cooperatives in East Java have been able to motivate youth at the secondary school level (case of Ar Rahman BIM) and involving youth (in the case Banyuwangi) and introduced to the students in universities through cooperative modules and clinicsThe expansion of the bussines must follow the interests of the members covering educational funds even religious activities. Starting with one type of business, the famous cooperative was able to develop up to seven units of bussines.

POLICY IMPLICATION

The implementation of a program must refer to the general guidelines of the program and introduced program should consider the real needs of the members. It needs some strategies to motivate people to get attracted into cooperatives such as intentisive socialization, consulting services and poviding seed capital.

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