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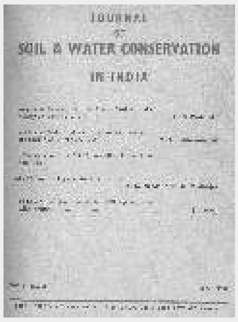

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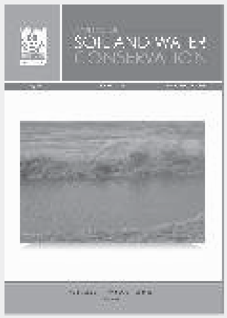

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SOIL CONSERVATION SOCIETY OF INDIA

JOURNAL OF SOIL AND WATER CONSERVATION NEW SERIES

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Contents

Pledge

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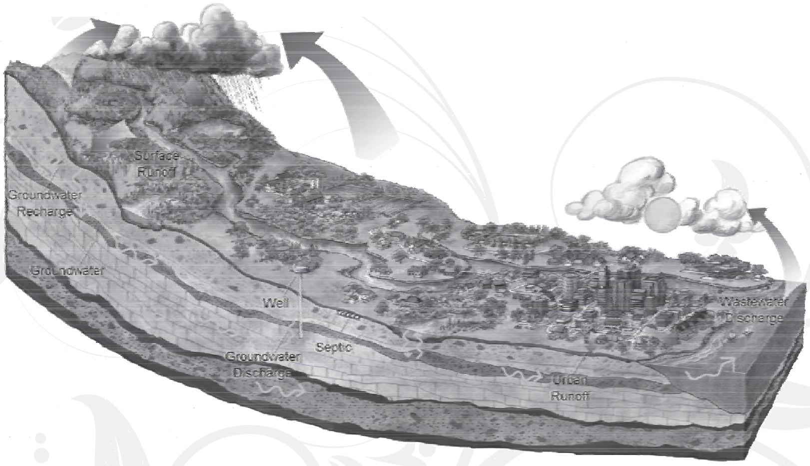

I pledge to conserve Soil,
that sustains me.
I pledge to conserve Water,
that is vital for life.
I care for Plants and Animals and the Wildlife,
which sustain me.
I pledge to work for adaptation to,
and mitigation of Global Warming.
I pledge to remain devoted,
to the management of all Natural Resources,
With harmony between Ecology and Economics.

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Identifying feasible mitigation or remedial measures for waterlogging problems at Wonji plain (Ethiopia)

MEGERSAOLUMANA DINKA

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ABSTRACT

Wonji-Shoa Sugar Estate has been producing sugar for about 60 years and is currently affected by chronic waterlogging problem. Waterlogging is threatening the sustainable production and productivity of the sugar estate significantly.Unless corrective measures for mitigating GW rise are developed and the existing problems are tackled soon, severe crises in the region are inevitable. Therefore, the current study attempted to present the current status of GWTD and then suggest feasibleremedial measures. More emphasis were placed on diagnosis and mitigation of shallow groundwater issues. The feasible management measures to be adopted in the future pathways to reduce, if not avoid, the effects of waterlogging for the sustainability of irrigated agriculture are suggested. The recommended remedial measures can be categorized into: engineering, management and agronomic aspects. Therefore, the effectiveness of the recommended correction measures requires greater coordination and collaboration of each and every department and administrative bodies within the sugar estate, including research and training directorate.

Key words: Drainage, groundwater, irrigation, management measures, piezometers, waterlogging

INTRODUCTION

In arid and semi-arid regions, irrigation development plays a great role for crop production and hence food self sufficiencyand economic development.For instance, total food grain production in Haryana area (India) increased from about 2.6 to 13.0 million tons within a period of about four decades (1967-2005) as the corresponding irrigated area increased from 1.7 to 5.4 million ha (Joharer *et al.* 2009). In Ethiopia, irrigation development has been prioritized as an important catalyst to stimulate the national economic growth of the country since it is considered as a cornerstone of food security and poverty reduction (MoWR 2002; World Bank 2006; Awulachew *et al.* 2007; Rufeis *et al.* 2007; Hagos *et al.* 2009; Dinka and Ndambuki 2014). The Ethiopia Government made a remarkable investment for the development of irrigated agriculture (of various scale) in recent time (post-2000), especially in Awash River basin which sustains about 30% of the Ethiopian population. A concerted effort has been made to develop new irrigation schemes (Awulachew *et al.* 2007; Hagos *et al.* 2009) on about 250,000 ha irrigated land and rehabilitate the existing ones (Dinka and Ndambuki 2014; Dinka *et al.*, 2014).

Irrigation development has a number of direct and indirect (agricultural) benefits. Some of its benefits (direct and indirect) include: (i) increase in yield per unit of land and water, leading to increased income for farmers; (ii) food security at micro level (consumption) due to increased yield, lower risk of crop failure and increased cropping intensity (*i.e. year round production*); (iii) diversification of cropping patterns; (iv) shift from subsistence production (low-value) to market oriented (high-value) production; and(v) employment generation. The contribution of irrigation to the national economy of the country is presented by Awulachew *et al.* (2007) and Hagos *et al.* (2009). In addition to that, irrigation provides significant non-agriculture benefits related to water supplies (municipal and industrial), recreation, tourism, and wildlife. Though it is difficult to quantify, the indirect benefits of irrigation could

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be larger than the direct benefits (Bhattarai *et al.* 2007). Bhattarai *et al.*(2007) reported thatthe indirect benefit of irrigation plays a larger role for poverty alleviation and maintaining food security than the direct benefit in term of increased crop productivity.

However, irrigation development has multiple benefits to food security and economic development if and only if there is proper utilization and management of the available water resource. Despite the positive contributions, irrigation development also generates negative impacts (direct and indirect) on crop production, socio-economic and environment. For instance, most of the large-scale irrigation developments in the Awash River Basin (Ethiopia) are suffering from the twin problems: waterlogging and salinization. Extensive areas of irrigated lands in the Middle and Lower Awash Valleys (Amibara, Dofan, Malka-Sadi, Malka-Warar, Matahara) of Ethiopia were degraded due to poor agricultural water management and other forms of land degradation (Awulachew *et al.* 2007; Girmaand Awulachew 2007;) and the performances of the existing ones are not satisfactory.

Wonji-Shoa Sugar Esatate (WSSE) is currently affected by critical waterloging problem. Waterlogging is a worldwide phenomenon which occurs mainly due to the rise of *groundwater table depth (GWTD)* beyond the permissible limits. About 90% of the sugarcane plantation fields have GWTD above the threshold level (1.5m) recommended for sugarcane (Dinka and Ndambuki 2014; Dinka *et al.* 2014), which resulted in significant yield reduction and other allied problems related to machinery operations (land preparation, cultivation, harvesting, etc), agronomicpractices (*weeding, fertilizing, cultivation, etc*) and yield-increasing interventions (*eg., crop varietal selection, optimum planting date, optimum dry-off period, ratoon reshaping, varietal selection, cane cycling*). The sugar estate is currently forced to produce only 55% of the attained potential in the 1960's.

Despite years of research and management efforts, GWTD continued rising. Past trends (0.035 m / yr) indicate that the GWTD has the potential to inundate Wonji plain and is anticipated to devastate production during the next 10-15 years (Dinka and Dilsebo 2010). Unless the potential causes of waterlogging are identified and feasible strategies for mitigating waterlogging developed, severe crises in the region are inevitable. The potential causes of waterlogging were already identified by the works of Dinka and Ndambuki (2014). Hence, attention must be given to devise appropriate water management policies and strategies. Therefore, the current study presents the status of waterlogging and suggests appropriate mitigation (water management) measures to combat the impacts of waterlogging to the sustainable production and productivity of WSSE in particular and to environment of the region in general. More attention was given to the feasible effective management measures to be adopted in the future pathways to reduce, if not avoid, the effects of waterlogging.

METHODOLOGY

The study area

This study was conducted at Wonji-Shoa Sugar Estate (WSSE), which is situated in the Wonji Plain, Upper Awash Basin, Central Rift Valley of Ethiopia, just immediate downstream of Koka Dam (Fig.1). It is located at a distance of about 110 kms south east of Addis Ababa and about 10 km south west of Adama town. The estate proper has about 6,100 ha (excluding the current under expansion) of cultivated land and the factory has a total crushing capacity of 3500 TCD (ton of cane per day). It is divided into nine management sections (*refer the sections designated by R, L & E in Fig. 1*), each has its own section managers. Sugarcane is the most crop grown in the plantation, with few crotalaria and haricot bean on heavy black clay soil during fallow period in the case of cane after fallow system (Dinka et al. 2014). The characteristics of WSSE are summarized in Table 1.

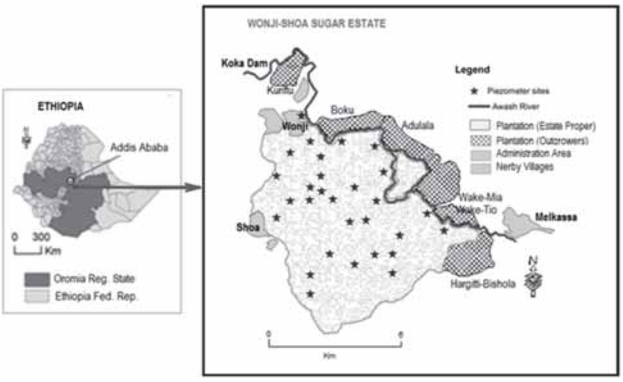


Fig.1. *Left:* Wonji-Shoa Sugar Plantation (estate proper and outgrowers) showing GW monitoring sites, storage reservoirs, networks of irrigation and drainage canals, administrative areas, and villages / towns. *Right:* PVC tube manual installation at WSSE using auger tubes and the PVC after installation.

Table 1. Characterization of WSSE (including outgrowers)

Item	Description
Scheme Name	Wonji-Shoa
Latitude	8º 21' – 8º 29' N
Longitude	39º 12' – 39º 18' E
Elevation (av.)	1540 m.a.s.l
Slope	0.05 - 0.1%
Distance from Addis Ababa	110 km south-east
Established by[a]	H.V.A
Year of first establishment	1954
Irrigated area (net)[b]	7300 ha
Soil type (predominant)	Clay
Crops grown[c]	mostly sugarcane
Average yield (1954-2010)	
• Cane	205 ton / ha
• Suger	165 Qt / ha
Water source / availability Water diversion (head work)	Awash river / Abundant 8 centrifugal pumps
Excess water storage	Reservoirs (earthen)
Irrigation Practice	
Method of water delivery	Open channel
Irrigation system	Furrow
Field water application	Blocked-end furrow
Climate (1954-2010)	
Av. annual rainfall[d]	820mm
Av. annual ET_o	1596.5 mm
Av. daily Pan Evap.	6.8 mm / day
Av. min. temp.	14.5ºC
Av. max. temp.	27.7ºC
Av. relative hum.	64 %
Av. Sunshine hrs	8.5 hrs / day
Agro-ecology[e]	Semi-arid

[a] HVA – HanglerVonder Amsterdam, which is a Dutch Company[b] including 1120 ha of outgrowers, 260 ha occupied by canals, roads, living quarters, factory; and excluding the current project areas under expansion at Dodota and Wake-Tio[c]Crotolaria and Haricot bean are alsosometimes grown during furrow periods on heavy black clay soils[d]Mean av. Rainfall in recent time (1994-2007) based on the record data of the whole rainage available in the plantation is 684.4 mm only.[e]According to Dinka &Ndambuki (2013), Climate of the area is between the transition of semi-arid to sub-humid. [f]Outgrowers refers to farmers association surrounding the estate proper (*See Fig. 1*). They producing sugarcane and supplying to the estate factory

Data collection and analysis

Networks of piezometers (all PVC types) were installed manually in Sept 2007 in order to monitor GWTD of WSSE (estate proper only). The piezometer sites (Fig 1, Right) were selected purposively in order to cover the range of soil types, water sources and topographic conditions. The locations (latitude, longitude, elevation) of each piezometer were registered using hand held Geographic Positioning System (GPS). Groundwater depth monitoring was commenced just after piezometer tube re-installation and continued until 2010; with the monitoring frequency of twice per month. In addition, secondary data (digital plantation base map, toposheet, production data, and meteorological data) were collected from different sources: database of the sugar estate, researchers and friends, previous reports (published and unpublished) and own personal observation.

The observed GWTD values were analysed for seasonal and annual values. The hydrographs (water-level vs time) of representative pizometers were plotted in sigma plot (Ver 12.0). Moreover, Universal Kriging (UK) technique was used to produce the average GWTD maps since the GWTD of the area exhibited normal distribution and showed strong spatial autocorrelation. GWTD maps were produced in GIS (ArcView 3.3 software package) from the monthly observed GWTD point measurement data. Prior to GWTD mapping, the different maps (*plantations base map, toposheet* and *DEM*) were georeferenced to the required accuracy. Then, the different features of the plantation shown in Fig. 1 were digitized in ArcView 3.3, assisted by plantation base map and toposheet.

Depending upon the status of GWTD, detailed explanations were provided regarding the implications of waterlogging to the region and the need for mitigation measures. Recommendations weremaderegarding possible effective strategies to be adopted in the future pathways to reduce, if not avoid, the effects of waterlogging for the sustainable production and productivity of the sugar estate in particular and environment of the region in general. Since it is difficult to address all the potential management measures, recommendations were madedepending on the prevailing actual condition of the area and other findings. An attempt was made to support most of the discussions by referring to other available reports (published & unpublished) elsewhere in the world.

RESULTS AND DISCUSSION

Status of groundwater table depth

The recent (2007-2010) magnitude and seasonal characteristics of GWTD values for some selected piezometers are presented in Fig. 2. The figure depict that the GWTD of the study area ranged between 0.1m and 2.5 m below the ground. The mean average values are in the range of 0.2 – 2.0; thus, all plantation fields are classified to be shallow (i.e. waterlogged). Majority (H” 90%) of the plantation area has average GWTD less than

1.50 m below the ground surface, hence, classified as critically waterlogged since they are above the critical depth (1.5m, Kahlown *et al.* 2005) recommended for sugarcane crop.

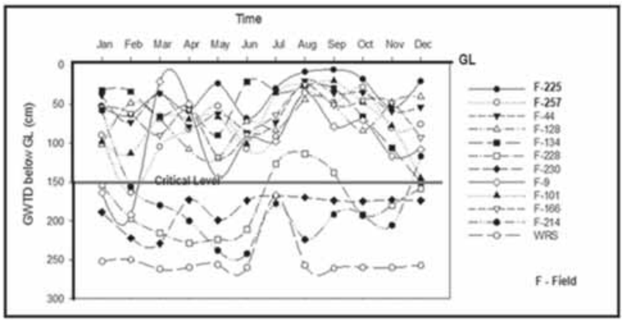


Fig.2.Characteristics (monthly variables) of some Piezometers installed at WSSE (2007-2010)

Feasible nanagement (remedial or control) measures

The current study results (Fig. 2) and others (eg., Dinka and Dilsebo 2010; Dinka and Ndambuki 2014; Dinka *et al.* 2014) revealed that the GWTD of the study area is very shallow and showing fluctuation, mostly rising trend. Such characteristics of GWTD are expected to negatively impact the socio-economics and environment of the region; thus, a concern for the sustainability of the sugar estate. Shallow GWTD is threatening the sustainable production and productivity of the study area.

Dinka and Ndambuki (2014) indentified the main potential causes of groundwater rise in the study area as: (i) excess recharge from direct rainfall and surface runoff coming from the surrounding escarpments; (ii) un-controlled irrigation water management (iii) poor drainage facilities (*natural & artificial*); (iv) flat topography and clay soil property; (v) contribution from Awash River; (vi) flooding problem; (vii) seepage and tail end losses. They also suggested other possible factors (*rift system influence, sub-surface contribution from Koka Dam and Awash River, climate change, etc*) for the rise of GWTD in the area.

Some of the above enumerated factors as the causes for the rise and / or fluctuation of GWTD of the study area are mostly anthropogenic factors due to human activities, while the others are due to natural phenomenon. Although there is little option to change the natural effects, the estate has options to modify the anthropogenically induced effects. Most of the problems caused by shallow GWTD could be mitigated or avoided. Therefore, those areasof the plantation experiencing shallow and variable GWTD needs more attention to prevent its hazards in the future. The assumption here is that any strategy that can effectively drain the water in shallow GWTD areas reduces the GWTD in other parts of the plantation due to potential difference.

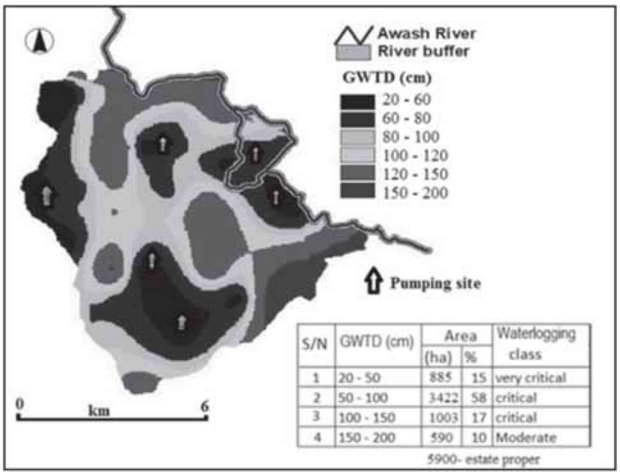
Hecker *et al.* (1998) indicated that recognizing the presence of shallow GWTD and taking precautions to mitigate its potential hazards can minimize the subsequent need for cost effective corrective measures. Therefore, the authors of this paper would like to strongly recommend to the management of the sugar estate to take feasible corrective and control measures as quick as possible. Any strategies that reduce water recharge / abstraction to / from groundwater are highly recommended. Some of the feasible management measures recommended by the authorsto control the rise of GWTD in the study areapresented in sub-sections 3.2.1 to 3.2.9. These measures are presented according to their relative effectiveness to the magnitude of the problem. Most of the measures illustrated are those that reduce groundwater recharge and / or increase groundwater abstraction.

Redesign, optimizationand improvement of the existing irrigation system

A complete redesign, optimization, rehabilitation and improvement of the existing furrow irrigation systems based on the actual prevailing soil, crop, climatic and GWTD conditions of the areaare highly recommended. These activities were also recommended for Nile irrigation system in Egypt (Dominy *et al.* 1980). These require addressing socio-economic, technical, administrative and organizational issues.Any management options that improve the efficiency and effectiveness of the existing irrigation system should be considered during the change.

Appropriate methods of irrigation water management options can be practiced specific to each plantation section. These includes: (i) real time irrigation scheduling, (ii) improving / upgrading water delivery system and upgrading water use efficiency at farm and field levels, (iii) extending irrigation interval (i.e. reducing irrigation intensity), and / or (iv) reducing the amount of water applied. These recommended options can be practiced effectively until the average GWTD is lowered below the recommended threshold level (1.5m). Real time irrigation scheduling requires determining the contributions of shallow GWTD to the crop root zone through capillary action and then comparing it with the water requirement of sugarcane to decide the amount and timing of irrigation. Improving field water delivery system(eg., turnouts) and other control structures (eg., *distribution tanks, flow divisors, road crossings, canal falls, regulating, measuring*) is a key for a better water management and other yield increasing interventions. It should be noted that a complete optimization, rehabilitation and improvement throughout the system might take some time. Thus, the existing irrigation system should be effectively operated and maintained until the rehabilitation and improvement program can be accomplished throughout the system.

Different study reports (e.g. Kahlown *et al.* 2005; Liu and Luo 2011) have indicated that shallow GWTD is expected to contribute to the crop ET. For sugarcane crop, the GW contribution increases as a function of increment in GWTD (Kahlown *et al.* 2005). In the case study area (Fig. 3), about 90% of the plantation areas have GWTD less than



S/N	GWTD (cm)	Area (ha)	Area %	Waterlogging class
1	20 - 50	885	15	very critical
2	50 - 100	3422	58	critical
3	100 - 150	1003	17	critical
4	150 - 200	590	10	Moderate

Fig. 3. Delineated GWTD for WSSE (Estate Proper) for the average recorded period (2007-2010) and recommended pumping sites (indicated by upward arrows).

1.5 m, and even about 58% have GWTD less than 1 m. Therefore, significant GW contribution to crop ET is expected, in some cases exceeding the crop (irrigation) water requirement. Hence, it is possible to completely eliminate irrigation requirements without compromising on crop yield. Thus, effective drainage is required instead of irrigation for some periods of time depending upon the crop growth stage and the status of GWTD. This strategy is very important to maximize productivity and control the GWTD at desired level.

Redesign, optimization and improvement of the existing drainage systems (Natural & Artificial)

Drainage plays an essential part in safeguarding the threats of shallow water table to production and productivity of the area. Since poor performance of the existing drainage system is identified as one of the main factors for the rise of water table of the study area, complete redesign and rehabilitation of the existing surface drainage system plays a great role to control therise of GWT. More attention should be paid to some of the existing drainage structures requiring improvement (redesign and rebuilt). The improvement should be made in such a way that surface drains should permit a quick flow of drainage water from the plantation fields as well as protect the incoming surface runoff from the surrounding escarpments. This method is relatively cost effective compared to subsurface drains. The redesign and reconstruction of drains should follow USBR (1993) drainage manual.

The authors would like to suggest the following available strategies to improve the existing surface drainage systemsand achieve sustainable productionof the study area:

(i) creation of additional new drainage systems (main and lateral drain), especially in extremely shallow areasfor easy release of arrested water (*see the proposed new drainage lines in Fig. 4*);

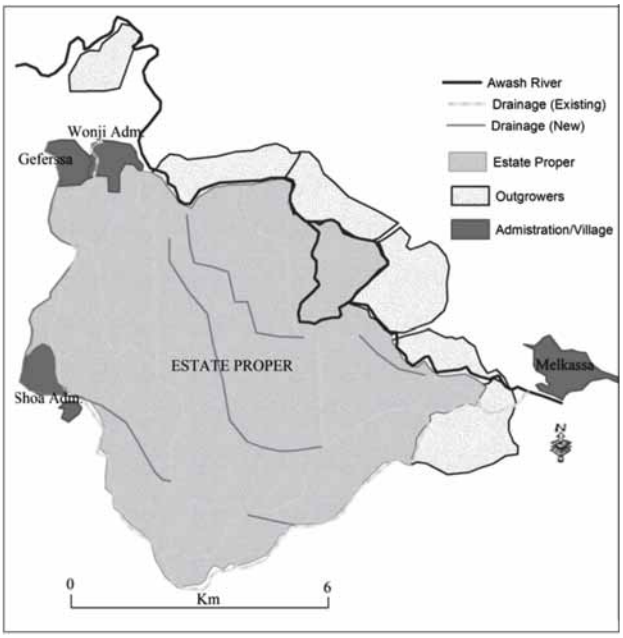


Fig. 4. Central and Main Drainage Network: Existing and new proposed ones

(ii) strengthening the existing collector, lateral, central / intermediate, main and border drains to the required depth, spacing and shape;
(iii) construction of intercepting drains along the main irrigation and drainage canals;
(iv) strengthening the border dykes; and
(v) improving natural drainage system within the sugar estate and surrounding areas.

Improvement of the central and main drains would help collector and lateral drains to remove excess rainfall and excess irrigation water effectively from the plantation fields. Moreover, reshaping the border and main drains and improving the natural drainage system are extremely important to control the effect of the incoming surface runoff from the surrounding escarpment as well as to effectively drain excess water from the plantation fields. Interception drains (surface or sub-surface)have a potential to intercept both surface and sub-surface water. Surface interception drains would help intercepting seepage water from canals and prevent the water from reaching groundwater, thus preventing waterlogging. The planning, design and construction of surface and sub-surface interception drains follow the requirements and procedures for surface and sub-surface drainage systems, respectively. Bucur and Savu (2006)can be referred for design considerations for intercepting drainage. Strengthening the border dykes (i.e. making it water impermeable) would help the seepage and overflow of water from Awash River. Improvement in the natural drainage may include removing obstructions, improving the slope of natural drainage, cross drainage works, and river training works.

Table 2. Comparison of the obtained measurement results of groundwater quality parameters with the recommended usual range in irrigation water (Ayers and Wastcot, 1985)

Parameter	Unit	Obtained range	Usual range in irrigation water*
EC_w	dS / m	0.2 – 3.0	0 – 3
TDS	mg / l	115 –1847	0 – 2000
Ca^{++}	me / l	1.2 –8.0	0 – 20
Mg^{++}	me / l	0.5 – 6.2	0 – 5
Na^{+}	me / l	1.0 – 21	0 – 40
CO^{--}_3	me / l	minute	0 – 1
HCO_3^{-}	me / l	3 – 32	0 – 10
Cl^{-}	me / l	1 – 9	0 – 30
SO_4^{--}	me / l	minute	0 – 20
K^{+}	mg / l	0.0 – 2.0	0 – 2
SAR	-	1.5 – 12.5	0–15
RSC	.	1.3 – 4.8	0–2.5

*according to Ayers and Westcot (1985)

Conjunctive use of surface and groundwater

Different theoretical and experimental studies (Belitz and Phillips 1992; Barlow *et al.* 1996; Sharma 2001; Ahmed *et al.* 2002; Jhorar *et al.* 2009) have revealed conjunctive or consumptive use is one of the most effective strategies for lowering water table. Thus, pumping water from groundwater and using it for irrigation purpose (either separately or blending / mixing with canal water) is on of the feasible strategy to control the rise of the water table of the study area.Conjunctive use is any scheme that capitalizes on the flexibility and efficiency gained through integrated management of surface water and groundwater supplies. It involves the coordinated and planned operation of surface- and ground-water resources (USBR 1995). The conjunctive use can be effectively modelled using simulation or optimization models.A regional classical conjunctive use model can be developed using GIS linked MODFLOW model (Ruud et al. 2001) or other optimization techniques such as simulation / prediction models, linear / dynamic programming, non-linear programming, etc. Detailed conjunctive use modeling approach can be obtained from other research reports (e.g., Fredericks *et al.* 1998; Ruud *et al.* 2001; Qureshi *et al.* 2004; Karamouz *et al.* 2004, 2005).

Experiences have showed that conjunctive use of surface-and groundwater has been successful in irrigated areas underlain with better quality waters (Tyagi and Rao 1998; Jhorar *et al*. 2009)and particularly when combined with improved irrigation water use efficiency (Barlow *et al.* 1996). Fortunately, the groundwater quality in the study area (Table 1) is within the recommended safe range for irrigation, except HCO_3 in few groundwater samples. Therefore, pumping surplus water in very shallow GWTD areas (as shown by the upward arrow in Fig. 3) and use for irrigation purpose should be highly prioritized by the management of the sugar estate. Pumping out water from north-eastern (E_1) near to storage reservoir along the ex-Awash route, central (L_1)around reservoir, southern (R_3 or L_3), eastern (E_2) and western (R_1) parts of plantation sections and storing in the nearby reservoirs are highly recommended. Note that R, L, E refers to plantation sections (see Fig. 1).Pumping can be continued until drawdown caused by the pumpingor GW level reached below the recommended permissible level (*usually 3m below ground surface*). The introduction of conjunctive use (e.g. lift irrigation) technique for groundwater utilization in the area has dual opportunity in reducing the groundwater level as well as use for irrigation supply, which has a further advantage in saving water and energy and reducingthe penalty / risksassociated with waterlogging (eg. reduced productivity and others).

Use of alternative efficient irrigation and drainage systems

Water saving sophisticated irrigation technologies such as sprinkler and drip systems can be practiced in the area. These technologies are found to be effective in shallow GWTD areas, including sugarcane(Sharma andMathur 1991; Sharma 2001).This is due to the fact that fairly high irrigation efficiencies (e” 70%) can be obtained with these sophisticated techniques.

Based on the current GWTD condition and soil type of the area, the authors suggest that the sugar estate introduce use of horizontal tile (or mole) drainage system (surface or sub-surface) into the area. Tile drainage has a direct advantage of holding the GWTD below the crop root zone to the required level (Punmia and Lal 1992). It also has an indirect advantage of reducing the environmental concerns (groundwater contamination) by agro-chemicals (fertilizers, herbicides, fungicides), especially when filters are used (Baker *et al.* 2004; Crumpton *et al.* 2006).Tile drains can be made from fired clay, concrete, corrugated plastics.The advantages of tile drains (agronomic, hydrologic, economic, water quality, etc) are extensively reviewed byFraser and Fleming (2001). The only disadvantage is its higher initial investment cost. Vertical drains (shallow skimming wells) can also be effectively utilized.Construction of shallow skimming wells, as demonstrated in the States of Punjab and Haryana (Rao *et al.* 1986), is a technically feasible and economically viable solution to combat waterlogging (Sharma 2001).

Moreover, combined uses of surface and sub-surface drainage systems are necessary in most of the poorly drained soils. Surface drainages are required to remove excess rainfall (*during and after heavy rainfall*) and excess irrigation (*during and after irrigation water application*); while sub-surface drains remove excess water stored in the effective root zone of crops. Sub-surface drainage systems are mostly practiced in Europe, America, India, Pakistan, China, and Egypt (Ritzema *et al.* 2006). The water that percolates into the ground and accumulates in the crop root zones are often removed by subsurface (subsoil) drainage system.However, the sugar estate can choose to use the existing ones or new technologies for irrigation and drainage system depending on the cost effectiveness (*determined based on cost-benefit analysis*), efficiency, ease of management, etc.

Lining of canal and other water courses

Seepage from canals and night storage reservoirs could be one of the main culprints of risingwater table in the study area since almost all available (irrigation and drainage) canals (except the 480m masonry lined primary canal) and reservoirs are alluvial type (unlined). Thus, an attempt should be made to reduce the seepage of water from the canals and watercourses through lining. This method is found to be a successful strategy for the control of groundwater rise or reclamation of waterlogged fields in other parts of the world like India and Pakistan (Aswa 1999). Lining some of the irrigation and drainage canals and night storage reservoirs, if not all, is advantageous not only in reducing seepage losses, but also in facilitating the flow of water by decreasing flow resistance, reducing erosion by stabilizing canal beds and banks, reducing sediment deposition by promoting movement, controlling weed growth and accumulation,and reducing maintenance costs. Any of the good performing lining materials such as concrete, masonry, geosynthetic, alluvial soils (*bentonite clay, lime, compacted earth*) can be used. The decision should be made based on the main canal selection criteria: durability, impermeability, hydraulic efficiency, resistance to corrosion, reparability, minimum operation and maintenance cost, and ultimately cost effectiveness.

Flood/erosion control measures

Any of the soil and water conservation techniques (*soil management, agronomic, vegetation and mechanical measures*) can be used as a flood / erosion control strategy. Afforestation (vegetation cover) for the surrounding escarpments plays a great role in the reduction of the incoming flood, since vegetation facilitates infiltration. Planting water absorbing plants / trees in waterlogged fields like Eucalyptos and Kallar grass (*Lepthochloa Fusca*) is also suggested. Mechanical measures recommended might be construction of effective dykes or levees along the course of Awash River and use of gully control measures. Flood / erosion control strategy might require establishment of environmental protection department by the sugar estate. It also requirescooperation work with regional government due to the fact that the work requires full participation and collaboration from the surrounding community.

Strengthening groundwater monitoring

The success and effectiveness of any water management measures suggested in this study largely depends on the availability of groundwater monitoring data. Continuous monitoring of groundwaterthrough piezometers or observation wells (holes) is extremely important to check the status of groundwater (depth and quality). Groundwater monitoring serve three purposes (USBR 1993): (1) to measure the static water level, (2) to measure the pressure of the water at a given point in an aquifer, and (3) to sample water quality.

In the study area, groundwater monitoring was interrupted in 2010 due to the frequent damage to the installed piezometers by heavy machinery (*during land preparation, cultivation and harvesting operations*) and humans. Thus, installation of continuously monitoring piezometers and observation holes within the plantation and surrounding areas are highly recommended. We suggest that the sugar estate devise effective way of protecting the holes or piezometers. There is a possibility of using few representative piezometers since the GWTD of the area showed strong spatial auto-correlation. Most importantly, the site, spacing, installation of piezometers and observation holes should follow the USBR (1993, 1995) manuals.

Introducing new technologies for water management

New technologies like Remote Sensing (RS) and Geospatial Information system (GIS) combined with hydrologic models plays a significant role for efficient water management. GIS technology is appropriate for efficient management of large and complex databases. Spatial records (data bases) for soil, climate, water and crop data can be stored in computer (GIS) for each field number or section so that the requirement for irrigation can be monitored easily.Some of the applications of RS, GIS and hydrologic models in water management include: (i) irrigation planning and operation, (ii) estimation of optional management practices and irrigation system characteristics, (iii) modeling the temporal and spatial variability of groundwater, (iv) mapping GW recharge and discharge areas, (v) detecting waterlogging and salinization, and (vi) estimation of evapotranspiration. In addition, RS and GIS have other applications in irrigated areas, such as assessment and simulation of crop growth, prediction of crop yield, and identification of optimum cropping pattern (*cropping system analysis*). Detailed applications of RS, GIS and hydrologic models in irrigated agriculture can be obtained from different literatures (such as Delecolle *et al.* 1992; Moran 1994; Schultz 1997; Moulin *et al.* 1998; Bastiaanssen and Bos 1999; Bastiaanssen *et al.* 2000, 1999; Droogers *et al.* 2000; Droogers and Bastianseen 2002; Ines *et al.* 2006, 2002; Dadhwal *et al.* 2003; Doraiswamy*et al.* 2006; Tweed *et al.* 2007; Sharma *et al.* 2011).

Others

Theother feasible strategies suggested by the authors to control waterlogging problem in the study area may include: *(i)increasing the tariff of water,(vii) use of crop rotation,* and *(iii) provision of training on water management*. Like the other basins in Ethiopia, water tariff for commercial farms in the Awash Basin is very low. Awash Control Authority can increase the price of water for large scale commercial irrigation farms within Awash basin. This strategy plays an indirect role for groundwater management (reduce GWTD) since it forces the commercial farms to find more efficient ways of irrigating their crops. This strategy is also recommended for farm managed small and medium irrigation schemes in other countries (Singh *et al.* 2012).

Crop rotation is currently practiced in the study area on heavy black clay soils. We also suggest the use of crop rotation on all clay soil types. In this system, certain plantation sections where the GWTD is extremely shallow can put under fallow (or planting crotolaria or beans), at least, for a year period. Moreover, appropriate awareness and training could be provided for field irrigators, laborers, field formen, supervisors and even section chiefs and top managers (planers and administrators) regarding the importance of irrigation and drainage in agriculture, appropriate water management and safe removal of excess irrigation water from the field.

SUMMARY AND CONCLUSION

The study result clearly revealed that shallow GWTD is threatening the production and productivity of the sugar estate. In the area, there is a possibility for the occurrence of total groundwater inundation in the near future, resulting in deleterious effects on the environment and the socio-economics of the region in particular and Awash Basin in general. As the area is situated in the uppermost part of MER, other factors are expected to exacerbate its rise even in the future. Hence, GWTD will continue to be an issue of concern in Wonji Plain.

All the possible sources of GW recharge (*irrigation, drainage, soil condition, topography, climate, hydrology and rift system influence*) could be the cause for the rise of GWTD in the study area. Unless corrective measures for mitigating GW rise are developed and the existing problems are tackled soon, severe crises in the region are inevitable. Therefore, efforts on the management of water resources in such area are extremely important for the sustainability of irrigated agriculture.

Most of the problems caused by shallow GWTD might be mitigated or avoided. Therefore, different feasible management strategies to be adopted in the future pathways to reduce, if not avoided, the effects of waterlogging for the sustainability of the sugar estate, in particular, and to the region, in general, are suggested. These includes: (i) redesign and rehabilitation of the existing irrigation and drainage system; (ii) conjunctive use of surface- and ground-water; (iii) use of alternative / modern irrigation and drainage system; (iv) lining canals and other water courses; (v) flood / erosion control activities;(vi) strengthening groundwater monitoring; (vii) use of advanced technologies for water management; and / or (viii) others (providing training on water management, increasing water price, crop rotation).

Above all, the authors would like to underline that the sustainability of irrigation scheme in the area largely depends on the appropriate water management measures, mostly irrigation and drainage system. Managing irrigation and drainage system helps to control the rise of GWTD as well as to maximize the water productivity of sugarcane. Therefore, radical redesign, rehabilitation and optimization of irrigation and drainage systems plays a leading role for the control of GWTD in the sugar estate and hence, should be prioritized by the managers of WSSE.

The recommended remedial measures can be categorized into: engineering, management and agronomic factors. Therefore, the effectiveness of the recommended measures requires greater coordination and collaboration of each and every departments and administrative bodies within the sugar estate, including research and training division. In order to sustain the sugar production and productivity (irrigated agriculture) in Wonji area, it is critically important to dedicate more effort and capital to manage the rise of GWTD.

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Soil productivity analysis under different land uses of Sundarban delta

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ABSTRACT

The study was undertaken in the micro watershed located in Kakdwip Block in saline eco-system of Sundarban. Composite surface soil samples(0-15 cm depth) of double and mono-cropped paddy fields as well as grassed and barren lands were analyzed for different physical (particle size distribution, bulk density, aggregate stability, water holding capacity, moisture evaporation, plasticity) and chemical (organic carbon, SAR, ESP, CEC, pH, EC as well as total N, available phosphate P_2O_5 and K_2O) properties. Result revealed that low land soils contain49.8% clay and it was more than 50% in both double and mono-cropped paddy fields, which resulted 99 % aggregation in these land uses. The higher (0.97) structural co-efficient under these two practices resulted maximum porosity (49.81%) under medium land situation andwater holding capacity (61.73%) as well. All the physical and hydrological parameters were found to be highly correlated with both clay and organic matter content of the soil. The pH of the soils under cultivated double and mono-cropped land was acidic (pH5.3 to 4.6); and alkaline in rest of the land uses. ECe was > 2.0 dSm^{-1} in both the land situations. Other chemical indicators *viz*., SAR, ESP, CEC was found to be relatively higher in lowland situations due to higher clay and organic matter content of the soil. Total nitrogen content did not show any variation w.r.t. land uses and land situations, but, considerably higher content of availableP_2O_5 and K_2O in either double cropped or mono-cropped lands in lowland situation was found to be associated with high clay content. Finally it was revealed that both double and mono-cropped paddy land under medium land situations have highest productivity. In lowland situation, productivity of cropped lands was marginally lower than those under medium land situation.

Key words: Sundarban, land uses, physical properties, chemical properties, productivity

INTRODUCTION

Soil serves as a medium for plant growth by providing physical support and acts as a source of water, essential nutrients and oxygen for the plants. Suitability of soil for sustenance of plant growth and related biological activities is a function of physical properties like porosity, water-holding capacity, structure and tilth as well as chemical properties like nutrient supplying capacity, pH and salt concentration. In fact, a large number of physical, chemical and biological properties of soil influenced soil organic matter content. The quality of soil determines land use, sustainability and productivity and plays an important role not only in production of food, fuel and fiber but also in maintenance of regional, national and international environmental quality. Further, improper soil management for enhancing crop production too leads to severe soil degradation through soil and nutrient loss, which thereby reduces soil productivity. In fact, a sustainable land management system helps in maintaining or improving resource quality. Identifying and characterizing changes in the dynamic component of soil quality is essential in evaluating sustainability of any soil management system (Pierce and Larson, 1993). The necessity for development of a soil health index was stimulated by the perception that human health and welfare is associated with the quality and health of the soil (Haberern, 1992). Soil quality investigations are, therefore, essentially needed to provide

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information for resource management and regulatory decisions on land use system.

No information on the quality and health of coastal saline soil of Sundarban delta is available. But it is pre-requisite for developing and planning any land and soil management system. The present study was, therefore, been considered essential to take up with the aim to investigate the effect of various land use systems on physical, chemical and hydrological properties of the soil and also to study relationship among these properties that influence quality of soil under some of the existing land uses in the watershed.

MATERIALS AND METHODS

The micro-watershed (25 ha) situated in Sundarban delta under coastal Saline Zone of West Bengal lying between $21^0$322 and $22^0$402 N latitude and $87^0$302 and 89^0 002 E longitude at about 3 m above mean sea level and 35 km away from the Bay of Bengal. Climate of the zone is subtropical humid. Mean annual rainfall ranges from 1450 to 1925 mm and more than 80% of it occurs during monsoon (June to September). Mean monthly maximum and minimum temperatures are 32.5 and 15.5^{0}C respectively. The delta has mostly low (LL) and medium (ML) land situations where only one crop of kharif-rice is grown. But, *boro*-paddy is also grown as second crop in very limited areas. The land-use systems of the delta, In general, are Double (L_1) and Mono-cropped (L_2) paddy lands as well as Grass (L_3) and Barren (L_4) lands. All the four land uses under two land situations were taken into consideration for the study.

Irrespective of land uses and land situations 20 composite surface soil samples (0-15 cm) collected were processed and analyzed for both physical and chemical properties. Physical properties *viz*., Particle size distribution, bulk density (BD), soil aggregate >0.25 mm, aggregate stability (AS), mean weight diameter (MWD), geometric mean diameter (GMD), structural coefficient (SC) and water stable aggregates (WSA) were determined and calculated using methods suggested by Yoder (1936) and Baver *et al.*, (1972). The chemical properties *viz*., Organic carbon (OC), pH, electrical conductivity (EC), cation exchange capacity (CEC), sodium adsorption ratio (SAR), exchangeable sodium percentage (ESP) and total available nitrogen (N), phosphate (P_2O_5), and potash (K_2O) were determined following standard methods (Jackson, 1973 and 1967, and Black, 1965). Productivity rating of the soils under different land uses in both the land situations was calculated using some selected physical, hydrological and chemical indicators essential for soil ecology as per rating scale suggested by Mukherjee (1996).

RESULTS AND DISCUSSION

[A] Physical Properties

Particle size distribution

Under low land situation, clay content in paddy soils was higher (Table 1) and it was 42.4 and 49.8 % under medium and low land situations respectively. On the contrary irrespective of land situation, clay content under double cropped (L_1) and mono-cropped paddy land (L_2) was more than 50 % while barren land under low land contained 43.6 % clay. However, sand and silt content, in general was relatively low under low land situation it was least in both double and mono-cropped lands. Relatively high clay content (54.9%) in both double and mono-cropped paddy lands may be attributed to repeated ploughing and puddling necessary for paddy cultivation. However, soils, in general, were heavy with silty-clay or silty-clay-loam texture. The clay content found to have significant positive correlations (Table 8) with WSA >0.25 mm (0.941), plastic limit (0.714), liquid limit (0.792) and organic matter (0.881). This corroborates the findings of Papendick (1991) and Kerlen and Stott(1994).

Table 1. Influence of land use on percentage distribution of soil particles under two land situations in Sundarban

Land use	Sand, %			Silt, %			Clay, %		
	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean
L_1	12.4	19.1	15.8	34.0	26.0	30.0	53.6	54.9	54.3
L_2	19.1	15.1	17.1	30.0	30.0	30.0	50.9	54.9	52.9
L_3	28.4	12.4	20.4	36.0	42.0	39.0	35.6	45.6	40.6
L_4	29.1	16.4	22.8	41.3	40.0	40.75	29.6	43.6	36.6
Mean	22.25	15.75	—	35.3	34.5	—	42.4	49.8	—

Note: 1. L_1 = Double cropped land; L_2 = Monocropped paddy land; L_3 = Grassed / Forest land & L_4 = Barren land2. LL = Low land situation, and ML = Medium land situation

Bulk density and porosity

Bulk density was highest (1.42 Mgm^{-3}) in barren land soils, while it varied from 1.34 – 1.37 Mgm^{-3} in other land uses (Table 2). It was further observed that the bulk density of soils under low and medium land situations were 1.44 and 1.40 Mgm^{-3}, respectively. Highest BD of barren land soils may be ascribed to soil compaction through low content of OC due to devoid of vegetation and human activities in addition to silt and clay deposition due to flood with tidal water. Relatively higher bulk density as observed in mono-cropped paddy land under low land situation was due to compaction caused by use of heavy machinery (tractor etc), repeated ploughing and puddling for paddy cultivation.

Table 2. Bulk density and total porosity of soil under different land-uses

Land use	Bulk density, Mg m^{-3}			Total porosity %		
	ML	LL	Mean	ML	LL	Mean
L_1	1.33	1.35	1.34	49.81	49.06	49.50
L_2	1.33	1.41	1.37	49.81	46.79	48.30
L_3	1.35	1.38	1.36	49.06	47.92	48.49
L_4	1.40	1.44	1.42	46.15	45.66	45.90
Mean	1.35	1.39	—	48.70	47.36	—

Note: *ibid*

Such variation in bulk density resulted variation in total porosity of the soil (Table 2). The difference in porosity of soils between medium (48.7 %) and low land (47.36 %), compared to relatively high porosity (49.81 %) as observed in mono and double-cropping systems in medium land situation and it was lowest (45.66 %) in barren land soils. Such variation in pore space was due to nature and distribution of soil particles. High porosity of soils under different land uses may be ascribed to repeated ploughing as well as addition and accumulation of organic matter through cultivation. The relationship between organic matter and water stability aggregates was linear (Table 9) and highly significant (r = 0.997**). The importance of porosity for water retention, aeration and drainage has been referred by Baver *et al.* (1972).

Soil aggregates

Maximum aggregation of soil particles was observed under low land situation (Table 3) and it was 99.0 % in double-cropped and mono-cropped paddy lands. However, soil aggregation was 1.13 times higher under the land uses in medium land situation in general; butin low land situation it was more than 95% in cultivated lands. The trend was similar in all the stability indices. Nevertheless, better soil aggregation in both cropped and grassed land uses were probably due to addition and accumulation of organic matter through organic manure and crop residues (Fig. 1). Similar result

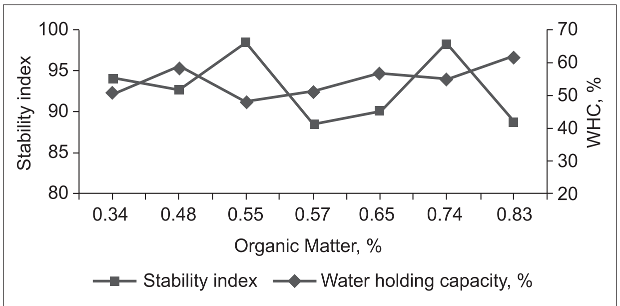

Fig. 1. Influence of organic mater on aggregate stability index and water holding capacity

was reported by Jo (1990). Both mean weight diameter (MWD) and structural co-efficient showed similar trend (Table 3). It was further observed that irrespective of land situations, structural co-efficient was maximum (0.97) in double cropped land followed by mono-cropped, grassed and barren lands (Table 3). Presence of organic matter and clay content led to attain such higher structural co-efficient or the structural stability. WSA >0.25 mm had positive and

Table 3. Various aggregate stability indices under different land use systems at two land situations in Sundarban

Land use	Percentage of Aggregates > 0.25 mm			Percentage of Aggregates Stability			Mean Weight Diameter (MWD), mm			Geometric Mean Diameter (GMW), mm			Structural Co-efficient		
	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean
L_1	81.56	99.0	90.28	80.52	98.62	89.57	2.26	2.68	2.47	1.02	1.04	1.03	0.81	0.99	0.90
L_2	98.98	95.28	97.13	98.60	94.16	96.38	2.75	2.79	2.77	1.07	1.14	1.11	0.99	0.94	0.97
L_3	82.6	56.64	69.62	79.89	55.94	67.92	2.36	1.62	1.99	0.97	0.76	0.86	0.80	0.56	0.68
L_4	81.88	53.28	67.58	55.94	52.1	54.02	2.28	0.56	1.42	0.99	0.50	0.75	0.81	0.52	0.07
Mean	86.26	76.05	—	78.73	75.21	—	2.41	1.19	—	1.01	0.86	—	0.85	0.75	—

Note: *ibid*

significant correlations (Table 8) with organic matter (0.609*) and clay (0.584*) content. The result conforms the findings reported by Khanna *et al.* (1975). Baver *et al.* (1972).

[B] Chemical Properties

Organic carbon

The soils of medium and low land situations did not differ in organic carbon content, but it largely varied from 0.20 to 0.48 percent amongst the land uses (Table 4). Higher carbon content in soils under double and mono-cropped systems was due to application of organic manure as well as *in situ* decomposition of plant residues. In fact, intensive cultivation helped in increasing the amount of organic carbon in the soil. Organic matter derived from organic carbon showed the trend similar to that of the organic carbon. Similar results were reported by Egawa and Kozosekiya (1956) for grass land and Mohammodi*et al.* (2005) for agriculture and forest ecosystem.

Soil pH

The result shows that the soils under both the land situations were found to be acidic reaction, which was more pronounce in both double cropped (pH5.3) and mono-cropped (pH 4.6) lands (Table 4). The reasons for transformation of inherent saline soil may be ascribed to the extensive use of urea as chemical fertilizer. However, pH of the grassed and barren lands under both the land situations showed saline in reaction (pH7.2 to 8.0) because of its inherent characteristics and non-application of any chemical fertilizer. Nevertheless, pH, in general, showed decreasing trend with increase in organic matter content (Fig. 2), the reason for such variation is to be explored.

Electrical conductivity (EC)

Electrical conductivity (EC) of soils indicates that the soil under both the situations are saline in

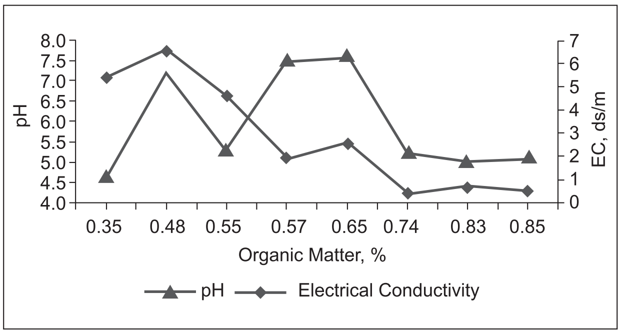

Fig. 2. Influence of organic matter on pH and electrical conductivity

nature (EC_e> 2 dSm^{-1}). Higher EC values of soils under low land situation indicate higher concentration of salt due to overflow and / or sea-water intrusion followed by capillary rise due to evaporation of soil moisture. It was 2.2 times higher in low lands than that in the medium lands. On the contrary, under double and mono-cropped lands EC of soils varied from 0.4 -1.9 d Sm^{-1} indicating the fact that the soils under these land uses are non-saline, which might be because of irrigation with sweet water and subsequent leaching of salt helped in maintaining low EC (Table 4). However, EC was relatively higher in low land situations possibly due to prolong stagnation of saline water. Soils under rest of the land uses were found to be saline (2.6 to 6.6 d Sm^{-1}). Significant inverse correlation of EC (Table 11) with organic carbon (r = - 0.595*) and CEC (r =- 0.820**) give an indication of their influence on buffering and / or reducing soil salinity.

Sodium Adsorption Ratio (SAR)

SAR did not show any significant difference amongst the land situations (Table 5). It was maximum (9.54) in grassland under medium land situation and was at par with barren land. Further, SAR, in general, did not show any significant relationship with any of the chemical properties.

Table 4. Influence of land use on pH, electrical conductivity, organic carbon and organic matter under two land situations

Land use	pH			EC_e, dSm^{-1}			Organic Carbon, %			Organic Matter, %		
	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean
L_1	5.2	5.2	5.2	0.7	1.9	1.3	0.48	0.33	0.41	0.83	0.57	0.70
L_2	5.3	4.6	5.0	0.4	1.2	0.8	0.43	0.48	0.46	0.74	0.83	0.78
L_3	7.6	8.0	7.8	4.6	2.6	3.6	0.32	0.38	0.35	0.55	0.65	0.43
L_4	7.5	7.2	7.4	5.4	6.6	6.0	0.20	0.28	0.24	0.34	0.48	0.41
Mean	6.4	6.3	—	2.78	6.15	—	0.36	0.37	—	0.62	0.55	—

Note: *ibid*

Table 5. Sodium adsorption ratio, exchangeable sodium percentage and cation exchange capacity of soil under different land uses at two land situations

Land use	Sodium Adsorption Ratio			Exchangeable Sodium Percentage			Cation Exchange Capacity cmol (p+) kg^{-1}		
	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean
L_1	8.74	8.12	8.43	8.61	10.75	9.68	21.61	22.32	21.97
L_2	6.11	8.21	7.16	9.17	12.32	10.75	19.93	20.14	20.04
L_3	9.54	7.18	8.36	8.32	9.73	9.03	18.31	19.09	18.70
L_4	6.32	6.74	6.53	8.03	10.12	9.07	17.83	17.37	17.60
Mean	7.68	7.56	—	8.53	10.73	—	19.42	19.73	—

Note: *ibid*

Cation Exchange Capacity (CEC)

Variation in CECunder different land situations was not observed but it was varied amongst the land uses (Table 5). It was highest (21.97cmol (p+) kg^{-1}) in soils under double cropping system followed by mono-cropped, grassed and barren lands. It was further observed that the CEC of low land soil, in general, was relatively higher than that under medium land. Further, under double cropped land in low land situation it was as high as 22.32 cmol (p+) kg^{-1}, which was 28.5% higher than that in the barren land under the same situation. Higher CEC of soils under low land situation may be due to deposition of silt and clay. It was further observed that CEC increased significantly with the increase in pH and organic carbon as supported by positive correlation (Table 11). On the contrary, it showed a highly significant inverse relationship (r = -0.820*) with EC_e. Similar relationship of CEC with pH has been reported earlier by Schofield, (1949). The result also indicates that CEC increased significantly (r = 0.804*) with the increase in the amount of clay (Table 10 and Figure 3). The result corroborates the findings of Grim (1962).

Nutrient availability of soil

The results revealed that irrespective of land situations no difference in the content of available N in soils under any land use systems was observed. However, available phosphate and potash content of cropped land soils under low land situation was relatively higher (Table 6). This may be ascribed to higher CEC of soils due to high claycontent in addition to application of chemical fertilizer for crop production by the small farmers in the zone. Similar observations were reported by Sanchez *et al.*, (2003).

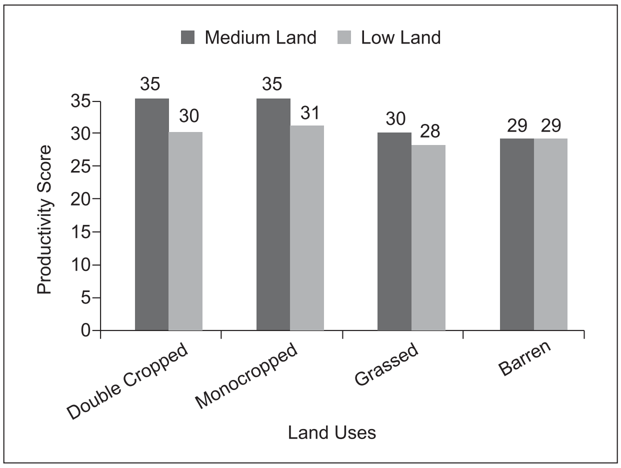

Fig. 3. Land productivity under different land uses at two different land situations

[C] Agricultural productivity Rating

Since biological indicators have not been taken

Table 6. Total nitrogen, available phosphorus and potash in the soil under various land uses in two land situations of Sundarban

Land use	Total nitrogen (N), kg ha^{-1}			Available phosphate (P_2O_5), kg ha^{-1}			Available potash (K_2O), kg ha^{-1}		
	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean
L_1	0.038	0.031	0.04	78.20	84.12	81.16	320	434	377
L_2	0.039	0.041	0.04	77.0	87.3	82.15	357	334	346
L_3	0.032	0.016	0.02	64.01	58.00	61.01	410	383	397
L_4	0.015	0.026	0.02	47.0	60.12	53.56	297	353	325
Mean	0.03	0.03	—	66.55	72.39	—	346	376	—

Note: *ibid*

Table 7. Productivity of land under different land uses in Sundarban

Land use	Organic carbon %	Average phosphorus kg ha^{-1}	Average potash kg ha^{-1}	Average pH	Conductivity (EC) dSm^{-1}	Seasonal rainfall	Depth of deep tubewell	Drainage condition	Net productivity rating
Medium land									
L_1	0.48 (3)	78.20 (6)	320 (6)	5.2 (5)	0.7 (5)	1904.8 (6)	300-320 m (1)	Moderate (3)	35
L_2	0.43 (2)	77.00 (6)	357 (6)	5.3 (5)	0.4 (6)	1904.8 (6)	300-320 m (1)	Moderate (3)	35
L_3	0.32 (1)	64.01 (6)	410 (6)	7.6 (6)	4.6 (1)	1904.8 (6)	300-320 m (1)	Moderate (3)	30
L_4	0.20 (1)	47.00 (5)	297 (6)	7.5 (6)	5.4 (1)	1904.8 (6)	300-320 m (1)	Moderate (3)	29
Low land									
L_1	0.33 (2)	84.12 (6)	434 (6)	5.2 (5)	1.9 (3)	1904.8 (6)	300-320 m (1)	Water logged (1)	30
L_2	0.48 (3)	87.30 (6)	334 (6)	4.6 (4)	1.2 (4)	1904.8 (6)	300-320 m (1)	Water logged (1)	31
L_3	0.38 (2)	58.00 (6)	383 (6)	8.0 (5)	2.6 (1)	1904.8 (6)	300-320 m (1)	Water logged (1)	28
L_4	0.28 (2)	60.12 (6)	353 (6)	7.2 (6)	6.6 (1)	1904.8 (6)	300-320 m (1)	Water logged (1)	29

Source: Agricultural Land Capability of West Bengal Part II: the Ganga Delta. Prof. K.N. Mukherjee.
N.B.: Items in different columns are not inter related
Note: Figures in the bracket indicate rank as per productivity rating scale

Table 8. Relationship between physical and hydrological indicators, indicated by correlation co-efficient

Variables	WSA^a > 0.25	MWD^b	Liquid limit	Plastic limit	Water holding capacity	Organic matter	Clay	Silt
WSA^a> 0.25	1	0.941**	0.386	0.050	-0.060	0.609*	0.584*	-0.636*
MWD^b		1	0.218	0.200	0.087	0.506*	0.433	-0.554*
Liquid limit			1	0.940**	-0.070	0.548*	0.787**	-0.55*
Plastic limit				1	-0.094	0.523*	0.707**	-0.502*
Water holding capacity					1	0.652*	0.405	0.501*
Organic matter						1	0.876**	0.554*
Clay							1	-0.728**
Silt								1

Note: 1. ^{a}, Water stable aggregate; $_b$, Mean weight diameter
2. ** and * indicate significance at 1 and 5 percent levels of probabilities

Table 9. Correlation Coefficients of physical indicators

Variables	WHC	WSA	Po	PI	Clay, %	OM	Es
Water Holding Capacity (WHC)	1.000	0.709*	0.901**	0.942**	0.775*	0.700	0.530
WSA>2.5mm (Wsa)		1.000	0.611	0.832**	0.960**	0.997**	0.785*
Porosity(Po)			1.000	0.735*	0.782*	0.609	0.721*
Plasticity Index (PI)				1.000	0.805**	0.821**	0.484
Clay, %					1.000	0.962**	0.902**
Organic Matter (OM)						1.000	0.795*
Evaporation (Es)							1.000

Note: WHC, water Holding Capacity; WSA, Water stable Aggregate >2.5mm; Po, Porosity, %; PI, Plasticity Index; OM, Organic Matter and Es, Evaporation, mmd^{-1}

into consideration in this study, few ecological elements have been selected for rating the land use systems on the basis of agricultural productivity. The ecological elements considered were organic carbon, phosphate and potash, pH, EC, rainfall, depth of groundwater table and nature of drainage.

The results (Table 7 and Fig. 3) indicates that of cultivated lands under medium land situation had maximum productivity score (35). But, under low land situation, it marginally varied between 30 and 31. However, the sequence of productivity of lands under medium land situation is double cropped =

Table 10. Correlation Coefficients (r) among the chemical properties

Variables	Clay	Electrical Conductivity	Cation Exchange Capacity	Sodium Adsorption Ratio
Clay	1	0.784**	0.804 **	0.359
Electrical Conductivity		1	0.820**	0.166
Cation Exchange Capacity			1	0.359

Note: ** indicates significance at 1% level of probability

Table 11. Correlation Co-efficient of the chemical indicators

Variables	pH	Electrical conductivity	Organic carbon	Cation exchange capacity	Exchangeable sodium percentage	Sodium adsorption ration
pH	1	0.650*	-0.910**	-0.667*	-0.360	-520*
EC_e		1	-0.595*	-0.820**	-0.290	-0.166
OC			1	0.659*	0.596*	0.277
CEC				1	0.321	0.360
ESP					1	0.065
SAR						1

Note: ** and * indicates significance at 1 and 5 percent probabilities.

mono-cropped > grass land > barren land and that under low land situation the trend observed is mono-cropped > double cropped > barren > grass land.

CONCLUSION

Considering physico-chemical properties of soils under different land situations and uses of Sunderban delta, it may be concluded that both double and mono-cropped paddy lands under medium land situations found to be of highest productivity. Under low land situation productivity of cropped lands was although lower than those under medium land, but variation between themwas marginal.

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Detailed soil survey – Systematics for evaluation of soil degradation

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ABSTRACT

Soil is a vital natural resource that functions and acts as life supporting system to plant, animal and mankind. Soil information thus play critical role for sustenance of mankind and necessitates generation of soil data base. Soil survey is a tool to generate soil data base with systematic study of soils with thorough traversing and examining soil to delineate soil boundary followed by characterization and classification of soil. The scale of soil survey depends on the purpose and objective of the project. Detailed soil survey is conducted either at cadastral scale or 1: 10 or 1:12.5K scale where cadastral map or airborne/spaceborne remote sensing data is used as base map to generate detailed soil data base. Detailed soil data base have wide utilitarian purposes covering scientific land use planning to maintenance of soil health at farm level besides non-arable applications. Various interpretative groupings could be developed out of the detailed soil and land characteristics for use in agriculture, forest and environment, water resources, rural development, information technology, soil reclamation, crop loan and insurance, soil and water conservation etc,. However, interpretation of soil mapping units and soil classification will provide detailed information about various kinds of soil degradation. Detailed soil survey may thus be termed as a soil systematics comprising mapping, characterization, classification and interpretation for use of soil data base. The detailed soil data base could be used for evaluation of soil degradation. The paper deals with the importance of phase level mapping of soils to evaluate degradation due to water induced soil *erosion vis a vis*soil classification to evaluate the other kinds of soil degradation such as salinity, alkalinity, acidity, water-logging at different levels of soil taxonomy.

Key words: Detailed soil survey, soil degradation, phases of soil series, diagnostic horizon and soil classification

INTRODUCTION

Soil, like air and water, is one of the world's most important natural resources. Together with air and water it forms the basis for life on planet earth. It functions many ways to provide ecological services which are essential for life. Not only does it play the major part in allowing us to feed the world's population, but it also plays a major role in the recycling of air, water, nutrients, and maintaining a number of natural cycles, thereby ensuring that there will be a basis for life in generations to come. Without soil, the world's population neither would nor could survive.

Soil information plays an important role in planning development programmes both for arable and non-arable purposes. It is vital to derive Land Capability which is generated out of Standard Soil survey. Two kinds of soil survey are practiced around the world such as reconnaissance and detailed soil survey (Anon 1970, Anon 2009). Soil survey is defined as systematic study of soils by exposing a soil profile of at least 1.5 metre in the field followed by delineation of soil boundary on base map with thorough traversing and characterization and classification of soils in terms of morphological, physical, chemical and mineralogical properties. Their importance in deriving land capability potential depends on the scale of data acquisition *vis a vis* usability for optimal land use planning that are described below.

- Reconnaissance Soil information generated on 1:50K scale where 2-3 kinds of soil are mapped in association. Land Capability Class (LCC) of various soil associations could be derived by averaging the LCC of individual soil exists in

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association or considering the LCC of dominant soilin the soil association that may help in Land Use Planning at district level.

- Detailed Soil Information generated on 1:4K / 1:8K / 1:15K scale where soils are mapped individually is adequate to derive LCC up to unit level that are essential for optimal land use planning, land budgeting, proper diagnosis of soil, crop planning and maintenance of soil health.

Soil information generated out of soil survey are documented in the form of report and maps which are provided to the user departments for formulation of working plan either at district or village level. The spatial and non-spatial soil information governs the soil resource data base.The soil information generated out of detailed soil survey includes following characteristics:

- Surface Characteristics – Physiography, Slope, Erosion, Drainage, Land Use, Coarse fragments
- Morphological Characteristics – Soil Depth, Genetic Horizon, Soil Colour, Soil Texture, Soil Structure, Soil Consistency, Mottles, Slickenside, Cracks, Coarse Fragments, Concretions, Pores, Soil Reaction
- Physical Characteristics - % Gravels, Particle Size Distribution, Particle Density, Bulk Density, % Pore Space, Water Holding Capacity, Moisture Equivalent, Permeability, Infiltration Rate, Cole Value
- Chemical Characteristics – Soil pH, Total Soluble Salt, Organic Matter, Cation Exchange Capacity, Exchangeable Cations, Base Saturation, Exchangeable Sodium Percent, Available N,P,K
- Interpretative Groupings – Land Capability Classification, Soil Irrigability Classification, Land Irrigability Classification, Paddy Soil Grouping, Hydrological Soil Grouping, Soil Fertility Rating

The practical purpose of soil survey is to enable more numerous, more accurate and more useful predictions [of land performance] to be made for specific purposes than could have been made otherwise in the absence of location-specific information about soils (Dent *et al.* 1981, Deckers 2012). Soil survey has been divided into two types (Rossiter 2000) as below:

- Utilitarian, to answer specific questions about the response of land to land use
- Scientific, to understand the soil as a natural body in the landscape

In many situations a scientific survey is the most efficient way to obtain a utilitarian survey as it is difficult to map the distribution of specific soil propertieswithout understanding the scientific basis of soil-landscape relations.

Scientific land use planning, diagnosis of soil for optimal utilization, maintenance of soil health, suitability of land for various crops, fertility management and dissemination of soil information to the farming community etc. could be dealt with the soil resource data base (Das, 2000) which should have the following datasets for the benefit of users.

1. Statistics with spatial distribution of various types of soils at detailed level
2. Morphological, physical and chemical properties of soils
3. Soil classification
4. Interpretative groupings of soil data for various applications in the field of agriculture, forestry, horticulture, soil and water resource development and non-agricultural applications
5. Land Capability map

Many countries place great importance in mapping their soil resources, as it provides invaluable information about the types of soil present, their distribution, and formation. Soil maps are used by a wide range of individuals, including farmers, town and country planners, conservationists, foresters, teachers and students to name but a few.

Historically, soil survey interpretations have been concerned primarily with soil interpretative predictions for the public that are specific to a land use. This contrasts with genetic or taxonomic evaluation of soils by scientists.Generally, soil maps are used to simply identify soils and their properties, but are sometimes required for more specific purposes, such as determining the suitability of a soil for particular crops, or the land drainage capabilities of an area. Soil survey data are used for various projects and programme. Some potential area for use of soil survey data are highlighted below (Seelig 1993):

- Agricultural Producers, Farm Managers, and Consultants
- Bankers, Investors, Land Appraisers, Credit Agencies and Directors of Tax Equalization
- Natural Resource Education
- Windbreaks, Woodland, and Wildlife
- Highway / Construction Engineers and Land Developers
- Planning Boards, Health Officials and Municipal Officials
- Geographical Information Systems (GIS)

- Water Resource Vulnerability
- High Efficiency Application of Agricultural Chemicals

Like all maps, soil maps can be created in different scales. Small scale maps (which show less-detail) provide an overview of a region, whilst large scale maps (which show high-detail) can be prepared where necessary for a local area such as a wildlife reserve or a farm. Mapping information can be produced in paper form, or increasingly in digital mapping form through the use of a GIS, which uses the computer to store and manipulate data about soils and other related themes.

Soil's functioningas a service provider to mankind is now under tremendous stress due to climate and land use / land cover changes resulting large scale degradation of soils. It is a serious threat and needs to be handled with judicious and scientific measure to sustain the soil ecosystem service (Daily *et al.* 1997). Soil survey data and map thus form a primary need of the hour.

In India soil survey started with the All India Soil Survey scheme in 1956 for nationwide soil survey. Subsequently, it has been institutionalized as All India Soil and Land Use Survey in 1958 to operate various kinds of soil survey to provide detailed soil and land characteristics to the State user departments for planning and implementation of soil and water conservation in the catchments of River Valley Projects and Flood Prone Rivers in the country (Anonymous, 2012a). Conducting detailed soil survey at cadastral scale (1:4 / 8 K) or larger scale is one of the activities of the Soil and Land Use Survey of India since inception.

There are many uses of soil survey data and maps but the mapping unit of detailed soil survey provides unique processes of soil degradation. In detailed soil survey, soils are mapped as types and phases of soil series where soil series is defined as soils having similar horizonations and characteristics down the profile excepting the texture of the surface soil.

Soil series represents the lowest category of soil taxonomy. The differentia used for series are generally same as those used for classes in other categories but the range permitted for one or more properties narrower than permitted in soil family or other higher categories in the system. The purpose of the series category, like that of the family, is mainly pragmatic, and the taxa in the series category are closely allied to interpretive uses of the system (Anonymous, 1999).

Soils of one series can differ in texture of the surface layer or of the substratum. They also can differ in slope, stoniness, wetness, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into soil phases. A phase can therefore be taken as a modifier of a certain kinds of soil, especially in the case of soil series. This allows flexibility in the definition of map units (Anonymous, 2012b).

Soil phases represent terrain characteristics and not soil properties. It is not considered in soil taxonomy but is an integral component of soil survey. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management (Anonymous, 2012c). Designing of map unit is a state of art of soil survey. The formulation and symbolization of soil mapping unit followed by Soil and Land Use Survey of India is systematic, scientific and connotative. Let's consider the soil mapping unitstaken from detailed soil survey of Nj3e sub-watershed of Nizamsagar catchment covering Bidar districts, Karnataka for example (Anonymous, 2012d). Kandagola moderately deep clayey soilsdevelopedover Basalt have been depicted on soil map (Fig. 1 and Table 1) withfour soil mapping units (KG3r B2, KG3r B2S, KG3r C2S, KG3r D2S).

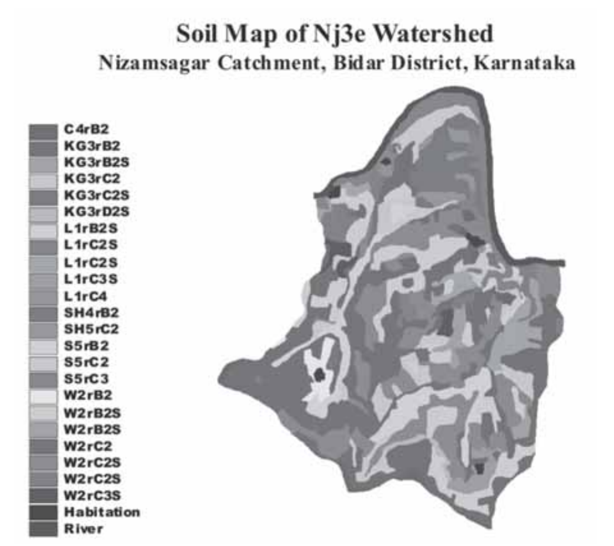

Fig.1. Soil Map of Nj3e sub-watershed of Nizamsagar catchment

Assuming KG3r B2 represents the ideal soils of Kandagola series which has been subjected to erosion processes resulting variation of land slope, soil erosion class and stoniness surface at places that has been symbolized as different phases of soil

Table 1. Soil Mapping Units with Phases of Soil Series

Soil Series	Mapping Unit	Description
Chimkod (C)	C4r B2	Chimkod, deep, clay, 1-3% slope, moderate erosion
Kandgola (KG)	KG3r B2	Kandgola, moderately deep, clay, 1-3% slope, moderate erosion
	KG3r B2S	Kandgola, moderately deep, clay, 1-3% slope, moderate erosion, stoniness
	KG3r C2S	Kandgola, moderately deep, clay, 3-5 % slope, moderate erosion, stoniness
	KG3r D2S	Kandgola, moderately deep, clay, 5-10% slope, moderate erosion, stoniness
Ladha (L)	L1r B2S	Ladha, very shallow, clay, 1-3% slope, moderate erosion, stoniness
	L1r C2S	Ladha, very shallow, clay, 3-5% slope, moderate erosion, stoniness
	L1r C3S	Ladha, very shallow, clay, 3-5% slope, severe erosion, stoniness
	L1r C4	Ladha, very shallow, clay, 3-5% slope, very severe erosion, stoniness
Shorhalli (SH)	SH4r B2	Shorhalli, deep, clay, 1-3% slope, moderate erosion
	SH4r C2	Shorhalli, deep, clay, 3-5% slope, moderate erosion
	SH5r C2	Shorhalli, very deep, clay, 3-5% slope, moderate erosion
Sultanpur (S)	S5r B2	Sultanpur, very deep, clay, 1-3% slope, moderate erosion
	S5r C2	Sultanpur, very deep, clay, 3-5% slope, moderate erosion
	S5r C3	Sultanpur, very deep, clay, 3-5% slope, severe erosion
Wadagaon (W)	W2r B2	Wadagaon, shallow, clay, 1-3% slope, moderate erosion
	W2r B2S	Wadagaon, shallow, clay, 1-3% slope, moderate erosion, stoniness
	W2r C2	Wadagaon, shallow, clay, 3-5% slope, moderate erosion
	W2r C2S	Wadagaon, shallow, clay, 3-5% slope, moderate erosion, stoniness
	W2r C3S	Wadagaon, shallow, clay, 3-5% slope, moderate erosion, stoniness

series in the soil mapping units. The soil behavior of different soil phases of Kandagola series obviously will vary and reflect in crop production where cotton and groundnut are usually grown. This may be explained other way in terms of cost of agriculture production, suppose X is the maximum amount of food grain (say groundnut) produced from KG3r B2 unit area with input and management cost of Y, similar production may not be achieved from other mapping units of Kandagola soil having different soil phases where input and management cost will be relatively higher. Management cost for slope gradation and removal of stone from concerned mapping unit area will be more to sustain X amount of production. Such variation may be attributed due to variation of soil characteristics emanated out of degradation process that is denoted by soil phases in the mapping unit.

Similar interpretation may be done with soil mapping units of any soil series to evaluate the degree of degradation due to water induced soil erosion. The mapping units of Sultanpur soil series (S5r B2, S5r C2, S5r C3) depict the erosion process along the slope resulting variation of soil phases in same soil.

Apart from soil erosion, the other kinds of soil degradation such as soil acidity, soil salinity, soil sodicity, water-logging etc., are mapped at the time of establishment of soil series with distinct naming based on different diagnostic horizons for identification of soils affected by salt affliction and impeded drainage. The presence of natric, kandic, calcic, gypsic, salic, duripan, fragipan, placic etc., diagnostic horizons in soil solum are indicative of soil degradation that helps to demarcate the problematic soils and mapped as separate soil series.

Based on morphological, physical, chemical and mineralogical properties, soils of each series are placed under different taxonomic units. Characterization and classification of soils are integral components of detailed soil survey. Soil taxonomic units thus provide the vital information of soil forming processes of soil development to understand the potential and problems for optimal utilization.

Soils having different kinds of problem could be identified from soil taxonomy at different levels of the classification system. Let us consider Loamy skeletal, mixed, hyperthermic Typic Ustorthents family of a soil series. The skeletal soil texture is indicative of weathering of parent material and their presence in surface soil might be due to truncation of upper layer by abrasive action of rain / run-off water.Similarly, Sodic Haplusterts represents soil sodicity at Subgroup level of the soil taxonomy; Typic Halaquepts reflects the salinity at Great Group level and impeded drainage condition at Suborder level and Typic Fragiaqualfs indicates aquic condition at Suborder level and presence of fragipan at Great Group level.

Detailed soil survey map and data thus portray various kinds of soil degradation that may be ascertained out of soil series, their phases and soil classification system. Thus it may be described as a soil systematics comprising mapping, characterization, classification and interpretation for use. The detailed data base may be utilized for identification of soil degradation and their evaluation for reclamation with suitable amendment practices to restore fragile eco-system at local level. Digital detailed soil data base, if created under GIS (geographic information system) environment would add new dimension in usability besides evaluating the dynamics of soil degradation. The updating status of soil degradation may be useful for adoption of optimal management practices to arrest the pace of degradation at certain time scale.

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Sustainable agricultural production and bio-diversity conservation through soil and water conservation measures

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ABSTRACT

The study was undertaken in the micro watershed located in Kakdwip Block in saline eco-system of Sundarban. Composite surface soil samples(0-15 cm depth) of double and mono-cropped paddy fields as well as grassed and barren lands were analyzed for different physical (particle size distribution, bulk density, aggregate stability, water holding capacity, moisture evaporation, plasticity) and chemical (organic carbon, SAR, ESP, CEC, pH, EC as well as total N, available phosphate P_2O_5 and K_2O) properties. Result revealed that low land soils contain49.8% clay and it was more than 50% in both double and mono-cropped paddy fields, which resulted 99 % aggregation in these land uses. The higher (0.97) structural co-efficient under these two practices resulted maximum porosity (49.81%) under medium land situation andwater holding capacity (61.73%) as well. All the physical and hydrological parameters were found to be highly correlated with both clay and organic matter content of the soil. The pH of the soils under cultivated double and mono-cropped land was acidic (pH5.3 to 4.6); and alkaline in rest of the land uses. ECe was > 2.0 dSm^{-1} in both the land situations. Other chemical indicators *viz*., SAR, ESP, CEC was found to be relatively higher in lowland situations due to higher clay and organic matter content of the soil. Total nitrogen content did not show any variation w.r.t. land uses and land situations, but, considerably higher content of availableP_2O_5 and K_2O in either double cropped or mono-cropped lands in lowland situation was found to be associated with high clay content. Finally it was revealed that both double and mono-cropped paddy land under medium land situations have highest productivity. In lowland situation, productivity of cropped lands was marginally lower than those under medium land situation.

Key words: Sundarban, land uses, physical properties, chemical properties, productivity

INTRODUCTION

Soil and water are the most vital natural resources and provide life supporting systems for living beings. Over-exploitation and improper management of these resources are causing serious threat to agricultural production, bio-diversity conservation and environment. About 10% of the world's soil has been lost through deforestation, erosion, urban development and other abuses of land. Approximately, 30% of the world's arable land has been abandoned because of severe soil erosion in last 40 years. Worldwide, soil is being lost a rate 13 to 80 times faster than it is being formed. It takes about 500 years to form 25 mm of soil under agricultural conditions, and about 1,000 years in forest habitats. In India, out of the total geographical area of 329 M ha, about 120.72 M ha (36.7%) is subjected to various forms of land degradation on arable (104.19 M ha) and non-arable land (16.53 M ha) and about 5334 million tones of soil (16.35 t ha^{-1} yr^{-1}) gets eroded annually. On the degraded arable land, water erosion is the chief contributor (73.27 M ha) followed by chemical degradation (17.45 M ha), wind erosion (12.40 M ha) and physical degradation (1.07 M ha). Water erosion (9.30 M ha) and chemical degradation (7.23 M ha) are also the major factors for land degradation in open forest areas. Land degradation through special problems affects 17.96 M ha area comprising 8.53 M ha waterlogged, 5.50 M ha saline soils including coastal sandy area, 3.97 M ha ravines and gullies, 1.73 M ha shifting cultivation and 2.73 M ha riverine areas and torrents. Denudation of forest land in various watersheds

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has resulted in recurring floods, *chos* and torrents. There are also serious problems of landslides and silting of rivers and reservoirs. The annual production loss in major rainfed crops due to water erosion in the country has been assessed as 15.7% of total production of cereals, oilseeds and pulses which equivalent to Rs 162 billion is considering minimum support price of 2008-09 (Anonymous 2009). Nearly 1/3 of the geographical area of the country spread over 99 districts in 13 states comprising about 39% of the country's cultivable area is frequently visited by or is prone to droughts of varying intensities. Apart from this moisture stress for successful crop production is felt in large tracts of rainfed / dry land areas. The expansion and intensification of agriculture have been major contributors to the loss of biodiversity worldwide. As agricultural production continues to rise to meet the growing demands of the world's population, it is critical to find ways to minimize conflicts and enhance complementarities between agriculture and biodiversity. The land degradation can be minimized and agricultural production coupled with bio-diversity conservation could be augmented by adopting suitable soil and water conservation measures on arable and non-arable lands following the concept of participatory integrated watershed management.

Bio-diversity

Biological diversity, generally shortened to *biodiversity*, encompasses all species of plants, animals, and microorganisms; the genetic variability within these species; and the ecosystems and ecological processes that form and sustain them. Biodiversity is more than just the number of species; it also includes their variety and uniqueness.

Today, much of the bio- diversity is being lost. The FAO estimates that since the beginning of this century, about 75% of the genetic diversity of agricultural crops has been lost. Crop diversity is the key to food security and sustainable agriculture because it enables farmers to adapt crops suited to their own ecological needs and cultural traditions. Without this diversity, options for long-term sustainability and agricultural self-reliance are lost. An estimated 60% of the world's agricultural land is still farmed by traditional or subsistence farmers, mostly in marginal areas. Majority of the world's farmers, therefore, self-reliance in food production depends on adapting technologies and germplasm to a wide range of poor production environments. Ultimately, farming communities hold the key to conservation and use of agricultural biodiversity, and to food security for millions of the world's poor.

Soil and microbial biodiversity

The staggering diversity of soil biota may be orders of magnitude higher than above ground diversity of plants and animals, but no one has yet made an exhaustive census of even one natural habitat. According to the Global Biodiversity Assessment, "a single gram of temperate forest soil could contain 10,000 million individual cells comprising 4,000-5,000 bacterial types, of which less than 10% have been isolated and are known to science;" more than 500 species of soil invertebrates (e.g. snails, earthworms, termites, mites, nematodes, etc.) have been recorded from a beech forest; over 2,500 species of fungi have been identified from a few hectares of land in southwest England. Soil biodiversity influences a huge range of ecosystem processes that contribute to the sustainability of life on earth. For example, soil organisms maintain critical processes such as carbon storage, nutrient cycling and plant species diversity. Soil biodiversity plays a role in soil fertility, soil erosion, nutrient uptake by plants, formation of soil organic matter, nitrogen fixation, the biodegradation of dead plant and animal material, reducing hazardous waste, the production of organic acids that weather rocks, and control of plant and insect populations through natural bio-control. Through production of food, fiber and renewable forms of energy, soil-based plant productivity supports the livelihood of every person on earth. Soil biota enhances crop productivity because they recycle the basic nutrients required for all ecosystems, including nitrogen, phosphorous, potassium and calcium. Soil organisms enhance the productivity of the soil by increasing water infiltration, thereby reducing surface water runoff and decreasing soil erosion. Termites, earthworms and other burrow-building soil organisms enhance soil productivity by churning and mixing the upper soil, which redistributes nutrients, aerates the soil and increases surface water infiltration. Earthworms and other invertebrates can bring to the surface from 10 to 500 t ha^{-1} $year^{-1}$ of soil, and thus play a critical role in the formation of topsoil. Cornell University entomologist David Pimentel estimates that the value of soil biota to soil formation on agricultural land worldwide is US$50,000 million per annum. Nitrogen from natural and commercial sources is vital to plants and animals. It is the main nutrient required for growth in plants and for building proteins in animals. Biologically fixed nitrogen (primarily nitrogen-fixing microorganisms that live symbiotically on the roots of leguminous plants and trees) makes an enormous contribution to global agricultural productivity. In poor soils, where alternative sources of fertilizer are either unavailable or unaffordable, biological nitrogen-fixation is vital to crop production. Worldwide, an estimated 140 to 170 million tonnes of nitrogen, valued at approximately US$90,000 million are fixed by microorganisms in agricultural and natural systems each year.

Soil biota plays a major role in stabilizing and regulating the earth's climate. Global warming is the result of increasing levels of carbon dioxide and other greenhouse gases in the Earth's atmosphere - primarily caused by the burning of fossil fuels by humans. The rate of exchange of carbon between the earth's surface, the oceans and the atmosphere, known as "the carbon cycle", is the primary mediating force with regard to climate change. Through the process of photosynthesis, green plants absorb carbon dioxide from the atmosphere. It is well known that trees and forests store the absorbed carbon in woody biomass. But it is actually soil organic matter that is the major global storage reservoir for carbon. The living microbes, fungi and invertebrates found in the soil are responsible for decomposing carbon and nitrogen and making them available for plant growth, while at the same time contributing to the rate of production and consumption of carbon dioxide, methane and nitrogen.

With growing awareness and need for low-input and sustainable agriculture, knowledge of soil biodiversity is increasingly important to future farming systems. A better understanding of soil biota will enable farmers to depend less on modification of the natural environment and place greater emphasis on using biological processes to optimize nutrient cycling, minimize the use of purchased inputs, and maximize the efficiency of their use.

Soil and water conservation measures for increasing crop production and biodiversity conservation

It is now well recognized that problem of rural poverty and natural resource degradation need to be addressed simultaneously with active involvement of the local community. A paradigm shift with greater emphasis on involving stakeholders, especially the asset-less, in planning and execution of the developmental projects on watershed basis has emerged in the recent past. A harmonized approach based on the common guidelines is now being adopted in government funded rural development programmes following watershed concept. Several need based development interventions are taken which include arable land renovation, water harvesting and crop improvement and drainage line treatments through mechanical measures. Field bunding, deep summer ploughing, contour cultivation, cover crops, intercropping, mulch, vegetative barriers, agro-forestry, afforestation, terracing and land leveling, contour bunds, field outlets for safe disposal of water, check dams, gully plugs, contour trenching, percolation tanks and ponds etc. are adopted for soil and water conservation and increasing the agricultural production and bio-diversity conservation. The problem about land degradation and salient findings of some of the field studies conducted at Central Soil and Water Conservation Research and Training Institute, Research Centre, Datia (M. P.) and projects managed through watershed management approach in Bundelkhand region have been discussed.

Soil and water conservation related problems of the region

The Bundelkhand region ($23^0 10' – 26^0 30'$ N and $78^0 20' – 81^0 40'$ E) with a geographical area of 7.07 M ha comprising six districts of Madhya Pradesh (Chhatarpur, Damoh, Datia, Panna, Sagar and Tikamgarh,) and seven districts of Uttar Pradesh (Banda, Chitrakoot, Hamirpur, Jalaun, Jhansi, Lalitpur and Mahoba) in Central India is reported as one of the most deprived regions of the country. It is characterized with undulating terrain, scare vegetation cover, hostile climate, lack of irrigation facilities and unfavorable edaphic conditions. About 70% of the total area in the region has been affected by varying degree of erosion hazards. The extensive wastelands in the form of ravine tracts, rocky wastelands in the form of ravine tracts, rocky wastes and scrub land are the results of continued soil degradation and biotic interference. Nearly 80% of total annual rainfall is received during monsoon season but water stress conditions are common even in rainy season. Though the rainfall received is scanty and erratic but high intensity showers received during the monsoon season result into sizable runoff and soil loss. The region is quite rich in bio-diversity but it is being lost mainly due to land degradation and frequent

Table 1. Status of forest cover in Bundelkhand

District	Geographic area	2009 Assessment					
		Very dense forest	Moderate dense forest	Open forest	Total	Per cent of G. A	Scrub
Madhya Pradesh							
Chhatrpur	8,687	184	822	742	1,748	20.12	279
Damoh	7,306	2	862	1,741	2,605	35.66	76
Datia	2,691	0	78	79	157	5.83	101
Panna	7,135	85	1,501	1,068	2,654	37.20	190
Sagar	10,252	2	1,178	1,726	2,905	28.34	135
Tikamgarh	5,048	1	93	309	403	7.98	132
Uttar Pradesh							
Banda	4,532	0	26	77	103	2.27	29
Chitrakoot	3,092	0	358	203	561	18.14	15
Hamirpur	4,282	0	66	108	174	4.06	39
Jalaun	4,565	0	65	179	244	5.35	48
Jhansi	5,024	0	33	167	200	3.98	121
Lalitpur	5,039	0	128	442	570	11.31	44
Mahoba	2,884	0	22	73	95	3.29	96
Total	70,537	274	5,232	6,914	12,419	17.61	1,302

Source: SFR 2009, Forest Survey of India

occurrence of droughts. Bundelkhand region used to have one drought in 16 years in 18th and 19th centuries which increased by three times during the period 1968 to 1992 and the recent past several years have witnessed of continuous drought situation in the region. Due to this situation the region is traditionally facing scarcity of water for drinking as well as agricultural purposes. About 53% area comes under rainfed agriculture and crop intensity is about 111%, consequently there exists a large proportion of cultivable waste and fallow land (Singh and Singh, 2010). The forest cover is very poor in many districts of the region (Table 1). Denuded hillocks are the major source of runoff and soil erosion. Therefore protection of available stock through closure to biotic interference has importance for natural regeneration in the region. Stray cattle are nuisance in the region due to locally called *Anna Pratha.* The cattle are let leave after harvest of the *rabi* crops till the sowing of crops in next *rabi* season, in other words leaving cattle for uncontrolled grazing.

RESULTS AND DISCUSSION

A ten years field study conducted at Datia revealed that closure/protection against biotic interference increased the tree population having DBH >15cm by about 6.2 fold irrespective of the species. A protected forest watershed developed almost 100% cover with the *Kardhai (Annogises pendula)* and *Dhak* (*Butea monosperma*) over a period of 10 years. These two forest species are very hardy and generally grow in co-existence on degraded lands. Protected forest watershed of *Kardhai* (*Annogises pendula*) with 100% cover having steep complex slope produced 2.3 % runoff as against 12.8 % from unprotected forest watershed. This suggested that *Annogises pendula* and *Butea monosperma* could be protected and planted on denuded hillocks to minimize erosion and meet out the requirements of fuel and fodder in the region (Tiwari and Narayan, 2010).

A field size runoff plot (80 x 20 m at slope 3%) based study indicated that earthen contour bunds at 0.7 m vertical interval yielded least runoff (2.0% runoff of rainfall) while contour bunds at 0.9 m vertical interval yielded 3.0% runoff (Table 2). Vegetative barriers also moderated the flow of runoff water. Vegetative barrier of C*enchrus ciliaris and Heteropogon contortus* yielded 12.3% and 7.2% runoff, respectively; however, maximum runoff (24.8%) was recorded under farmer's practice (control). Soil loss followed the same trend as that of runoff. Rainwater conservation is a very high priority in Bundelkhand region particularly in red soils areas. The results of this study suggested that earthen contour bunds at 0.7 m vertical interval were found superior to other soil conservation measures in minimizing runoff and soil loss from sloppy lands in red soils and achieving higher crop yield (Katiyar *et al.*, 2007).

Table 2. Runoff and soil loss as influenced by vegetative barriers and contour bunds in red soils

Interventions	Runoff (%)	Soil loss (kg ha^{-1})
Farmer's practice	24.8	1002
Vegetative barrier of *Cenchrus ciliaris* at 0.7 m vertical interval	12.3	285
Vegetative barrier of *Heteropogon contortus* at 0.7 m vertical interval	3.0	62
Contour bunds at 0.7 m vertical interval	7.2	194
Contour bunds at 0.9 m vertical interval	2.0	41

A study conducted to assess the effects of interventions in small watershed hydrology indicated that agriculture watershed with farmer's practice produced maximum runoff of 15.1% (Table 2). Grassed watershed produced 4.1% runoff. Agriculture watershed with *Vetiver* barrier produced 9.3% runoff, while agriculture watershed with *Vetiver* barrier at the out let produced 4.3% runoff. Protected forest with gradual removal of vegetation produced no runoff, followed by protected mixed forest watershed yielding 0.4% runoff. Forest watershed with contour trenches produced 3.1% runoff. Soil loss followed the same trend as that of runoff (Katiyar *et al.* 2007a). The results suggested that interventions in watershed affected the hydrology of the watersheds in terms of runoff and soil loss washed away from the watershed area. In a protected watershed even small removal of vegetation did not increase the runoff and soil loss. Interventions of different conservation measures reduced the runoff and soil loss from the watershed area.

Some experiences of watershed management Sheetalpur watershed, Hamirpur (U.P.)

A ravenous watershed watershed covering an area of 571 ha comprising the village of Sheetalpur and Kusmera in Hamirpur district of Uttar Pradesh was selected to demonstrate usefulness of watershed approach in the management of erosion problem and dryland agriculture in the region. About 30% of land had steep slope (>7.5%) and another 30% had slope of 3.0-7.5%. About 134 ha land was under ravine system and was devoid of vegetation. The upper portion of watershed was having mild slope (1-3%). As per watershed development plan various land developmental and vegetative measures viz., contour bunding, land shaping and terracing, bench terracing, gully plugging, plantation and grassland development, etc. were undertaken. Contour bunding was carried out on 41.4 ha land at an vertical interval of 0.9 m. About 200 ha land was developed through leveling and terracing with suitable water disposal structures. Another 190 ha land was treated with gully plug (check dam) structures with the provision of *pacca* drop inlet structure for safe disposal of runoff. About100 ha land was brought under irrigation by installing a tube well. Under agricultural and horticultural development, field demonstrations were conducted to introduce the new crops and varieties of different crops and vegetables coupled with improved package of practices. Under agroforestry programme, 60 gully plugs were planted with *Acacia* spp. and 25 with *Acacia nilotica, Dalbergia sissoo, Albizia lebbek, Acacia catechu* etc. The Forest department land in the watershed was afforested with *Acacia nilotica, Dalbergia sissoo, Albizia lebbek, Acacia catechu, Azadirachta indica,* bamboo and *Prosopis juliflora*. Nearly 59000 trees were planted / sown in the watershed area under Social Forestry programme (Bhushan *et al.* 1997). The impact of various soil and water conservation interventions was very encouraging:

Enhanced production: There was progressive increase in production because of soil and water conservation measures and improved agro-techniques in the watershed. The average crop productivity increased from 8.0 to 14.5 q ha^{-1} due

Table 3. Runoff and soil loss under different treatments in various small watersheds

Interventions	Runoff (%)	Soil loss (kg ha^{-1})
Agriculture (Farmers practice)	15.1	709
Agriculture with *Vetiver* barrier	9.3	313
Protected watershed with gradual removal of vegetation	0.0	0.0
Forest watershed with contour trenches	3.1	59
Agriculture with *Vetiver* barrier at the out let	4.3	94
Grass watershed with introduction of legumes	4.1	29
Protected mixed forest (forest + grass cover)	0.2	0.3

to adoption of soil and water conservation measures coupled with improved agro-techniques.

Sustainability in production: During 1987-88, the rainfall was very deficient and erratic in distribution, making it a severe drought year. Even in severe drought year the total grain production in watershed was 47% higher than pre-project period.

Ground water augmentation: There was quite improvement in the ground water level. Even in the severe drought year (1987) the ground water table remained in the depth ranging between 20-26 m.

Valley profile stabilization: The profile of the main drainage channel was modified by different conservation measures adopted in the watershed. Considerable quantity of silt was accumulated in the drainage way and in the pool before the gully plugs. Total siltation of 3089 cum was taken place which was equivalent to surface cover of 15 cm top layer on 2 ha area.

Eco-restoration: The entire forest land in the watershed was afforested adopting ring pits (45 x 45 x 45 cm^3) and seeds were sown on staggered trenches fenced with cattle proof trench. Overall, there was 71% survival due to moisture conservation by contour trenches and protection provided by way of cattle proof trench.

Bajni watershed, Datia (M. P.)

The project was undertaken during 1997 by the CSWCRTI, Research Centre, Datia (M. P.) in a typical watershed of 532 ha, representing Bundelkhand region. The watershed area had both red and black soils, the water holding capacity of red soils was very poor, while black soils had poor drainage. Most of the red soils in the watershed area were gravelly, light textured and prone to erosion. Scarcity of water for drinking as well as irrigation was the major problem. Community forest lands have very poor canopy cover and are used as grazing grounds, resulting in high runoff and soil loss. An appropriate mix of structural measures and low cost vegetative measures with a concept of participatory approach was evolved and demonstrated in the project. Development and implementation of economically viable, socially acceptable and environmentally sound technologies with people's participation was kept as the underlying principle for ensuring protection and production on sustainable basis. For development of wastelands, vegetative measures (agro-forestry and horticulture), structural measures (loose bounder an gabion check dams) for channel stabilization, minor land leveling / land shaping and bunding with waste weirs in agricultural lands, contour trenches and cattle proof trench in pastures, de-silting of village pond were undertaken in the watershed area through people's participation. Alternative, sustainable and resource conserving land use systems such as agri-horti, silvi-pastoral, agroforestry and cultivation of fodder were also tried. Under common properly resources management, works like village pond renovation, drainage channel stabilization and pasture development in common grazing land were carried out in the watershed. The results of 5 years in terms of hydrological behavior (rainfall and runoff), sediment (soil loss), vegetation, ground water recharge, crop and fodder production were quite encouraging (Sharma *et al*. 2004):

Land development : Land leveling and bunding were carried out in 62.7 ha of land which benefitted about 71 farmers.

Water resource development: After renovation / deepening of village pond, the capacity was increased from 48 to 144 ha-cm. The constructed percolation tank having 40 ha catchment, 6.5 ha-m storage capacity and water spread area of about 2 ha, recharged 13 wells in the downstream side of the pond.

Runoff and soil loss: The runoff and soil loss decreased considerable under vegetative and mechanical measures adopted in the watershed. Runoff decreased from 29.0 to 21.0% with the adoption of vegetative measures, and to 16.3% under mechanical measures. Similarly, soil loss decreased from 14.42 to 9.76 with the adoption of vegetative measures, to 7.72 t ha^{-1} with mechanical measures imposed in the wasteland in the watershed area (Table 4).

Crop productivity: The crop productivity increased from 10.21 q ha^{-1} (1997-98) to 13.40 q ha^{-1} (2002-03) in terms of wheat equivalent yield.

Table 4. Runoff and soil loss under different soil conservation measures

Parameter	Unprotected wasteland (control)	Vegetative measures in waste land (protected)	Mechanical measures in wastes land
Runoff (%)	29.0	21.0	16.3
Soil loss (t ha^{-1} $year^{-1}$)	14.42	9.76	7.72

Fodder yield: Dry fodder yield increased from 0.09 t ha^{-1} under control to 1.64 t ha^{-1} under protected rocky waste lands with soil and water conservation measures.

Ground water availability: Water harvesting structures improved the ground water availability in the watershed area. Out of 40 wells, 38 well were influenced by the water harvesting structures. Duration of water availability of the wells increased on an average by 4 months. The wells those had water for 4 months, now have water for 8 months and likewise, those had for 8 months now have for whole year. Well recharge rate was also increased on an average by 50%.

The survival percent of different plant species increased because of better soil moisture availability in the watershed area.

Garhkundar – Dabar watershed, Tikamgarh (M. P.)

Garhkundar – Dabar watershed with an area of 850 ha is located in district Tikamgarh in Bundelkhand region. This watershed was selected by NRCAF, Jhansi in 2005 in order to improve upon, demonstrate and evaluate agroforestry technologies on watershed basis through participatory approach. To improve water resources in the watershed area, 9 drop structures / check dams, including one in untreated watershed, were constructed mainly on 3rd or 4th order streams in series. Further, to check sedimentation and conserve moisture, 150 gabions of various sizes were laid mainly on 1st and 2nd order streams. Three *khadins* (water spreader) were constructed in series to reduce erosive velocity of running water, apprehend soil loss and create water storage to augment the ground water recharge. In addition, field / contour bunding was done in an area of about 40 ha with the provision of drainage structures. The impact of various watershed activities was as under:

The runoff and soil loss reduced by 34 and 43%, respectively in treated area as compared to untreated area (control). There was more than 2 m increase in water level in 53.3% wells inside the watershed. The surface water in *Nallah* was available throughout the year against 4 months only in untreated area. The number of dry wells in 2009 reduced to 2% from 86% in year 2006. The cropping intensity in treated watershed was 116% as compared to 96% in untreated control. Crop productivity of wheat increased in treated watershed from 2424 to 2845 kg ha^{-1} and that of groundnut from 1180 to 1320 kg ha^{-1} as compared to untreated watershed. Farmers adopted aonla, guava and citrus based agroforestry system in 4.0 ha area. About 6000 forest tree saplings were planted along drainage channel in addition to 0.25 ha teak plantation on private land. Sufficient water was available in all open wells (1 to 6 m depth of water column) to support drinking and irrigation water in the coming *rabi* season.

Tejpura watershed, Jhansi (U. P.)

Tejpura watershed having an area of 775.7 ha was treated (1983-85) by various soil and water conservation measures on micro-watershed basis such as contour bunding (23.28 ha), submergence bunding (558.94 ha), excess runoff disposal structures (70 nos.), check dams (4 nos.) constructed across the seasonal nallah of 6.5 km in length helped in bringing 125.7 ha land under cultivation. Irrigation potential also improved from 3.8 to 78 per cent. Conservation structures helped in increasing the ground water recharge in wells by 3 to 7 m at different seasons. Number of dugout wells increased from 5 to 167. Likewise yields of crops increased by 2.2 to 7.33 times. New crops introduced in the watershed included groundnut, soybean and vegetables. On an average the annual productivity of the watershed increased from initial 6 q $ha^{-1}$to 39.9 q ha^{-1}. The area has been converted form single cropped area to almost double cropped as the cropping intensity increased from 83 to 185%.

CONCLUSION

The land degradation can be minimized and agricultural production coupled with bio-diversity conservation could be augmented by adopting suitable soil and water conservation measures on arable and non-arable lands following the concept of participatory integrated watershed management.

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Inorganic pollution in soils: Causes, effects and amelioration

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ABSTRACT

Contamination of soil and water with toxic inorganic substances has become a widespread phenomenon and the problem attains greater significance due to human health hazard by bioaccumulation and subsequent biomagnifications in food webs. In order to reduce transference of heavy metals into food web, their accumulation in agricultural land is required to be reduced because, soil is a primary recipient by design or accident for myriad of chemical contaminants from wastes and chemicals used in modern society. Although soil acts as a physical factor by its sieving action, a chemical filter by adsorbing and precipitating the chemical substances and a biological filter by decomposing organic materials. But, owing to non-judicious use of chemical fertilizers, pesticides and waste materials in agricultural land, soils are being contaminated with toxic inorganic substances. Once these materials enter into the soil, they become a part of biological cycles and adversely affect all forms of lives. Thus, this is very high time to adopt preventive and / or curative measures to reduce the level of inorganic chemical pollution in soil, water and food items to save the humanity from hazardous effects of toxicants. In the view of above facts, attempts have been made to review the literatures on sources, potential hazards and remediation of inorganic toxicants to conserve biodiversity on earth.

Key words: Heavy metal toxicity, pollution pathway, entry of toxicants in food webs, toxicant related health problems, pollution - control measures

INTRODUCTION

The amount of toxicants released into the environment every year from inorganic sources is now estimated to exceed that from organic and radioactive sources combined (Kabata-Pendias and Pendias, 1992). A fair share of these inorganic substances ends up contaminating soil and water resources. The end products of inorganic contaminants are quite toxic to human and animal health. Arsenic and cadmium are extremely poisonous; mercury, lead, nickel and fluorine are moderately so; boron, copper, manganese and zinc are relatively lower in mammalian toxicity (Brady and Well, 2007). Background information on the sources of toxicants, pollution pathway, pollutant related health problems and amelioration techniques has become essential for thinkers, planners, politicians and agricultural scientists. These aspects of environmental pollution have been discussed as under:

Sources of Inorganic pollutants in soils and water

There are many sources of inorganic chemical contaminants that can accumulate in soils. The burning of fossil fuel, smelting and other processing techniques release tons of toxic elements into the atmosphere which later deposited on the vegetation and soil (Brady and Well, 2007). Lead, nickel and boron are gasoline additives that are released into the atmosphere and carried to the soil through rain and snow (Moore and Ramamoorthy, 1984). Borax is used in detergents, fertilizers and forest fire retardants, all of which commonly reach the soil (Brady and Well, 2007). Superphosphate and limestone contain small quantities of cadmium, copper, manganese, nickel and zinc (Pierzynski *et al*., 2000). Arsenic was for many years used as an insecticide and as a defoliant or vine killer (Brady and Well, 2007). Some of these toxic heavy metals are found as a constituent in specific pesticides and in domestic and industrial sewage sludge (Maiti *et*

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al., 1992).

Basically, inorganic chemical pollutants enter into the soil and water through pedogenic or anthropogenic pathways. Out of pedogenic sources, parent material is the most important source of soil pollution. If a parent material is rich in certain heavy metals, soil derived from it will also be rich in that metal owing to their lower mobility and higher densities (Kumar *et al*., 2010). For example, soils derived from pyromorphite will be rich in arsenic (Sächsische Landesanstalt für Landwirtschaft, 2003). Soils rich in heavy metals act as a natural buffer controlling the transport of the pollutants to the atmosphere, hydrosphere and biota.

Industrialization, faulty method of waste disposal, faulty agricultural practices, mining of minerals and unscientific drainage of effluents are important anthropogenic pathways causing inorganic chemical pollution in soil (Adriano, 2001). The United Nation Environment Programme (UNEP) calculated that 2 billion hectares of land that was once productive has been irreversibly degraded in the past 100 years due to contamination and inaccessibility (Adejumo, 2010). Sources of heavy metals in soil and their recycling have been depicted in Fig. 1.

Potential of sewage-sludge to cause chemical hazards: Application of sewage and sludge to meet out nutritional and water requirement of crops is quite common practice in urban area especially for cultivation of vegetable crops. It has been reported by Juwarker *et al.* (1991), and Maiti *et al.* (1992) that high concentrations of heavy metals in untreated sewage-sludge cause chemical pollution in soil (Table 1). On the basis of experimental results of Taywade and Prasad (2008) and Kharche *et al* (2011) it was found that continuous supply of sewage water increases pollutant concentration in soils and plants (Table 2 and 3). So, sewage should be applied in field for agriculture purposes only after treatment with suitable amendment. It is pertinent to mention that in some of the cases, inorganic chemicals are not sufficiently high to be toxic to the plants and living organisms but biomagnifications makes the concentration of heavy metal toxic to the living beings.

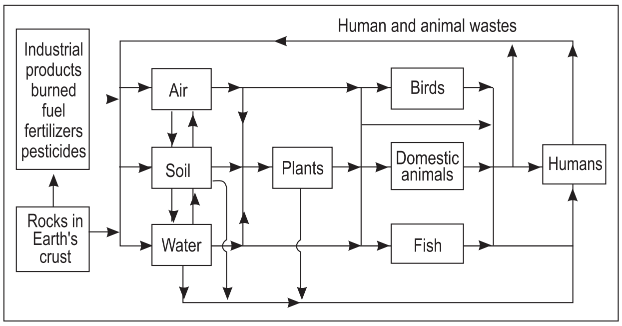

Fig. 1. Sources of heavy metals and their recycling

Effects of inorganic chemical pollution on life

In natural environment, heavy metals has no adverse effect on plant and human life but due to pedogenic and biogeochemical processes and anthropogenic inputs, concentration of heavy metals rises in soils and as a result concentration of heavy metals in crops reaches to toxic level for human health (Kirkham, 1983). Irrespective of their sources, toxic elements present in the soil become a part of food chain (Soil→Plant→Animal Human). Once the elements become part of this cycle, they may accumulate in animal and human body to toxic levels and further become responsible for decreasing immunobiological defenses, intrauterine

Table 1. Regulatory limit and pollutant loading rates of heavy metals in sewage-sludge

Elements	Maximum concentration in sludge USEPA mg/kg	Heavy metals loading rate (mg/kg) in different cities				
		Delhi	Chennai	Nagpur	Ahmedabad	Jaipur
As	75	-	-	-	-	-
Cd	85	5.5	8.3	1.5	3.5	7.3
Cr	3000	53.5	38.5	49.2	60.4	176
Cu	4300	440	210	272	535	265
Hg	57	-	-	-	-	-
Mo	75	-	-	-	-	-
Ni	420	815	60.5	14.8	32.3	37.5
Pb	840	34.5	16.6	24.3	76.8	66.9
Se	100	-	-	-	-	-
Zn	7500	1610	935	832	2141	1720

USPEA = US environmental protection agency (1993)

Table 2. Availabilities of micronutrients and heavy metals of top soil (0-16cm) as affected by sewage irrigation for thirty years in Nagpur and Ahmednagar districts of Maharashtra

Location	Irrigation status	Nutrient content (mg/kg)						
		Fe	Cu	Zn	Mn	Pb	Cr	Cd
Chafegadi (Nagpur)	Non irrigated	9.87	1.97	0.25	12.04	0.13	0.018	0.012
	Sewage irrigated	19.13	2.91	0.11	12.13	0.28	0.042	0.018
Kuhi (Nagpur)	Non irrigated	9.36	2.20	0.14	9.45	0.93	0.018	0.016
	Sewage irrigated	17.05	7.69	0.51	14.16	0.70	0.028	0.012
Asoli (Nagpur)	Non irrigated	2.12	5.99	1.66	4.13	0.78	0.026	0.010
	Sewage irrigated	8.54	8.22	6.11	24.44	2.01	0.030	0.040
Ahmednagar	Well-irrigated	7.37	5.19	2.17	20.1	-	1.04	0.07
	Sewage irrigated	11.47	9.09	3.09	9.04	-	1.29	0.29

Table 3. Mean heavy metal contents in cabbage plants grown on sewage and well- irrigated soils

Heavy metal	Concentration (mg Kg^{-1})		Tolerance level (mg Kg^{-1}) suggested by Melsted (1973) and Naidu *et al.* (1996)
	Sewage irrigated	Well-irrigated	
Fe	821.7 (524-1361)	736.5(702-771)	750
Mn	220.3(186-263)	29.3(28.2-30.5)	300
Zn	124.9(101-159)	72.4(70.2-74.7)	300
Cu	127.3(118-138)	16.6(15.7-17.5)	150
Cd	2.75(2.25-3.25)	0.63(0.50-0.65)	3.0
Cr	2.09(1.62-2.47)	1.65(1.55-1.75)	2.0
Ni	134.7(123-142)	70.5(65-76)	50

Values in parentheses show the range of the concentration recorded

growth retardation, impaired psychological faculties, disabilities associated with mal-nutrition and high prevalence of upper gastrointestinal cancer rates (Ghosh *et al.*, 2011). Serious systemic health hazards can develop as a result of extreme dietary accumulation of heavy metals such as Cr, Cd, Ni and Pb. The nature of the effect can be toxic, neurotoxic, carcinogenic, mutagenic or teratogenic and become apparent only after several years of exposure (Singh, 2011). To greater and lesser degree, all the toxic heavy metals are harmful to humans and animal health but toxicity symptoms of some of the elements become visible after few year of consumption (Moore and Ramamoorthy, 1984). Major sources of toxicants and their ill effects on human health have been presented in Table 4.

Forms of heavy metals in soils

On the basis of experimental results of different workers it has been concluded by Brady and Well (2007) that heavy metals are found in four major forms in our soil system – (1). Soluble or exchangeable forms, which are available to the plants to uptake. (2). Elements bounded by soil organic matter and being released over a period of time. (3). Association of heavy metals with carbonates in soils, and (4). Association of heavy metals in soils with oxides of iron and manganese.

Permissible limits of heavy metals in soil, water and food

Soil and water are primary sources of toxic contaminants for plants, animals and human beings. Concentration of toxicants beyond permissible limit in soil and water will prove phytotoxic (Kabata-Pendias and Padias, 1992). Plants containing heavy metals even within permissible limit may prove fatal for animal and human beings due to bioaccumulation and subsequent biomagnifications of toxicants in food chain (Singh, 2011). Indian standard for heavy metals in soil, food and drinking water and suggested critical concentrations of these toxicants for word soil and irrigation water has been presented in Table 5.

Measures to protect the humanity from heavy metal toxicity hazards

Three primary methods of alleviating toxic inorganic substances from soil, water and air are as under:

(1) Elimination or drastic reduction of the toxins

Table 4. Sources and human health effects of inorganic soil pollutants.

Chemicals	Major uses and sources of soil contaminants	Organisms principally harmed	Human health effects
Arsenic	Pesticides, animal feed additives, coal, petroleum, irrigation water, plant desiccants, detergent	H,A,F,B	Cancer, skin lesions, cumulative poison
Lead	Combustion of oil, gasoline and coal, steel and iron production, solder in water pipes, paint pigment.	H,A,F,B	Brain damage, convulsions
Cadmium	Electroplating, pigments for plastic and paints, plastic stabilizers, batteries and phosphate fertilizers	H,A,F,B, P	Heart and kidney disease, bone embrittlement
Chromium	Stainless steel, chrome plated metals, pigments, leather tanning and refractory brick manufacture	H,A,F,B	Mutagenic
Copper	Fly ash, fertilizers, windblown copper containing dust, water pipes and mine tillage.	F,P	Rare, essential nutrients
Mercury	Pesticides, catalyst for synthetic polymers, metallurgy and thermometers	H,A,F,B	Nerve disease
Nickel	Combustion of coal, gasoline and oil, alloy manufacture, electroplating, batteries and mining.	F,P	Lung cancer
Selenium	High se geological formation and irrigation water containing high content of se	H,A,F,B	Rare, loss of hair and nail, deformities
Zinc	Galvanized iron and steel, alloys, batteries, brass, rubber manufacture, mining and old tires.	F, P	Rare, essential nutrients

H = Human, A = Animals, F = Fish, B = Birds, P = Plants
Source : Brady and Well (2007)

Table 5. Indian standards for heavy metals in soil, food and drinking water and suggested critical concentrations of these toxicants for word soil and irrigation water

Heavy metal	Soil (mg Kg^{-1}) (Dept. of Environmentt, 1989)	Soil (mg Kg^{-1}) (Kabata-Pendias and Padias, 1992)	Soil (mg Kg^{-1}) (Seto and Deangelis, 1978)	Irrigation water (mg L^{-1}) (FAO, 1985)	Indian Standard (Awasthi, 2000)		
					Soil (mg Kg^{-1})	Food (mg Kg^{-1})	Water (mg L^{-1})
Cd	3	3-8	3	0.01	3-6	1.5	0.01
Cr	400	-	-	0.1	-	20	0.05
Cu	200	60-125	100	0.2	135-270	30	0.05
Fe	-	-	-	5.0	-	-	0.03
Ni	110	100	32	0.2	75-150	1.5	-
Pb	-	-	-	-	250-500	2.5	0.10
Zn	450	70-140	216	2.0	300-600	50	5.00
As	-	-	-	-	-	1.1	0.05
Mn	-	1500-3000	1500	0.2	-	-	0.10

in soil, water and air by controlling their entry.

(2) Immobilization of toxins by means of soil management to prevent its' movement into food or water supplies; and

(3) Removal of toxins from soil and water by chemical, physical or biological remediation in the case of severe contamination.

Reducing soil application of the toxins

This method requires action to reduce unintentional aerial contamination from industrial operations and from automobile, truck and bus exhausts. Anthropogenic activities including the indiscriminate dumping of urban and industrial effluents responsible for heavy metal accumulation in soil (Lal *et al.*, 2008) must be stopped or decreased soon. Also, there must be judicious reduction in intended applications of the toxins through chemical pesticides, fertilizers, irrigation water and solid wastes which is possible by popularizing bio-pesticides, bio-fertilizers and treatment of water and wastes by suitable materials. If soil is already affected by the toxicants then polluted soils are typically taken to a landfill, or treated and then taken to a landfill. Inorganic amendments commonly used to correct heavy metal toxicity in soils have been incorporated in Table 6.

Table 6. Mineral amendments used for the reduction of heavy metals

Amendment/Ameliorant immobilized	Metals
Al-Montmorillonite	Cd, Ni, Zn
Clinoptilolite	Cd, Pb, Zn
Di ammonium phosphate	Cd, Pb, Zn
Ferrous sulphate	As, Cr
Hydroxyappetite	Cd, Cu, Ni, Zn
Lime	Cd, Cu, Ni, Zn, Pb
Manganese oxide	Cd, Pb
Water treated sludge	Cd, Cu, Pb, Ni, Zn
Red gypsum (Byproduct of Titanium di oxide pigment manufacturing industry)	As, Cu
Red mud (Byproduct of bauxite refining industry)	Heavy metals
Phosphogypsum (By product of gypsum)	Cu, Pb, Cd
Fly ash (Pulverized)	Heavy metals
Biochar	Al
Organic matter	Cd and other heavy metals

Source: Brunori *et al.* (2005),Glaser et al.(2002), Illera *et al.* (2004), Lombi *et al.* (2004), Puschenreiter *et al.* (2005) and Singh (2011)

Immobilizing the toxins

Soil and crop management can help to reduce the continued cycling of inorganic toxicants. This is done primarily by keeping the chemicals in the soil rather than encouraging their uptake by plants (Brady and Well, 2007). The soil becomes the sink for the toxins, and thereby breaks the soil-plant-animal cycle through which the toxins exert its effect (Dowdy *et al.*, 1994). The soil breaks the cycle by immobilizing the toxins. For example, most of these elements are rendered less mobile and less available if the pH is kept near neutral or above (Elliot *et al.*, 1986). Draining of wet soils will be beneficial, since the oxidized forms of several toxic elements are generally less soluble and less available for plant uptake than the reduced forms. However, the opposite is true for chromium, which occurs principally in two forms Cr^{3+} and Cr^{6+}. Hexavalent chromium forms compound that are mobile under a wide range of pH conditions and are highly toxic to humans. Trivalent chromium on the other hand forms oxides and hydroxides that are quite immobile except in very acid soil (Brady and Well, 2007). Fortunately, active soil organic matter is quite effective at reducing chromium (Lossi and Frankenberger, 1994).

Heavy phosphate applications reduce the availability of some metal cations but may have opposite effect on arsenic (Brady and Well, 2007). Leaching may be effective in removing excess boron, although moving the toxin from soil to water, so bioremediation should be alone to save the human being from B toxicity (Dowdy *et al.*, 1994). Covering of soil with unpolluted soil may be useful to reduce lead uptake by the plants.

Care should be taken in selecting plants to be grown on metal contaminated soil. Generally plants translocate much larger quantities of metals to their leaves than to their fruits or seeds (Dowdy *et al.*, 1994). So, leafy vegetable crops are not grown in this soil.

Remediation Techniques

Remediation refers to removing toxicants from soil, water and air. Physical removal, UV treatment, microbial remediation, phytoremediation and isolation are the most commonly used remediation techniques. Selection of techniques for remediation of heavy metal toxicity depends on nature and type of pollutants.

Ultra-Violet treatment: The UV treatment is most effective to treat liquid solution containing toxicants. Adding a catalyst like hydrogen peroxide can greatly enhance the remediation efficiency of UV treatment (Singh, 2011). The UV treatment is gaining popularity because it can efficiently destroy harmful pathogens and emerging pollutants.

Phytoremediation: Certain plants have been reported to accumulate heavy metals in considerably higher proportions without showing any toxicity symptoms (Beltagi *et al.*, 2002). Plants have been found that accumulate more than 20,000 mg/kg nickel, 40,000 mg/kg zinc and 1000 mg/kg cadmium. These hyper accumulating plants would pose a serious health hazards if consumed by animals or human beings. But, they may facilitate a new kind of bioremediation for metal contaminated soils because the traditional physico-chemical methods to clean up the polluted soils are typically cost-prohibitive and destructive (Patel *et al.*, 2005). Conclusively, it can be stated that a viable and remunerative option could be the cultivation of non-edible crops, which are economically remunerative as well, like cut flower, aromatic and medicinal plants etc. (Lal *et al.*, 2008).

Genetic and bioengineering techniques are being utilized to develop high yielding hyper accumulating plants that can remove larger quantities of heavy metals contaminating from soils. Also, research to insert genes responsible for contaminant accumulation into other higher yielding plants, such as canola and Indian mustard is underway (Brady and Well, 2007).

A combination of chelates and phytoremediation has been used to remove lead from contaminated soil. Treatment of lead and arsenic contaminated water with harmless chelating legends may be useful for making the water usable and harmless.

Microbial remediation: The microbes often use the toxicants as a food source. Microbes are commonly used to treat sewage and oil spills, but can break down a wide range of toxicants (Singh, 2011). Microbes can be added to a polluted soil to speed up the treatment.

Isolation: Often when a contaminant is difficult or extremely expensive to remove or destroy, it is simply isolated from the surrounding environment. This is typically done with clay, concrete, manmade liners or a combination of these. The idea is to create a barrier around the toxicants so that no water can pass through to contaminate the surroundings.

Application of biosurfactants for amending contaminated soils

Biosurfactants can enhance the mobility of heavy metals by reducing the interfacial tension between the metals and soil and by forming micelles. Biosurfactant foam has been found to be very effective to amend metal polluted soils. Column experiments conducted to evaluate the feasibility of rhamnolipid foam to remove heavy metals from a sandy soil contaminated with 1706 ppm cadmium and 2010 ppm nickel showed that flushing with 20-pore-volume of solution of the foam generated by a 0.5% rhamnolipid solution with an initial pH value 10.0 proved to be the most effective. These operations were able to remove 73.2% of Cd and 68.1% of Ni from heavy metal contaminated soil (Mulligan and Wang, 2006).

Nanotechnology application in soil and water contaminant remediation

In recent years, a great deal of attention has been focused on the application of nano-structured materials as adsorbents or catalysts to remove toxic and harmful substances from contaminated soils. Iron nanoparticles are valuable for treatment of ground and surface water contaminated with chlorinated organic compounds such as pesticides, polychlorinated biphenyles (PCBs), organic dyes and many other organic compounds (Agarwal and Joshi, 2010; Li *et al*., 2007).

In situ stabilization of heavy metals by nano particles is quite helpful to reduce ground water contamination, plant uptake and exposure to human and animal beings (Boisson et al., 1999). The use of nano zero valent iron (ZVI), bimetallic nanoparticle and emulsified zero valent nanoparticles forms the whole sole for both soil and ground water remediation (Das, 2011). Recently developed carbon nanotube may prove to be a most effective tool in remediating contaminated waste water (Li *et al.*, 2007). The nano ZVI (Fe^0) and reactive nanoscale iron product (RNIP) get oxidized into +2 and +3 oxidation states thereby reducing other organic as well as inorganic toxicants. Metallic iron (Fe^0) serves as an electron donor

$$Fe^0 \rightarrow Fe^{2+} + 2e \qquad \text{....(1)}$$

Chlorinated hydrocarbons accept the electrons and undergo reductive dechlorination

$$RCl + H^+ + 2e \rightarrow RH + Cl \qquad \text{....(2)}$$

From a thermodynamic perspective, the coupling of the reaction (1) and (2) is often energetically highly favorable

$$RCl + Fe^0 + H^+ \rightarrow RH + Fe^{2+} + Cl \qquad \text{....(3)}$$

The standard reduction potential (E^0) of ZVI (Fe^{2+}/Fe) is -0.44 V, which is lower than many organic compounds like chlorinated hydrocarbons and metals such as Pb, Cd, Ni and Cr. Hence, these metals are prone to reduction by ZVI nanoparticles (Das, 2011).

Development of prediction models for transport of nanoparticles in soil, and their interaction with soil pollutants, as a function of soil properties, nanoparticle properties and toxicant properties would enable soil scientists to design highly effective, low-cost, soil radiation strategies (Montas and Shirmohammadi, 2004). The application of nanotechnology for the remediation of heavy metal toxicity from soil and water holds great promise. The search for new and advanced nanoparticles for amelioration of inorganic chemical contaminants from soil and water is the need of future research.

CONCLUSION

Inorganic chemical contamination in soil and water through anthropogonic and geogenic sources has become a noticeable issue for thinkers, planners, politicians and agricultural scientists because it is a threat to sustainable agricultural development, soil quality, food security and also to ecosystem safety in developed and developing countries. This heavy metal toxicity is causing number of disorders related to human and animal health. A variety of *in situ* and *ex situ* remedial methods is being used to restore soil and animal health. Beside remediation techniques, application of organic and inorganic amendments, biosurfactants and nanoparticles have been found effective to save soils, environment and human heath from hazardous effect of heavy metal toxicity. Scientists and Technologists will have to explore the benefits that humanity can derive from existing and future technologies to reduce inorganic chemical contamination level in soil, water and food for sound human health.

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Identifying edaphic resources and constraints in the sloping uplands of the eastern ghat highland zone of Odisha

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ABSTRACT

The present study was carried out with an objective of exploring the soil related potentials and problems of the sloping uplands of the Eastern Ghat Highland zone of Orissa. Soil analysis was carried out up to 30 cm depth from two land categories differing in the topo-position (hill bottom and upland), at sites having agriculture as major land use. Even though the productivity of these lands are very low with less remunerative and marginal crops like ragi, minor millets and niger commonly grown in these situations, analysis showed these moderately acidic soils to be medium to high in organic matter and available K content. The only primary nutrient found to be deficient was phosphorous, which could be due to high fixation by the Fe and Al –compounds. The available water capacity varied from 10.4 to 13.0 % (w / w) with 17.5 to 24.4 % clay content. Computations of various erodibility indices, viz. dispersion ratio, clay ratio, modified clay ratio and erosion index revealed the soils in both land categories to be moderately to highly erodible. From the study, it was concluded that the production constraints of these lands could be more attributed to land features, particularly relief than soil fertility as such.

Key words: Eastern ghats, erodibility, sloping uplands, soil fertility, soil properties

INTRODUCTION

The Eastern Ghats Highland zone of Odisha is agro-ecologically characterized by a sub-tropical, sub-humid climate with about 1500 mm of annual average rainfall distributed over 75-80 rainy days. Predominantly, red loam to red sandy loam soils are found in the region which can be categorized under the Sub Order *ustalfs* having well drained and moderately acidic characteristics. In spite of the abundant rainfall, the crop productivity is very low in almost all land situations that has intricate linkage with the socio-economy and natural resources degradation status of the region. The region is severely affected by soil erosion (Sikka et al., 2000). This region has a characteristic topo-sequential feature with conspicuous catenary association, comprising of hillocks on the top, sloping lands in the middle and fertile flat lands (widened and terraced gully beds serving as drains to sediment-rich runoff from upper topo-sequences) in the valleys. The catenary association shows well drained coarse textured soils on the mound of the slope to ill drained clay to silty clay soils at the base of the slope, i.e. on the locally called *Jhola* lands (Lenka et al., 2012). Shifting cultivation, locally known as *podu* is the mainstay of agriculture in this tribal dominated rainfed belt of India. The reduction in restoration phase and long cultivation phase has led to the increased soil erosion and land degradation in the upper slopes, resulting in denuded and abandoned lands with outcrops and sparse vegetation. Due to high and intense rainfall (about 1,500 mm year^{-1}) and very sparse vegetation cover, a large amount of runoff is generated on sloping uplands and degraded hillocks, which severely erode the downside cultivated lands (silt production rate 2.07–8.96 ha-m per 100 sq km), and thus, jeopardizing the sustainability of crop productivity and ecological balance (Sudhishri et al., 2008 ; Dass et al., 2009). This indicates that for maintaining productivity and soil quality in all the topo-positions (i.e. uplands, medium and low

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lands), the sloping uplands need to be stabilized and restored with appropriate land use measures.

Corresponding to the catena positions, there are basically four micro-farming situations, viz. hill bottom (locally called as *Dongar*), upland, medium land and low land (*Jhola*) in the region. Highlands (that include both hill bottom and uplands) constitute about 55 per cent of the cultivated land (MANAGE, 2001) and thus form a substantial base for agriculture dependent population of the region. In spite of the large share in cultivated area, contribution of these lands is less to production as compared to that for the medium and low land conditions. Again, mostly marginal crops like ragi (*Eleusine coracana*), upland paddy, niger (*Guizotia abysynnica*) and minor millets like *Suan* (*Panicum miliare*) are grown in these lands with low level of management and input use (Paikaray et al, 2002). Owing to locational disadvantage, not much of research investigation has been made to explore the potential and problems of these lands. The present study, thus, was undertaken to identify the soil related potentials and constraints of these lands to assist in devising of appropriate production augmentation strategies for ensuring sustainable natural resource management along with equity, sustainability and improved socio-economy of the region.

MATERIALS AND METHODS

Study location

The study was taken up in four different watershed sites, viz. Sakriput, Kokriguda, Pungar and Pottangi, representing south-eastern Ghats Highland zone in Koraput district of Odisha. The district is situated between 18^o 10'-20^o 10' N latitude and 82^o 10'- 83^o 20' E longitude. The altitudinal range of the study area varied from 600-1000 m above MSL. The climate and vegetation of the study area is typical to that in high altitude areas and comes under sub-tropical, sub-humid type climate with annual average of maximum and minimum temperature of 30.6 and 17.0 ^{o}C, respectively. Soils of the area is predominantly red lateritic and acidic with pH around 6.0 and taxonomically as per USDA classification, soils of the study area come under *udic paleustalfs*.

Soil sampling

Two topo-positions, viz. hill bottom (locally called *Dongar*) and upland were selected for the study. The *Dongar* lands situated on the mound of the slope or hill bottom are undulated with slope varying from 3-8%. The uplands occupy the next lower position in the catenary sequence with similar undulating features. Soil samples were collected from two different depths (0-15 cm and 15-30 cm) of the two selected topo-positions at sites having agriculture as major land use from the mentioned four villages. The samples were collected by a screw auger from five locations at each sampling site and one composite sample was prepared by mixing the five auger samples. For each watershed village, three composite samples were prepared. The composite samples were air dried under shade and ground, passed through a 2.0 mm sieve for further analysis.

Soil analysis

The processed soil samples were analyzed for soil physical, chemical and physico-chemical properties including the nutrient availability status employing the standard procedures. Using 1:2.5 soil : water suspension, soil pH and electrical conductivity were determined by glass electrode and Conductivity Bridge, respectively (Jackson, 1973).

Soil organic carbon was determined by Walkley and Black's wet-digestion method (Jackson, 1973). Proportion of sand, silt and clay was determined by International pipette method (Baruah and Barthakur, 1999). The available P was estimated by Bray and Kurtz I method and available K by 1 N neutral NH_4OAC extraction using a flame photometer (Jackson, 1973). The field capacity and permanent wilting point were estimated by Pressure Plate Appartus, and the water holding capacity by saturating the soil samples through capillary rise on porous ceramic plates.

Soil erodibility characterization

Soil erodibility was characterized through various erodibility indices, viz. dispersion ratio (Middleton, 1930), clay ratio (Bouyoucos, 1935), modified clay ratio (Bryan, 1967) and erosion index (Sahi et al., 1977), as shown below:

$$\text{Dispersion ratio} = \frac{\text{\% silt+clay in undispersed sample}}{\text{\% silt+clay in dispersed sample}}$$

$$\text{Erosion index} = \frac{\text{Dispersion ratio}}{\text{\% clay / 0.5 water holding capacity}}$$

$$\text{Clay ratio} = \frac{\text{\% sand+silt}}{\text{\% clay}}$$

$$\text{Modified clay ratio} = \frac{\text{\% sand+silt content}}{\text{\% clay + \% organic matter content}}$$

RESULTS AND DISCUSSION

Soil properties

The study found the soil to be moderately acidic with pH varying from 5.74 – 6.74 and very low in soluble salt content, as revealed from very low electrical conductivity values (Table 1), which could be primarily attributed to high rainfall condition and highly porous nature of the soils that causes leaching of substantial amount of bases to the deeper layers. In terms of organic matter content, the soils rated medium to high with up to 1.46% organic carbon at Pottangi, which may be due to its higher altitudinal location as compared to the other three sites. In general, *Dongar* lands were found to be higher in organic matter than the upland soils. However, this is affected by the condition of the overlying hillock, as can be observed in case of Sakriput site with degraded hillocks, where the *Dongar* soils were found to be having 0.56% and 0.47% organic carbon for 0-15 cm and 15-30 cm depths as compared to 1.17% and 0.93% for the same depths in upland condition. The Bray's available P ranged from 4.48 to 26.88 kg/ha, with most of the samples coming under the category of low availability. However, out of the four locations studied, it was in the medium range in case of Kokriguda. The low range of available P is primarily attributed to the high Fe and Al content and low level of soil moisture because of rapid drying of these sloping lands, thus the resultant fixation of phosphorus. Available-K status was found to be medium in case of all the locations studied.

As far as the physical and hydro-physical properties are concerned, soils varied from sandy loam to sandy clay loam in texture with clay content varying from 17.5 to 24.4% (Table 2). Silt content was marginally higher in uplands as compared to that in *Dongar* lands, where as the reverse was true for clay content. Water holding capacity (WHC) of the soils ranged from 32.5 to 36.6% (w/w), with *Dongar* lands having marginally higher WHC than the uplands, which may be due to slightly higher organic matter status and higher clay content in the former than the latter. The field capacity (at 0.2 bar suction) ranged from 17.4 to 21.2% (w/w) and permanent wilting point (PWP) varied from 6.3 to 8.3% (w/w). Soils are well drained with moderately low available water capacity ranging from 10.4 to 13.0% (w/w).

Soil erodibility indices

Computation of erodibility indices reveals the soils to be erodible, with dispersion ratio, clay ratio, modified clay ratio and erosion index values

Table 1. Soil chemical and physico-chemical properties of the sloping lands at the studied locations

Topo-position	Depth (cm)	pH (1:2.5)	EC (1:2.5) (mmhos/cm)	Organic carbon (%)	Avail – P (kg/ha)	Avail - K (kg/ha)
			Sakriput			
Dongar	0-15	6.08	57.8	0.56	7.84	220.4
	15-30	5.74	67.8	0.47	7.90	198.6
Upland	0-15	6.21	54.4	1.17	6.72	213.5
	15-30	5.80	78.5	0.93	8.96	232.7
			Kokriguda			
Dongar	0-15	6.10	71.8	0.82	25.76	195.4
	15-30	6.37	75.4	0.87	15.68	187.9
Upland	0-15	6.59	66.9	0.50	26.88	169.0
	15-30	6.80	68.2	0.57	21.28	220.4
			Pungar			
Dongar	0-15	6.13	69.1	1.22	6.70	172.8
	15-30	6.04	64.1	1.16	5.60	186.4
Upland	0-15	6.33	78.4	0.72	8.96	235.0
	15-30	6.59	122.4	0.49	12.30	257.8
			Pottangi			
Dongar	0-15	6.05	100.4	1.37	6.72	243.4
	15-30	6.57	218.0	1.46	4.48	199.8
Upland	0-15	6.74	94.1	0.87	13.44	302.3
	15-30	6.69	79.6	0.79	6.58	289.6

Table 2. Physical and hydro-physical characteristics of soils under the two land categories

Land situation	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Soil texture	WHC (w / w)	FC (w / w) (-0.2 bar)	PWP (w / w) (-15 bar)	Water Available (w / w)
Sakriput									
Dongar	0-15	57.1	20.5	22.4	Scl	34.2	20.2	7.2	13.0
	15-30	56.3	23.2	20.5	Scl	36.4	18.4	8.0	10.4
Upland	0-15	60.1	22.4	17.5	Sl	32.5	17.6	6.3	11.3
	15-30	58.3	23.2	18.5	Sl	34.4	19.8	6.9	12.9
Kokriguda									
Dongar	0-15	60.4	18.2	21.4	Scl	32.8	19.2	7.3	11.9
	15-30	57.2	18.4	24.4	Scl	36.6	21.2	8.3	12.9
Upland	0-15	58.7	21.4	19.9	Sl	32.2	19.5	7.7	11.8
	15-30	58.8	22.6	18.6	Sl	33.1	17.4	6.6	10.8
Pungar									
Dongar	0-15	62.8	16.3	20.9	Scl	34.2	19.4	7.8	11.6
	15-30	57.2	21.1	21.7	Scl	33.7	20.2	8.2	12.0
Upland	0-15	54.8	21.8	23.4	Scl	31.8	18.5	8.4	10.1
	15-30	57.6	22.0	20.4	Scl	32.4	21.4	7.2	14.2
Pottangi									
Dongar	0-15	55.8	24.0	20.2	Scl	35.2	21.4	8.2	13.2
	15-30	58.4	22.9	18.7	Sl	33.4	20.7	7.5	13.2
Upland	0-15	60.4	18.1	21.5	Scl	32.7	22.4	8.5	13.9
	15-30	54.5	23.4	22.1	Scl	33.5	19.7	7.6	12.1

Scl : Sandy clay loam Sl : Sandy loam FC: Field Capacity PWP : Permanent Wilting Point

Table 3. Soil erodibility indices of the sloping uplands (up to 30 cm depth) at two locations

Topo-position	Depth	Dispersion ratio	Clay ratio	Modified clay ratio	Erosion index
Sakriput					
Dongar	0-15	32.7	3.4	3.3	28.1
	15-30	24.0	3.8	3.7	23.1
Upland	0-15	30.0	4.7	4.2	27.9
	15-30	23.7	4.4	4.0	20.4
Kokriguda					
Dongar	0-15	26.4	3.6	3.4	20.2
	15-30	26.8	3.0	2.9	20.1
Upland	0-15	28.2	4.0	3.8	22.8
	15-30	30.9	4.3	4.1	27.4
Pungar					
Dongar	0-15	30.4	3.8	3.4	24.8
	15-30	31.4	3.6	3.3	24.4
Upland	0-15	28.6	3.3	3.1	19.4
	15-30	27.5	3.9	3.7	21.8
Pottangi					
Dongar	0-15	32.2	3.9	3.5	28.0
	15-30	30.7	4.4	3.8	27.4
Upland	0-15	31.4	3.6	3.4	23.8
	15-30	31.0	3.5	3.3	23.4

coming well above the threshold limits of erodibility. Dispersion ratio, clay ratio, modified clay ratio and erosion index varied from 23.7 to 32.7, 3.4 to 4.7, 2.9 to 4.2 and 19.4 to 28.1, respectively for both soil depths and land categories (Table 3). The soils were categorized to be erodible as per the criteria of Middleton (1930) in terms of dispersion ratio (i.e. soils with dispersion ratio above 15 are classified as erodible and below 15 as non-erodible). Further using the scheme of classification adopted by Singh *et al.* (2002-03) to categorize the erodibility intensity, it was found that values of dispersion ratio of these soils correspond to moderately high erodibility, clay ratio to very high and erosion index to moderate to high erodibility condition. The moderate to high erodibility in these soils can be subscribed to the weak soil structure and poor aggregation in such lands (in spite of the medium to high organic matter status), where the slope factor results in substantial runoff that causes washing of the cementing material as well as prevents effective cementation and aggregation. This may be possible that due to recurrent erosion process, the cementing agents do not get sufficient time for stabilizing soil aggregates. The soil mechanical composition and the land use management (expressed through soil organic matter content) largely decide the erodibility characteristics, as revealed from other studies (Gupta et al., 2010).

CONCLUSION

It can thus be concluded that the major production constraints of these lands are more determined by land features, particularly the slope and topographic condition rather than soil characteristics as such. From the soil characteristics point of view, these lands are not that poor as commonly believed on the basis of their low productivity level. The soils are medium to high in organic matter and available K status while poor soil structure and low available P are the two major constraints of these soils. In spite of medium to high organic matter content, soils of these lands remain highly erdoible that indicate factors associated with poor soil structure and low level of aggregation than organic matter as such. Organic matter content has a definite role for reducing erodibility and increasing available water capacity of these lands but more crucial will be allowing the soil organic matter to help in building favorable soil structure and increased aggregation. In this context, certain conservation measures as appropriate to the local climate and the adaptability by the farming community, is to be recommended. In view of the above, the production improvement technology for these lands can take into account three basic strategies, viz. enhancing P- availability through bio-fertilizers, soil structure improvement through agronomic practices including tillage alteration and measures to increase the water retention through reduction of slope by technologies involving runoff barriers. There is a definite need for detailed studies related to soil structure and aggregation of these soils.

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Effect of drip and surface irrigation with plastic mulching on growth, yield, WUE and economics of growing brinjal in coastal Odisha

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ABSTRACT

A field experiment was conducted on the loamy sand soil in coastal Odisha during the *rabi* season for two years (2006-2008) to evaluate the growth, yield and economic feasibility of drip irrigation with black plastic mulch (LLDPE) in brinjal crop. Actual evapotranspiration for brinjal crop was estimated using modified Pan Evaporation data. The net irrigation volume (V) was determined after deducting the effective rainfall. The water requirement of crop was estimated to be 330 mm. Effect of three irrigation levels viz. VD, 0.8 VD and 0.6 VD (VD = full irrigation volume with drip) in conjunction with LLDPE mulch and no mulch were studied on biometric and yield response of brinjal crop. The results of surface irrigation were compared with those of drip irrigation under no mulch and in conjunction with LLDPE mulch. The study revealed that, better plant growth, more number of fruits per plant and higher yield was recorded in drip irrigation system with plastic mulch. The highest yield (34.8 t/ha) was recorded under 100 % net irrigation volume with drip irrigation (VD) and plastic mulching as compared to other treatments. This system increased the yield and net seasonal income by 65 % and 83 % respectively, as compared to conventional surface irrigation with a benefit cost ratio of 1.86. The benefit cost ratio was the highest (2.18) for full irrigation volume with drip (VD) without mulch. Only drip irrigation could increase the yield by 36 % in absence of mulch. Similarly, only plastic mulch could increase the yield by 19 % in surface irrigation system.

Key words: Brinjal; drip irrigation; economics; mulch; water requirement; water use efficiency; Yield

INTRODUCTION

Presently in India 7.49 million ha area is cultivated with vegetable with an annual production of 116.03 million tonnes. It is estimated that, by 2020 AD the vegetable demand of the country would be around 135 million tones. To achieve this target, our attention must be focused on the vertical expansion (tier cultivation e.g. cultivation under greenhouse) with more production per unit area, strengthened with the boon of the technology instead of horizontal expansion just by increasing the crop area (Rai and Pandey, 2008). The working group on horticulture constituted by the Planning Commission had recommended deployment of hi-tech horticulture and precision farming for achieving vertical growth in horticulture. Hi-tech interventions in horticultural crops proposed by National Committee on Plasticulture Applications in Horticulture (NCPAH), Govt. of India are drip irrigation and *in-situ* moisture conservation through plastic mulching (Samuel and Singh, 2004). Drip irrigation has created interest among farmers because of less water requirement, possible increased production and better quality produce. Economic evaluation of drip irrigation in fruit crops (coconut, mango and sapota) in Odisha revealed that this system conserves considerable amount of water and results better returns despite higher initial investment (Behera and Sahoo, 1998). The response of banana to drip irrigation in terms of yield improvement was found to be different in different agro-climatic and soil conditions in India (Tiwari *et al*, 1998b; Shrivastava *et al*, 1999;

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Bharambe *et al* 2001; Pattanaik *et al*, 2003; Agrawal and Agrawal, 2005). Response of vegetable to drip irrigation in terms of increase in yield was also different in different agro-climatic and soil conditions in India (Okra: Tiwari *et al*, 1998a; Horo *et al*, 2003; Vankar and Shinde, 2007; Mishra *et al.*, 2009); (tomato: Shrivastava *et al*, 1994; Singh, 2007). Use of soil cover and mulching is also known to be beneficial chiefly through their influence on soil moisture conservation, solarization and control of weeds. Beneficial response of plants to mulch includes early production, more yield and reduced insect and disease problems (Tiwari *et al.*, 1998a; Pattanaik *et al.*, 2003; Barua and Phookan, 2009). Linear Low Density Poly Ethylene (LLDPE) plastic films has been proved better mulch because of its puncture resistance quality, thinness and lower cost (Panda, 2004).

Brinjal (*Solanum melongena* L) is a popular vegetable crop grown in the sub-tropics and tropics. This plant is said to be the native of India, where more than sixteen species closely related to brinjal are found to grow in wild in various parts of the country. With properties of anti rheumatism, it also lowers cholesterol, combats constipation, diuretic, relieves colic and reduces stomach ulcers. Brinjal works as sedative, calmative and stimulant for the liver and intestine (Anonymous, 2006). The average national productivity of brinjal is around 16.5 tons/ha, while the average productivity in Karnataka and Andhra Pradesh is 22.1 tons/ha and 21.0 tons/ha respectively. In Odisha, the brinjal production in 2005-06 is 1853.9 tonnes from an area of 127900 ha with a productivity of 14.5 tons/ha (Anonymous, 2007). Keeping the above facts in view, the present study was undertaken to study the effect of drip irrigation system and plastic mulch on brinjal crop in coastal Odisha.

MATERIALS AND METHODS

A field experiment was conducted at Precision Farming Development Centre experimental site located at O.U.A.T., Bhubaneswar. The soil of experimental site was loamy sand and acidic having p^H of 5.8. The seed of brinjal variety Anushree was sown on 1st week of October during the year 2006 and 2007 and 25 days old seedlings were transplanted with a spacing of 75 cm x 60 cm. The experiment was laid out in randomized block design having eight treatments and replicated thrice with a plot size of 6 m x 3 m. Each treatment was spaced 0.5 m apart to avoid overlapping of treatments. The treatments were;

T_1 = 100% irrigation requirement (IR) through drip irrigation (VD);
T_2 = 80% IR through drip irrigation (0.8VD);
T_3 = 60% IR through drip irrigation (0.6VD);
T_4 = 100% IR by surface irrigation (V);
T_5 = 100% IR through drip irrigation with black LLDPE mulch (VD+M);
T_6 = 80% IR through drip irrigation with black LLDPE mulch (0.8VD+M);
T_7 = 60% IR through drip irrigation with black LLDPE mulch (0.6VD+M)
and T_8 = 100% IR by surface irrigation with black LLDPE mulch (V+M)

The cultural practices of the crop were followed as per the recommendations by Indian Council of Agricultural Research, New Delhi (Thamburaj and Singh, 2003). The LLDPE film of 50-micron thickness was used for mulching around the plant. The lateral lines of 12 mm diameter LLDPE pipes were laid along the crop rows and each lateral served one row of crop. The laterals were provided with on line turbokey dripper of 4 lit/hr discharge capacity. LLDPE pipes of 75 mm diameter were used for main and 63 mm diameter was used for sub-main. The main line was directly connected to a 1.5 hp pump installed to lift water from an open sump. The manifold unit was connected with a screen filter, a pressure gauge and control valve. The duration of delivery of water to each treatment was controlled with the help of gate valves provided at the inlet end of each lateral. In case of surface irrigation, irrigation was scheduled at weekly interval.

Estimation of irrigation water requirement

The water requirement of the crop was computed on daily basis by using the following equation as suggested by Shukla *et al.* (2001).

$V = E_p.K_p.K_c.S_p.S_r.W_p$

Where,

V = Volume of water required (litre / day / plant)

E_p = Pan evaporation as measured by Class-A pan evaporimeter (mm / day)

K_c = Crop co-efficient (co-efficient depends on crop growth stage)

K_p = Pan co-efficient

S_p = Plant to plant spacing (m)

S_r = Row to row spacing (m)

W_p = Fractional wetted area, this varies with different growth stage (0.3 to 1.0)

The water requirement of brinjal crop was estimated on daily basis for all months of a particular year by drip method. Daily operating time for drip irrigation system was worked out taking the application rate per plant. Drip system was scheduled to operate on alternate days; hence total quantity of water delivered was cumulative water requirement of two days.

Observations on water requirement, growth character and yield of brinjal were recorded and analyzed statistically following the standard procedures (Panse and Sukhatme, 1985). The water use efficiency (WUE) of the crop was determined by dividing the yield with water requirement of the crop.

Benefit-cost analysis

Benefit-Cost ratio and net profit were carried out to determine the economic feasibility of the crop using surface and drip irrigation as suggested by Tiwari *et al.* (1998a). The seasonal system cost of drip irrigation system included depreciation, prevailing bank interest rate, and repair and maintenance cost of the system. The fixed cost of drip irrigation system was determined to be Rs 110000/ha. The useful life of drip system was considered to be 10 years. The system cost was evaluated by distributing the fixed cost of system over life period of drip irrigation set. For calculating depreciation, the life of the drip irrigation set and 10 % junk value was considered. The interest was calculated on the average of investment of the drip irrigation set taking into consideration the value of the set in the first and last year @ 10 % per annum. Cost of repairs and maintenance of set is @ 2 % of initial cost of the drip irrigation set per year. The cost of cultivation includes expenses incurred in land preparation, interculture operation, fertilizer, crop protection measures, irrigation water and harvesting with labour charges. Therefore, total seasonal cost was worked as: depreciation, interest, repairs and maintenance cost of set + cost of cultivation + cost of mulch. The income from produce was calculated using prevailing average market price of brinjal @ Rs 8000 per tonne.

RESULTS AND DISCUSSION

Growth and yield attributes

Two years pooled data of biometric parameters like plant height, number of branches per plant, number of leaves and average yield attributing characters such as days taken to first harvest, weight of root, weight of shoot, no. of fruits per plant and the yield of brinjal and are presented in Table 1. The results revealed that, these characters and yield responded significantly superior to different levels of irrigation and mulching in the treatment T_5 as compared rest of the treatments. The treatment T_5 recorded 102 %, 246 %, 14.3 % and 50.3 % wt. of root, wt. of shoot, no. of days taken to first harvest and no. of fruits per plant respectively than control (T_4). The height of plant under treatment T_5 (100% irrigation requirement through drip irrigation with LLDPE mulch) was recorded highest (105.6 cm), which is 28.5 % higher than the height of plant under surface irrigation without mulch (T_4). As regards to no. of branches per plant, maximum value was recorded in T_5 (28.5) followed by T_6 (27.1) and lowest value in T_4 (20.1). Similarly, highest no. of leaves was observed in case of T_5 (196.2) as compared to lowest leaves of 152.5 in treatment T_4. The highest increase in vegetative growth in treatment T_5 might be due to availability of soil moisture as well as temperature at optimum level as compared to the lowest value in treatment T_4 (Tiwari *et al*, 1998a; Tiwari *et al*, 1998b; Pattanaik *et al.*, 2003). It results into unfavourable moisture regime (moisture stress or excess moisture) in the soil through surface

Table 1. Growth, yield and water use efficiency of brinjal as influenced by different treatments

Treatments	Plant height, cm	No. of branches/plant	No. of leaves	Days taken to first harvest	No. of fruits/plant	Wt. of root, gm	Wt. of shoot, gm	Yield t/ha	Water requirement, mm	Water use efficiency, kg/ha-mm
T_1	95.7	23.4	176.4	71.2	39.4	32.3	120.1	28.7	330	86.9
T_2	92.6	22.3	171.7	72.8	37.8	30.8	110.2	27.9	264	105.7
T_3	88.8	21.7	164.8	77.2	35.7	28.4	86.9	25.4	198	128.3
T_4	82.2	20.1	152.5	75.6	30.2	22.5	52.4	21.1	330	63.9
T_5	105.6	28.5	196.2	64.8	45.4	45.6	181.5	34.8	330	105.5
T_6	103.4	27.1	194.4	67.4	43.2	41.5	167.3	32.2	264	121.9
T_7	97.9	25.3	184.2	69.8	40.5	35.4	137.5	29.1	198	146.9
T_8	87.2	21.3	162.8	76.6	34.7	28.1	85.8	25.1	330	76.1
SE (m)	0.955	0.698	1.246	0.771	0.490	0.886	1.372	0.426	-	-
CD (0.05)	2.898	2.117	3.779	2.340	1.486	2.687	4.162	1.293	-	-

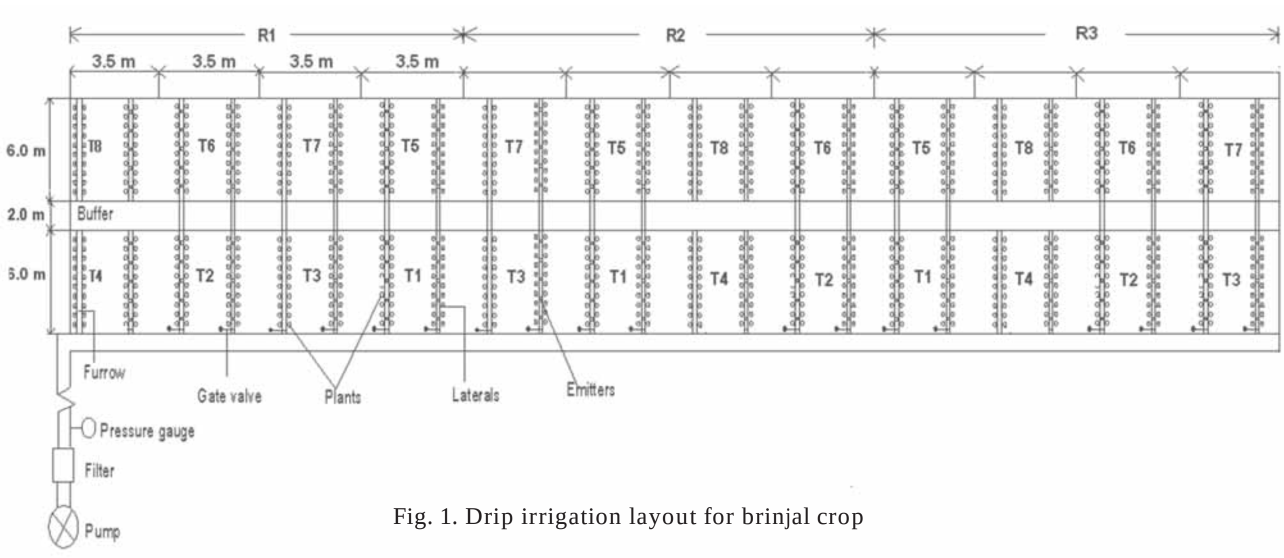

Fig. 1. Drip irrigation layout for brinjal crop

irrigation and competition of weeds for nutrients (Pattanaik *et al*., 2003; Agrawal and Agrawal, 2005). The increased growth attributes might have adequate quantity of water and nutrients, which resulted in triggering the production of plant growth hormone, viz. indole acetic acid (IAA) and higher number of leaves throughout the cropping period (Sankar *et al*., 2008). All the yield attributing characters are significantly higher in treatment T_5 than other treatments. Mulch has significant effect on yield attributing characters than non-mulch treatments.

Crop yield

The drip irrigation in combination with mulch significantly increased the yield of brinjal as compared to drip irrigation without mulch (Table 1). Among the various treatments the highest yield (34.8 t/ha) was recorded under treatment T_5, which increased by 65 % over surface irrigation. Drip irrigation with LLDPE mulch treatments (T_5, T_6 & T_7) increased the percentage in yield by 21 %, 15 % and 14 % respectively as compared to drip irrigation without mulch treatments (T_1, T_2 & T_3). The low yield was recorded under surface irrigation method. This might be due to water stress during critical growth period, coupled with aeration problem in first few days immediately after irrigation. Again, due to heavy application of irrigation water the availability of nutrients for crop growth was less due to leaching and also due to heavy weed infestation between the crops (Pattanaik *et al*., 2003). This result corroborated the findings of Tiwari *et al.* (1998a); Tiwari *et al.* (1998b) and Singh (2007). In drip irrigation system, water is applied at a low rate for a longer period at frequent intervals near the plant root zone through lower pressure delivery system. It increased the availability of nutrients near the root zone with a reduction in leaching losses. More nutrient availability, especially near the root zone might have increased the translocation of photosynthetes to storage organ of brinjal resulting in an increased weight of brinjal (Sankar *et al*., 2008). Based on the results, drip irrigation treatments (T_1, T_2 and T_3) increased yield by 36 %, 32 % and 20 % higher respectively as compared to surface irrigation (T_4). Thus, it revealed that, the 20 % higher yield of brinjal was attained with 40% less quantity of water through drip irrigation as compared to surface irrigation. This result is in close agreement with the findings of Tiwari *et al.* (1998a). The beneficial effect of yield characters advantage *vis-à-vis* better water-use-efficiency through drip irrigation is attributed to the continuous supply of water in required quantity at right time without flooding to cause hypoxia. Therefore, the roots remain well aerated (Sankar *et al*., 2008). Mulch alone in surface irrigation method (T_8) could increase yield upto 19 % than without mulch treatment (T_4). The beneficial effect of black LLDPE mulch in tomato and okra was also reported earlier by Shrivastava *et al.* (1994); Tiwari *et al.* (1998a); Tiwari *et al.* (1998b); Horo *et al.* (2003); Singh (2007); Vankar and Shinde (2007).

The water requirement for 100 % net irrigation volume under drip irrigation system for tomato was 330 mm. The highest yield was obtained under treatment T_5 with the same quantity of water requirement (330 mm). Thus it can be concluded that drip irrigation gave highest yield with the same quantity of 330 mm of water as compared to surface irrigation and drip irrigation system with LLDPE plastic mulch increased yield by 65 % over surface irrigation with same quantity of irrigation water. Similar results have been obtained by Singh (2007) for tomato crop at South Dinajpur district of West Bengal.

Water use efficiency

Water use efficiency (yield per mm of water used) decreased with increase in irrigation levels i.e. 0.6 VD, 0.8 VD and VD for all the treatments of drip irrigation system. There was significant effect of LLDPE mulch over drip irrigation system alone. The increase in water use efficiency for drip irrigation system alone (T_1) and drip irrigation system with LLDPE mulch (T_5) over conventional surface irrigation (T_4) was 35 % and 65 % respectively. Similar trend has been reported in B.C. ratio, net profit per mm of water used and yield per mm of water used for okra by Tiwari *et al.* (1998a); for tomato crop by Tiwari *et al.* (1998b) and Singh (2007).

Economic feasibility

Maximum net returns of Rs 181100/ha with B: C ratio of 1.86 was recorded in treatment T_5 and the lowest net return of Rs 105900/ha with a B: C ratio of 1.12 in treatment T_8 (Table 2). It is observed that the mulched treatments (T_5 and T_6) gave better net return per ha than their corresponding treatments without mulching. But higher ratios were recorded in treatments without mulch than their corresponding treatments of LLDPE mulch. The B: C ratio was highest (2.18) in conventional irrigation method (T_1) due to comparatively lower system cost and no mulch was used. However, the net seasonal income in drip irrigated treatments with mulch was observed to be maximum (Rs 181100) in treatment T_5 followed by T_6 (Rs 160300), T_1 (Rs 157300) and T_2 (150900). Similar trend in B.C. ratio under drip irrigation and plastic mulching experiments has been reported by Tiwari *et al.* (1998a) for okra crop; Tiwari *et al.* (1998b) and Singh (2007) for tomato crop. Maximum net profit per mm of water used (684.3) and yield per mm of water used (146.9) was recorded in treatment T_7 respectively, where the water used was also lowest of value 198 mm. The highest net return of Rs 157300 / ha was obtained in treatment consisting of drip without mulch (T_1), which is Rs 58400 / ha (58 %) higher than control (T_4), proving the beneficial effect of drip irrigation system.

CONCLUSION

The drip irrigation is observed to be economical and cost effective when compared with conventional surface irrigation. The use of drip either alone or in combination with mulching can increase the brinjal yield up to an extent of 65 % over surface irrigation. It was also observed that,

Table 2. Economic analysis of various treatments for brinjal

Cost Economics	Treatments							
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Fixed cost, Rs/ha	110000	110000	110000	-	110000	110000	110000	-
Seasonal system cost, Rs/ha								
a. Depreciation	9900	9900	9900	-	9900	9900	9900	-
b. Interest	5500	5500	5500	-	5500	5500	5500	-
c. Repair & maintenance	2200	2200	2200	-	2200	2200	2200	-
d. Total	17600	17600	17600	-	17600	17600	17600	-
Seasonal cost of cultivation, Rs/ha	54700	54700	54700	69900	54700	54700	54700	69900
Cost of mulch, Rs/ha	-	-	-	-	25000	25000	25000	25000
Seasonal total cost (2d+3+4), Rs/ha	72300	72300	72300	69900	97300	97300	97300	94900
Water used, mm	330	264	198	330	330	264	198	330
Yield of produce, t/ha	28.7	27.9	25.4	21.1	34.8	32.2	29.1	25.1
Income from produce, Rs/ha	229600	223200	203200	168800	278400	257600	232800	200800
Net profit (8-5), Rs/ha	157300	150900	130900	98900	181100	160300	135500	105900
Benefit cost ratio (9/5)	2.18	2.09	1.81	1.41	1.86	1.65	1.39	1.12
Net profit per hectare per mm of water used (9/6), Rs/mm/ha	476.7	571.6	661.1	299.7	548.8	607.2	684.3	320.9

330 mm of water would be required to irrigate one hectare of brinjal crop with the drip system in the sub-humid agro-climatic conditions of Bhubaneswar. In the absence of drip, even mulch alone could increase the yield by 19 %. Similarly, drip alone could increase the yield by 36 % without mulch. The net income could be increased by 83 % over the normal surface method by adopting drip with mulch alongwith 65 % increase in yield.

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Water and energy use pattern by different irrigation systems in wheat under partially reclaimed sodic soils

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ABSTRACT

A field study has been undertaken to evaluate the performance of sprinkling irrigation (LEWA and Sprinkler) systems over surface method with varying irrigation schedules based on IW / CPE ratios. Three different water application methods namely Surface, Sprinkler, and LEWA (Low Energy Water Application) were opted. Depth of irrigation applied through Surface method of irrigation was 6 cm for three different irrigation schedules based on IW / CPE ratio 1.0, 0.8, and 0.6, whereas, in case of Sprinkler and LEWA methods, the depth of irrigation opted was 4 cm and irrigation schedules were same based on IW / CPE ratio of 1.0, 0.8 and 0.6. This paper presents the comparative field performance of three irrigation methods namely Surface, Sprinkler, and LEWA in context to water and energy uses while irrigating wheat crop under sodic environment. All three irrigation methods operated at three different irrigation schedules based on IW / CPE ratio of 1.0, 0.8, and 0.6. The results indicates, that, Surface method performs better when scheduled at IW / CPE ratio of 1.0, whereas, LEWA and Sprinkler at IW / CPE ratio of 0.8. Comparing the benefits of best performing irrigation schedules it is, observed that LEWA and Sprinkler when scheduled at IW / CPE ratio of 0.8 results in water saving of 33% of applied irrigation depth over Surface method scheduled at IW / CPE ratio of 1.0. The energy uses amongst the better performing irrigation schedules results, 33% saving of energy by LEWA and 6% by Sprinkler when scheduled at IW / CPE ratio of 0.8 over Surface method scheduled at IW / CPE ratio of 1.0.

Key words: Irrigation management, irrigation schedule, sodic soils, water productivity, energy productivity

INTRODUCTION

India posses' approximately 6.73 mha salt affected land. Out of which about 3.77 mha are alkali or sodic soils. Over 2.1 million hectares of salt-affected land is located in the country's key bread basket in the North. Uttar Pradesh alone has about 1.37 million hectares of sodic and saline soils, besides, Rajasthan 3.75 lakh hectares, Haryana 2.32 lakh hectares and Punjab 1.5 lakh hectares of land affected by salt accumulation (Sharma *et al.* 2004). Alkali or sodic soils in Indo-gangetic plains are generally light to medium textured, sandy loam in the surface and clay loam in lower depths with CaCO3 concentration at 0.5 – 1.0 m depth. The major characteristics of sodic soils are that they have a relatively low EC, but a high amount of Na^+ occupying exchange sites, often resulting in the soil having a pH at or above 8.5. Other symptoms of sodic soils include less available water, poor tilth and sometimes a black crust on the surface formed from dispersed organic matter. Thakur *et al.* 2013, also highlights that soil texture, soil structure, and slope have the largest impact on infiltration rate. These conditions tend to inhibit seedling emergence and hinder plant growth. These characteristics of sodic soils also create unfavorable condition for root penetration.

Based on the above, following points of relevance to irrigation needs of crops grown in sodic soils is reported: (Abrol *et al.* 1988)

(a) Capacity of these soils to absorb water is restricted by poor infiltration characteristics,

(b) Available water storage capacity of sodic soils is relatively low because of lower soil moisture retention at higher suction values and higher retention at lower suction values. The effective

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capacity of soils to supply water is further reduced because of the poor hydraulic conductivity of sodic soils, seriously limiting water movement from lower soil to meet the evapo-transpirational needs. It results into the exhaustion of available water supply soon and requires the replenishment of water at shorter intervals.

(c) Unfavorable soil conditions (high pH and high levels of exchangeable sodium) in subsoil layers in sodic or partially reclaimed sodic soils restrict root penetration of crops to lower soil layers. Consequently, the roots remain generally confined to the upper few centimeters depending upon the degree of soil improvement. Thus, the depth of soil available for moisture extraction following irrigation is restricted further because of surface confinement of crops roots.

Different methods are in vogue to schedule irrigation and to decide what will be the depth to be applied in rice wheat systems (Parihar *et al.*, 1974), (Parihar *et al.*, 1976), and (Parihar *et al.*, 1978a). (Parihar *et al.*, 1978b) concluded that wheat should be irrigated at around 60% and 70% depletion of plant available soil water storage to avoid yield loss, with the lower value for the lighter soil, compared with a deficit of 50% determined by (Singh and Malik 1983) on a sandy loam in Haryana. The recommended practice involves one irrigation prior to soil preparation, an irrigation (70 mm) at the crown (nodal) root initiation stage, 3-4 weeks after sowing, then a 70 mm irrigation whenever cumulative pan evaporation minus rain reaches 93 mm (an "IW/Pan" ratio of 0.75), with the last irrigation no later than mid-March for crops "sown on time". This method saved up to 160 mm of irrigation water compared with applying 70 mm at each of 5 key stages. (Narang and Gulati 1995) suggested that there was scope to reduce wheat irrigations further by publicizing data from evaporation and rainfall and training farmers to keep their own evaporation-rain budgets. (Sharma D. K. 1994) reported optimum schedule of irrigation for wheat and its response to irrigation based on ratio of irrigation water and cumulative pan evaporation (IW/CPE). It was reported that maximum water use efficiency observed when irrigation was scheduled at 1.0 IW/CPE ratio. Besides smart scheduling, method of irrigation also plays an important role in water use efficiency. Pressurized irrigation systems (sprinkler, surface and subsurface drip) are known to have the potential to increase irrigation water use efficiency by providing water to match crop requirements, reducing runoff and deep drainage losses, and generally keeping the soil drier reducing soil evaporation and increasing the capacity to capture rainfall (Camp, 1998). There are few reports of the evaluation of these technologies in RW systems. Little is known about how to manage potentially more efficient but highly expensive irrigation systems to achieve high yields and save water for RW systems. (Sezen and Yazar, 2006) reported use of sprinklers at 7-day interval with highest irrigation level resulted in higher wheat yield (50%-93%). They also mentioned decrease in yield level with decreasing level of irrigation. (Al-Ghobari and EI Marazky, 2013 and 2014), reports improvement in WUE (water use efficiency) and IWUE (irrigation water use efficiency) of sprinkler system when irrigation scheduled at 80% of Etc through smart irrigation system. (Chourushi Shibani and Patel Kanan, 2013) reports water saving to tune of 26.2%, 38.1% and 50% when sprinkler irrigation system is scheduled at IW/CPE ratio of 1.0, 0.8 and 0.6 respectively over surface method. It was also observed in their study that there is additional yield benefit in case of sprinkler irrigation when scheduled at IW/CPE ratio of 1.0 and 0.8 but reflected yield loss at IW/CPE ratio of 0.6 in comparison to surface. This finding reflects that use of pressurized irrigation (sprinkler, drip and micro sprinkler etc.) may further facilitate in enhancing water use efficiency and minimizing expenditure on energy used for pumping. Secondly, applying low depth of irrigation by adopting surface technique is difficult and cumbersome process with respect to sprinkler irrigation systems and others.

Keeping this in view a field study has been undertaken to evaluate the performance of sprinkling irrigation (LEWA and Sprinkler) systems over surface method with varying irrigation schedules based on IW/CPE ratios of 1.0, 0.8 and 0.6 under partially reclaimed sodic soils at Shivri farm of CSSRI-RRS, Lucknow. The paper presents the findings of the study focusing water and energy saving while practicing irrigation in winter wheat under sodic environment.

METHODOLOGY

The experiment was conducted at Shivri farm of CSSRI-RRS, Lucknow. The sodicity status of the experimental plot shows that pH of soil at depth of 0-15 cm and 15-30 cm was 8.71 and 9.23 respectively. The corresponding EC_2 measured 0.33 and 0.48, Organic Carbon (%) 0.25 and 0.16 and ESP 16.1 and 30.9. This shows that soil is moderately sodic. The av. rainfall trend shows total rainfall received during wheat growing period was 104.21 mm. The av. maximum one day rainfall was 37.11 mm. Total av. evaporation recorded during the wheat growing period was 293.41 mm. Three modes of irrigation were adopted namely Surface, Double Nozzle Impact Sprinkler (commercially available), and LEWA (Low Energy Water Application device developed by ICAR-RCER, Patna) (Singh S. R. *et al.*, 2004: Singh A. K. *et al.*, 2008 and Singh A. K. *et al.*, 2010). The rate of water application depth of Sprinkler (double nozzle impact sprinkler) was 2 cm / hr and of LEWA 2.8 cm / hr, whereas in case of Surface method water supply from the pump was fed directly to field. The depth of water applied was 6 cm for surface method and 4 cm for sprinkler and LEWA. The irrigation was scheduled based on the IW / CPE ratio of 0.6, 0.8 and 1.0. Irrigation time at each event measured to obtain the total volume of water applied. Overall, a total of nine treatments were imposed in four replications. A 8 hp high speed diesel pump was used as source having discharge in the range of 3 lps-5 lps with fuel consumption rate of 1 lt per hour. To impose the planned irrigation schedule daily rainfall and evaporation data were recorded. Periodic monitoring of soil moisture, soil properties, and plant growth parameter etc. has been undertaken. The irrigated plot size in case of surface was of 8.6 m x 40 m and 12 m x 40 m incase of Sprinkler and LEWA. The representative area considered for recording plant observations incase of Sprinkler and LEWA was within 6 m x 40 m falling between two lines of Sprinkler and LEWA nozzles. The cost of fuel (diesel) per litre considered in analysis was Rs. 55 and cost of Rice and Wheat produce as Rs. 1000 per quintal. The water productivity (Rs. / m^3) and energy productivity (Rs. / per unit cost of diesel) have been calculated by considering the cost of total yield, water used through irrigation and cost on diesel incurred to pump the prime mover for practicing irrigation.

RESULTS AND DISCUSSION

Irrigation events

In surface method, two irrigation at IW / CPE ratio of 1.0 and 0.8 and one irrigation at IW / CPE ratio of 0.6 was applied. Whereas, in case of Sprinkler and LEWA three nos. of irrigation at IW / CPE 1.0, two nos. of irrigation at IW / CPE ratio of 0.8 and one nos. of irrigation at IW / CPE ratio of 0.6 was applied.

Effect of irrigation regime on plant growth and yield

The effect of various irrigation schedules on plant growth and yield were observed and discussed further in the section. Fig. 1 depicts plant height observation of wheat recorded at one-month interval. It is observed height of plant under various irrigation regimes varied between 14.5 cm to 19.6 cm after 30 days, 30.2 cm to 47.8 cm after 60 days, 62.5 cm to 77.1 cm after 90 days, and 66.7 cm to 78.7 cm at the time of harvesting. This variation reflects that, by the time of harvesting the plant height for most of the LEWA and sprinkler irrigation irrigated plots were higher in comparison to height observed in case of surface irrigated plots. In addition, the higher plant height was observed at higher IW / CPE ratio, which reduces at lower IW / CPE ratios.

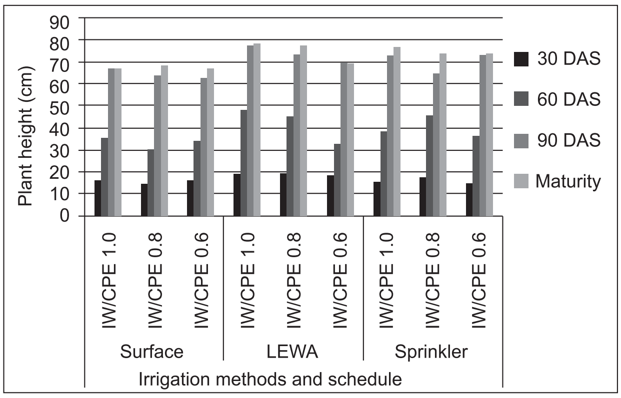

Fig. 1. Plant height of wheat under varying irrigation regime

Observing the plant height as per different methods, it was observed that in surface irrigated plots the plant height varied between 14.7 cm after 30 DAS to 68.5 cm at maturity, in LEWA irrigated plots the plant height varied between 18.5 cm after 30 DAS to 78.7 cm at maturity and in Sprinkler irrigated plots the plant height varied between 14.7 cm after 30 DAS to 76.9 cm at maturity. This reflects better growth environment for wheat plant under LEWA and Sprinkler plots incomparison to surface irrigated plots. The observation regarding nos. of tillers, nos. of ear per, bundle weight and grain weight running meter observed at the time of harvesting and presented in Table 1.

It is observed from Table 1 that amongst surface irrigated plots irrigation schedule of IW / CPE ratio of 1.0 performs better with grain weight of 10.63 g per running meter over irrigation schedule of IW / CPE ratio of 0.8 and 0.6, amongst LEWA and Sprinkler irrigated plots irrigation schedule of IW / CPE ratio of 0.8 performs better with grain weight per running meter of 12.3 g and 12.44 g respectively

Table 1. Plant and Yield characteristics at harvesting of Wheat

Irrigation Methods	Irrigation Schedule	Nos. of Tillers / running meter	No. of Ear / running meter	Bundle wt / running meter (g)	Grain / running meter Weight (g)
Surface	IW / CPE 1.0	110.60	98.40	135.41	10.63
	IW / CPE 0.8	89.40	84.80	102.53	9.10
	IW / CPE 0.6	99.20	93.20	129.43	9.68
LEWA	IW / CPE 1.0	127.80	119.20	221.81	11.69
	IW / CPE 0.8	127.40	113.20	220.67	12.30
	IW / CPE 0.6	84.40	76.80	99.45	8.75
Sprinkler	IW / CPE 1.0	85.80	82.80	156.51	10.41
	IW / CPE 0.8	95.80	83.00	184.48	12.44
	IW / CPE 0.6	80.20	72.00	127.36	9.69

over irrigation schedule of IW / CPE ratio of 1.0 and 0.6. This further reflects that LEWA and Sprinkler irrigated plots performs better when scheduled at IW / CPE ratio of 0.8 over best performing Surface irrigated plot at IW / CPE ratio of 1.0. The yield of all the plots were harvested and depicted through Fig. 2.

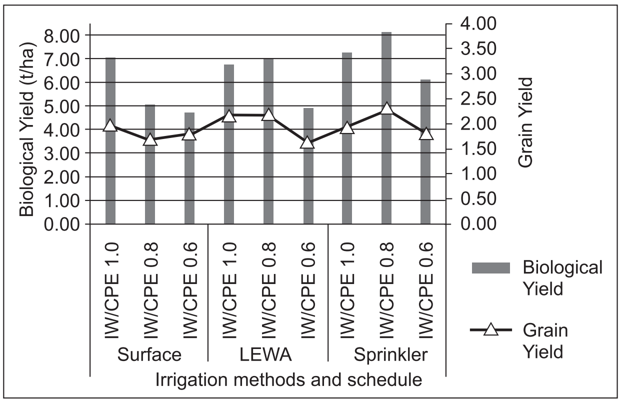

Fig. 2. Biological and Grain yield of wheat under varying irrigation regime

It is observed from Fig 2, that, the biological and grain yield is higher when irrigation schedule of IW / CPE ratio of 1.0 is practiced with surface method, whereas, amongst LEWA and Sprinkler irrigated plots IW / CPE ratio of 0.8 results in higher biological and grain yield. The grain yield of best performing irrigation regime under surface, LEWA and Sprinkler irrigated plots are 1.97 t / ha, 2.16 t / ha and 2.3 t / ha respectively.

Water and energy used to practice irrigation

Irrigation depth of 12.0 cm (two irrigation), 12.0 cm (two irrigation) and 6.0 cm (one irrigation) was applied in surface irrigated plots at 1.0, 0.8 and 0.6 IW / CPE ratio respectively, in LEWA irrigated plots 12.0 cm (three irrigation), 8.0 cm (two irrigation) and 4.0 cm(one irrigation) at 1.0, 0.8 and 0.6 IW / CPE ratio respectively while in sprinkler irrigated plots 12.0 cm (two irrigation), 8.0 cm (two irrigation) and 4.0 cm (one irrigation) at 1.0, 0.8 and 0.6 IW / CPE ratio respectively were applied. These irrigation depths does not include the soil moisture enhanced due to rainwater (10.4 cm during the crop growth period from different rainfall events) and initial available moisture available in wheat fields due to pre sowing irrigation for field preparation and sowing which considered common for all treatments. Correspondingly energy (diesel) used for pumping under various irrigation regime were 3 lt, 3lt and 1.5 lt incase of surface irrigated plots with IW / CPE ratio of 1.0, 0.8 and 0.6 respectively, 6 lt, 4 lt and 2 lt incase of sprinkler irrigation plots with IW / CPE ratio of 1.0, 0.8 and 0.6 respectively and 4.2 lt, 2.8 lt and 1.41 lt incase of LEWA irrigated plots with IW / CPE ratio of 1.0, 0.8 and 0.6 respectively.

Water saving

The volume of water applied per square meter was analysed based on the applied irrigation depth under different irrigation schedules and their respective wetted area is depicted through Fig. 3. It is observed that at IW / CPE ratio of 1.0 the water uses per unit irrigated area by all method are same whereas at IW / CPE ratio of 0.8 and 0.6 the volume

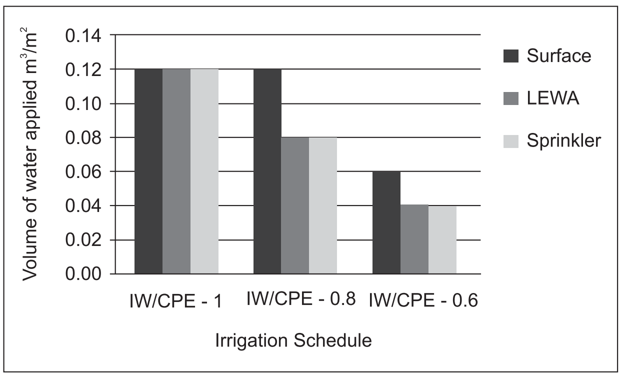

Fig. 3. Volume of water applied per unit irrigated area

of water per unit area used by LEWA and Sprinkler is lower than the surface method of irrigation. This shows that no differnce in water use at IW / CPE of 1.0 was observed but when irrigation is scheduled at IW / CPE ratio of 0.8 and 0.6, LEWA and sprinkler results into water saving of approximately 33% over surface method.

Energy saving

The fuel (diesel) used to apply the respective volume of water applied in irrigated area was analysed based on the applied irrigation depth under different irrigation schedules and their respective wetted area is depicted through Fig. 4. It is observed that at IW / CPE ratio of 1.0 the energy used by surface and LEWA is at par and resulting saving in energy by 30% over sprinkler. The pattern changes when IW / CPE ratio changes to 0.8 and 0.6 where, LEWA results saving of energy by 32% over surface and 29% over sprinkler. It is also observed that at IW / CPE ratio of 0.8 and 0.6 sprinkler too results in saving of 4% of energy over surface.

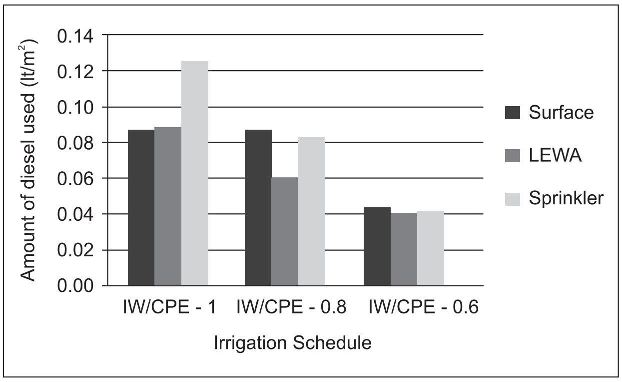

Fig. 4. Energy used to irrigate per unit irrigated area

Irrigation water and energy productivity and yield trends

The irrigation water and energy productivity is estimated based on the irrigation water used and cost incurred to apply irrigation has been depicted in Fig-5 alongwith wheat yield under different irrigation regime. It is observed that corresponding water and energy productivity of LEWA and Sprinkler irrigated plots are higher incomparison to Surface irrigated plots. The water productivity (Rs. / m^3) in surface irrigated plots was observed as 20.8, 9.8 and 11.4 for IW / CPE ratio of 0.6, 0.8 and 1.0 respectively, incase of LEWA 40.5, 28.2 and 16.2 for IW / CPE ratio of 0.6, 0.8 and 1.0 respectively and incase of sprinker 44.8, 28.8 and 16.1 for IW / CPE ratio of 0.6, 0.8 and 1.0 respectively. The energy productivity also followed the same trend and it is observed that energy productivity (Rs. / per unit cost of diesel) observed incase of surface was 5.2, 2.4 and 2.9 for IW / CPE ratio of 0.6, 0.8 and 1.0 respectively, incase of LEWA 10.0, 7.0 and 4.0 for IW / CPE ratio of 0.6, 0.8 and 1.0 respectively, and incase of sprinkler 7.8, 5.0 and 2.8 for IW / CPE ratio of 0.6, 0.8 and 1.0 respectively. This reflects that water and energy productivity of LEWA and sprinkler is higher w.r.t. Surface irrigated plots. Considering yield scenario under different irrigation regime, it is observed that within Surface irrigated plots irrigation schedule of IW / CPE ratio of 1.0 results in higher yield by 8% to 14% over IW / CPE ratio of 0.8 and 0.6 respectively. Consequently, within LEWA and sprinkler irrigated plots higher yield by 14% to 16% over IW / CPE ratio of 1.0 and 22% to 28% over IW / CPE ratio of 0.6 is obtained at IW / CPE of 0.8.

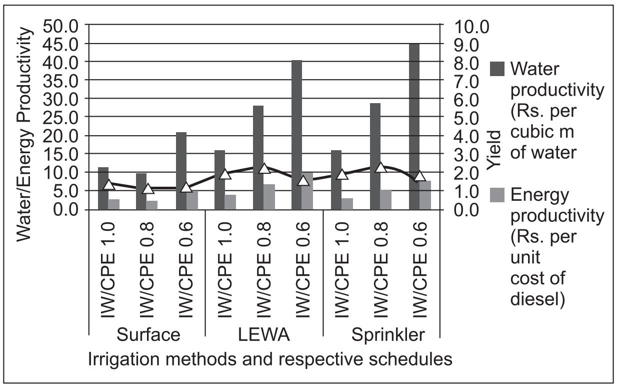

Fig. 5. Water and energy productivity and yield of wheat

CONCLUSION

The overall performance based on water and energy productivity and yield achieved, it is observed, that, incase of surface method irrigation schedule of IW / CPE of 1.0 performed better, whereas, incase of LEWA and Sprinkler, irrigation schedule of IW / CPE ratio of 0.8 performed better. Considering best performing irrigation schedules under Surface, LEWA and Sprinkler irrigaed plots, it is observed, that sprinkling methods (Sprinkler and LEWA) when scheduled at IW / CPE ratio of 0.8 results in higher yield by 10% to 15% over Surface irrigated plots scheduled at IW / CPE ratio of 1.0. This may be due to better plant growth environment in the rootzone by applying lower depth of water at frequent interval. Besides benefit in yield, both the sprinkling methods (LEWA and Sprinkler) when scheduled at IW / CPE ratio of 0.8 resulted in water saving in the tune of 33% over Surface irrigated plots at IW / CPE ratio of 1.0, this further resulted, in an energy saving of 33% in LEWA and 6% in Sprinkler irrigated plots over

Surface irrigated plots at IW/CPE ratio of 1.0. Saving in energy also have impact on cost of irrigation.

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Drought investigation through rainfall analysis for pomegranate production at Solapur district of Maharashtra, India

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ABSTRACT

Rainfall is the major determinant of pomegranate production, especially in rain fed areas. The contribution of rain fed horticulture is almost half to the national production and thus it plays the key role in Indian food security. About 90 per cent of the pomegranate area is rainfed and thus the rainfall is very determinant characteristic in terms of both amount and distribution over space and time, it is very uncertain. Therefore, it would be necessary to go for localized predictions. In view of this, an attempt has been made to estimate the occurrence of drought at different *stations* of Solapur district through rainfall analysis of 33 years (1975-2007). Data are classified into certain degrees of drought severity (Drought, Normal and Surplus) based on a number of truncation levels corresponding to specified mean values of the rainfall. This study indicated that the average intensity of drought for all stations is higher in *Ambe season (bahar)* followed by *Hasta* and *Mrig* seasons *(bahars)* of Pomegranate.

Key words: Rainfall data, drought, normal, surplus and mean

INTRODUCTION

Drought is the weather related creeping natural disaster. It is a major factor of uncertainty that continues to haunt Indian economy. The year 2002 reminds us of one of the worst drought spells in recent times (Kalsi *et al*., 2006). Study of drought analysis is one of the important aspects in the rain fed farming as well as in water resource planning, irrigation scheduling, irrigation system design, moisture deficit prediction, hydrological and climatic studies, management and allocation of irrigation water. The success or failure of crops particularly under rain fed conditions is closely linked with the rainfall pattern.

Pomegranate cultivation planning in water shortage area is based on conservation, utilization and management of rainwater. Due to frequent droughts and related socio-economic constraints, per hectare yield in rainfed areas is very low (Rockstorm *et al.,* 2003). In this region, three flowering *bahars* are promoted for pomegranate production (NRCP 2009a). *Bahar* is a local word also widely used to express flowering seasons of horticulture crop. Here *bahar* word is used for flowering seasons of pomegranate. Thus, flowering seasons are defined as: *Ambe bahar* flowering period (January - February) and harvesting period (June-July), *Mrig bahar* flowering period (June-July) and harvesting period (December-January) and *Hasta bahar* flowering period (September-October) and harvesting period (January-February). In this drought investigation, drought investigated as meteorological drought but expressed on the basis of pomegranate seasons (*bahars)* to aid pomegranate growers to increase pomegranate production and to select appropriate season (*bahar)* for safe, disease free and quality production of pomegranate.

MATERIALS AND METHODS

The daily climatological data of 33 years (1975 – 2007) was collected from Indian Metrological Department, Pune. The study carried out for entire part of Solapur district (Maharashtra). The 11 *tehsils* in Solapur district having 14 rainguage stations have been considered. For the present research work (Table 1).

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Table 1. The details of the *stations* that were considered for the study

Tahsil / Station	Longitude	Latitude	Altitude (above msl)
Akalkot	17.51^{0} N	76.20^{0} E	487
Akluj	17.88^{0} N	75.01^{0} E	493
Barsi	18.23^{0} N	75.69^{0} E	528
Jeyur	18.26^{0} N	75.16^{0} E	516
Karmala	18.42^{0} N	75.20^{0} E	552
Madha	18.01^{0} N	75.51^{0} E	482
Malsiras	17.92^{0} N	74.95^{0} E	493
Mangalvedha	17.51^{0} N	75.46^{0} E	499
Mohol	17.81^{0} N	75.66^{0} E	457
North Solapur	17.65^{0} N	75.90^{0} E	463
Pandharpur	17.68^{0} N	75.33^{0} E	469
Sangola	17.43^{0} N	75.19^{0} E	505
Solapur	17.68^{0} N	75.92^{0} E	485
South Solapur	17.65^{0} N	75.90^{0} E	479

Evaluation of drought

Pomegranate *bahar* wise weekly rainfall determined for each year and *bahar* wise weekly events were classified as drought, normal and surplus week by suggested by the following criteria (Sharma *et al.*, 1979).

If 'm' is the mean weekly / monthly rainfall, then a week / month receiving rainfall less than A_1 is defined as drought, in between A_1 and A_2 is normal month and above A_2 is surplus month, where A_1 = m / 2 (50 %) and A_2 = 2 m (200%). Also if 'y' is the long term mean annual rainfall then the year is said to be classify as drought or normal or surplus as follows; drought year: if the year's is less than or equal to y – s amount, Normal year: if the year's rainfall in between y + s and y - s amount. Surplus year: if the year's rainfall is greater than or equal to y + s amount. Where's is the standard deviation of the annual rainfall series.

Statistical analysis of rainfall

The *bahar* wise rainfall for all the *stations* was analyzed statistically on weekly basis. Generally mean, standard deviation, coefficient of variation and skewness coefficient (C_s), Kurtosis taken as measures of variability of any hydrologic series. These parameters are used to describe the variability of rainfall in the present study.

RESULTS AND DISCUSSION

Analysis of rainfall data

The annual average rainfall of 33 years in the study area (Fig.1) is maximum at the Akalkot (733.43 mm) and minimum at the Malsiras (583.37 mm). At Akalkot, Solapur, North Solapur and South Solapur, it is more than 700 mm and at Akluj, Malsiras and Mohol it is less than 600 mm. There exists significant variation in the annual average rainfall at various stations is shown in (Fig.1).

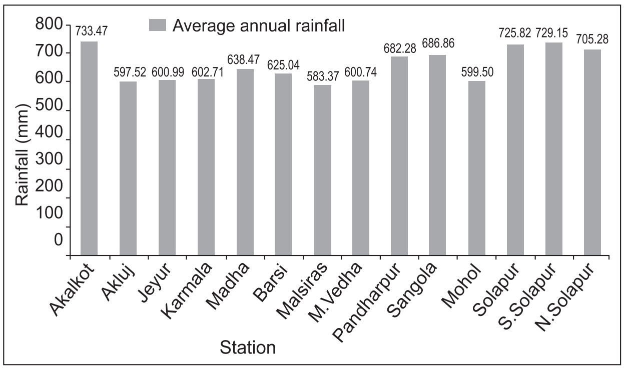

Fig. 1. Average annual rainfall patterns of the various *tehsils* of Solapur district

Statistical analysis of annual rainfall

The results on statistical presents (Table 2) reveal that the average annual rainfall of 33 years for the district is 650.80 mm with a standard deviation of 248.22 mm and CV of 38.52 per cent. Akalkot tehsil in the district receives the highest annual rainfall of 733.47 mm with SD of 246.3 mm and CV of 33.54 per cent while Malsiras tehsil receives the lowest mean annual rainfall of 583.27 mm with SD of 323.48 mm and CV of 55.45 per cent. Data on maximum and minimum annual rainfall revealed that Akluj received maximum (1667) and Malsiras received minimum annual rainfall (583.37). The mean annual rainfall increases as we move from west to east part of the district.

The values of coefficient of skewness indicate that all the tehsils are having positively skewed distribution of annual rainfall. The C_S varies from 0.09 (Barsi) to 1.75 (Malsiras). The values of coefficient of kurtosis indicate that all the tehsils are having positive values except for Akalkot, Jeyur, Barsi, Pandharpur and North Solapur. The Ck varies from -0.05 (Barsi) to 3.64 (Malsiras).The data also reveal that the standard deviation of annual rainfall varied from 189.61 (Barsi) to 382.31 mm (Akluj). The highest CV (63.98) in Akluj, whereas lowest CV (30.34) in Barsi tehsil. The rainfall analysis for tehsils in Solapur district indicates that tehsil wise annual rainfall pattern in the district is very much erratic.

There is a large spatial and temporal variation of rainfall in the district. Similar statistical analyses

Table 2. Annual rainfall parameters under different *stations* of Solapur district

Tehsil	Mean (mm)	Max (mm)	Min (mm)	Standard Deviation mm	Coeff. of Variation %	Skew-ness	Kurtosis
Akalkot	733.47	1263	351	246.03	33.54	0.65	-0.70
Akluj	597.52	1667	107	382.31	63.98	1.72	2.68
Jeyur	600.99	1152	286	235.18	39.13	0.78	-0.07
Karmala	602.71	1152	208	229.22	38.03	0.76	0.42
Madha	638.47	1206	312	232.49	36.41	0.86	0.34
Barsi	625.04	1086	228	189.61	30.34	0.09	-0.05
Malsiras	583.37	1667	107	323.48	55.45	1.75	3.64
Mangalvedha	600.74	1105	278	203.29	33.84	0.64	0.23
Pandharpur	682.28	1154	258	247.94	36.34	0.53	-0.66
Sangola	686.86	1279	334	232.59	33.86	0.74	0.46
Mohol	599.50	1293	220	211.90	35.35	0.89	2.24
Solapur	725.82	1296	375	222.59	30.67	0.63	0.18
S. Solapur	729.15	1292	291	240.19	32.94	0.68	0.15
N. Solapur	705.28	1296	223	278.19	39.44	0.52	-0.24
District	650.80	1279	256	248.22	38.52	0.80	0.62

of rainfall have been carried out by Pandey *et al.* (1999) over different districts of Gujarat; Nath and Deka (2002) for Jorhat region of Assam; Singh *et al.* (2002) at Jhansi of Uttar Pradesh; De and De (2003) for Sriniketan of West Bengal; Singh and Singh (2004) for Bikramganj region of Bihar, Dixit *et al.* (2005) in Konkan region of Maharashtra; Jat *et al.* (2005) for Udaipur region of Rajasthan and Jhajharia *et al.* (2007) for Guwahati region of Assam and large variation in annual rainfall parameters were observed over different regions.

Weekly drought investigation

The data of 33 years (1975-2007) analysed, each *bahar* includes 8 specific month (35 weeks of the year) and total week considers for analysis are 1155 (35 weeks of specific bahar x 33 year).

Weekly drought investigation for Ambe bahar (December-July)

Bahar wise weekly (1155 weeks) rainfall data of 33 years (Table 3) revealed the average weekly drought of *Ambe bahar*. In the 33 (1975-2007) years, total drought weeks highest in Akluj are 943 weeks with 76.98 per cent and lowest in Solapur is 760 weeks with 70.05 per cent. The total normal weeks highest in north Solapur is 157 weeks with 14.47 per cent and lowest in Pandharpur is 95 weeks with 8.92 per cent. Similarly the total surplus weeks highest in Akalkot are 177 weeks with 15.32 per

Table 3. Weekly drought investigations of *Ambe bahar* for all *stations* of Solapur district

Station	No. of Drought week	No. of Normal Week	No. of surplus Week	% of drought week	% of normal week	% of Surplus week	Coeff. of variance in %
Akalkot	843	135	177	72.99	11.69	15.32	103.17
Akluj	914	112	129	79.13	9.70	11.17	119.01
Jeyur	943	126	156	76.98	10.29	12.73	113.46
Karmala	890	107	158	77.06	9.26	13.68	113.79
Madha	920	128	177	75.10	10.45	14.45	108.68
Barsi	829	155	171	71.77	13.42	14.81	99.90
Malsiras	919	103	133	79.57	8.92	11.52	120.18
Mangalvedha	881	118	156	76.28	10.22	13.51	111.68
Pandharpur	888	95	172	76.88	8.23	14.89	113.59
Sangola	866	119	170	74.98	10.30	14.72	108.40
Mohol	864	109	182	74.81	9.44	15.76	108.16
Solapur	760	157	168	70.05	14.47	15.48	95.39
S. Solapur	785	134	166	72.35	12.35	15.30	101.47
N. Solapur	786	139	160	72.44	12.81	14.75	101.65

cent and lowest in Akluj is 129 weeks with 11.17 per cent. The percentage of coefficient of variation between Drought, Normal and surplus weeks for every *station* highest in malsiras *station* is 120.18 per cent and lowest in Solapur is 95.39 per cent. Also the weekly drought variation curves of *Ambe bahar* for every *station* presented in (Fig. 2).

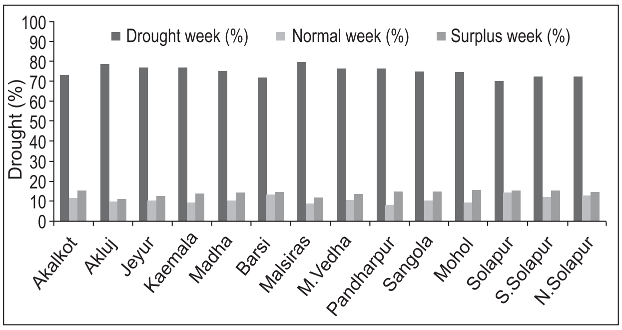

Fig. 2. Weekly drought variation curves of *Ambe bahar* for all *stations* in Solapur district

Weekly drought investigation for Mrig bahar (July-December)

The (Table 4) revealed the weekly (1155 weeks) drought incidences of *Mrig bahar* for all *stations* of the Solapur district. In the 33 (1975-2007) years, total drought weeks are highest in Akluj are 784 weeks with 67.88 per cent and lowest in Solapur is 653 weeks with 58.43 per cent. The total normal weeks highest in North Solapur is 256 weeks with 23.59 per cent and lowest in Malsiras is 191 weeks with 16.54 per cent. Similarly the total surplus weeks highest in Akalkot are 216 weeks with 18.70 per cent and lowest in Akluj is 166 weeks with 14.37 per cent. The percentage of coefficient of variation between Drought, Normal and surplus weeks for every *station* highest in malsiras *station* is 89.76 per cent and lowest in Solapur is 65.75 per cent. Also the weekly drought variation curves of *Mrig bahar* for every *station* presented in (Fig. 3).

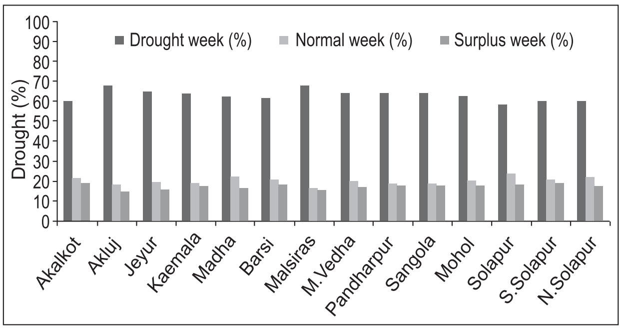

Fig. 3. Weekly drought variation curves of *Mrig bahar* for all *stations* in Solapur district

Weekly drought investigation for Hasta bahar (August-March)

The (Table 5) revealed the weekly (1155 weeks) drought of *Hasta bahar* for all *stations* of the Solapur district. In the 33 (1975-2007) years, out of 1155 weeks the total number of drought weeks highest in Akluj are 933 weeks with 76.16 per cent and lowest in Solapur is 779 weeks with 71.80 per cent. The total normal weeks highest in north Solapur are 149 weeks with 13.73 per cent and lowest in Malsiras is 108 weeks with 9.35 per cent. Similarly the total surplus weeks highest in Madha is 181 weeks with 15.67 per cent and lowest in Akluj is

Table 4. Weekly drought investigations of *Mrig bahar* for all stations of Solapur district

Station	No. of Drought week	No. of Normal Week	No. of surplus Week	% of drought week	% of normal week	% of Surplus week	Coeff. of variance in %
Akalkot	692	247	216	59.91	21.39	18.70	69.17
Akluj	781	208	166	67.62	18.01	14.37	89.24
Jeyur	792	238	195	64.65	19.43	15.92	81.54
Karmala	737	221	197	63.81	19.13	17.06	79.24
Madha	761	267	197	62.12	21.80	16.08	75.29
Barsi	708	239	208	61.30	20.69	18.01	72.77
Malsiras	784	191	180	67.88	16.54	15.58	89.76
Mangalvedha	740	225	190	64.07	19.48	16.45	79.98
Pandharpur	738	215	202	63.90	18.61	17.49	79.42
Sangola	738	219	198	63.90	18.96	17.14	79.45
Mohol	721	236	198	62.42	20.43	17.14	75.74
Solapur	634	256	195	58.43	23.59	17.97	65.75
S. Solapur	653	225	207	60.18	20.74	19.08	69.81
N. Solapur	658	237	190	60.65	21.84	17.51	71.26

Table 5. Weekly drought investigations of *Hasta bahar* for all *stations* of Solapur district

Station	No. of Drought week	No. of Normal Week	No. of surplus Week	% of drought week	% of normal week	% of Surplus week	Coeff. of variance in %
Akalkot	844	136	175	73.07	11.77	15.15	103.37
Akluj	887	123	145	76.80	10.65	12.55	112.96
Jeyur	933	117	175	76.16	9.55	14.29	111.50
Karmala	875	120	160	75.76	10.39	13.85	110.34
Madha	916	130	179	74.78	10.61	14.61	107.84
Barsi	857	125	173	74.20	10.82	14.98	106.36
Malsiras	899	108	148	77.84	9.35	12.81	115.74
Mangalvedha	859	136	160	74.37	11.77	13.85	106.67
Pandharpur	867	118	170	75.06	10.22	14.72	108.63
Sangola	871	121	163	75.41	10.48	14.11	109.46
Mohol	861	113	181	74.55	9.78	15.67	107.44
Solapur	779	149	157	71.80	13.73	14.47	99.94
S. Solapur	782	137	166	72.07	12.63	15.30	100.73
N. Solapur	789	142	154	72.72	13.09	14.19	102.34

145 week with 12.55 per cent. The percentage of coefficient of variation between Drought, Normal and surplus weeks for every *station* highest in Malsiras tahsil is 115.74 per cent and lowest in Solapur is 99.94 per cent. Also the weekly drought variation curves of *Hasta bahar* for every *station* presented in (Fig. 4).

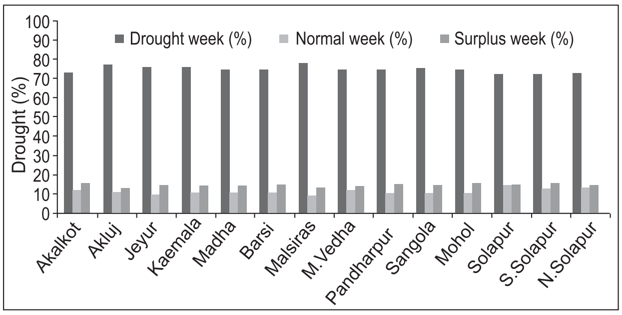

Fig. 4. Weekly drought variation curves of *Hasta bahar* for all *stations* in Solapur district

The results of the *bahar* wise weekly drought investigation at different stations revealed that, there is a small variation in drought, normal and surplus weeks of rainfall in the district. Similar drought analyses of rainfall have been carried out by Sinha and Shewale (2001) over different subdivisions of India; Ana and Abaurrea (2002) for Universidad de Zaragoza region of spian; Pandey *et al.*, (2002) at Hawalbagh in Uttaranchal; Satpute (2004) for state Maharashtra of India; Jat *et al.*, (2005) at different districts viz. Jodhpur, Sriganganagar, Fatehpur and Pali districts of Rajasthan, Keshari (2006) Drought monitoring in southern Rajasthan using remote sensing and geographical information system; Kothari. (2007) Drought characterisation and its management under rainfed agro-ecosystem of Bhilwara district in Rajasthan; Smakhtin and Hughes (2007) for south Asia; Daniel *et al.*, (2007-08) for busia district (Uganda); Wong and Lambert (2009) for Australia, Vladislava and zoran (2010) climatological stations in Serbia; Rafiuddin *et al.*, (2011) over 4 sub-regions of the Bangladesh country.

CONCLUSION

The greater intensity of weekly drought for *Ambe bahar* is found in Malsiras followed by Akluj and Karmala and lowest intensity of weekly drought is found in Solapur and Barsi for all the weeks. The greater intensity of weekly drought for *Mrig bahar* is found in Malsiras followed by Akluj and Jeyur and lowest intensity of weekly drought is found in Solapur and Akalkot for all the weeks. Similarly the greater intensity of weekly drought for *Hasta bahar* is found in Malsiras followed by Akluj and Jeyur and lowest intensity of weekly drought is found in Solapur and South Solapur for all the weeks. Average intensity of drought for all station is higher in *Ambe bahar* followed by *Hasta* and *Mrig bahar*. But pomegranate production point of view *Hasta bahar* is more appropriate due to beneficial and efficient range of other meteorological factors like temperature, humidity, wind speed, sunshine hour and evaporation. The monitoring of drought using meteorological indicators are time consuming, laborious and not on real time but using this data reliable and economical monitoring of drought is possible compared to any other improved techniques.

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Assessment of critical limits for zinc in soils and rice plants in acid soils regionof Arunachal Pradesh

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ABSTRACT

A study was conducted in 24acid soils of Arunachal Pradesh, India to estimate the critical limit of Zn in soil and rice plants for predicting the response of rice (*Oryza sativa*) to zinc application. The DTPA-extractable Zn wassignificantly and positively correlated with pH, organic carbon,CEC, and clay contentsandnegatively correlated with silt and sand contents of soils. The DTPA-extractable Zn also showed a positive correlation with dry matter yield and plant Zn concentration. The critical concentration of Zn in these soils was established at 0.78 mg kg ^{1}for soil and at27.0 mg kg ^{1} in the plant tissues.Soils containing Zn below the critical limit responded appreciably to Zn fertilization. A negative response to Zn application was observed in soils with higher Zn contents.Rice dry matter yield increases with increasing level of Zn application up to 2.5 mg kg ^{1}in Zn deficient soils. The average response ofZn application to rice in Zn deficient soils was found to be 59.5% andwas 11.05% in Zn adequate soils.

Key words: Bray's percent yield, critical limits of Zn, physico-chemical properties of soil

INTRODUCTION

Rice is a primary food source for more than one third of world's population (Prasad *et al*., 2010).In Asia, India has the largest area under rice cultivation (44.3 million ha) accounting for 29.4 per cent of the global ricearea. The productivity level in India is low (2.04 t/ha) as compared toJapan (6.25t/ha), China (6.24t/ha) and Indonesia (4.25t/ha). The whole population of Arunachal Pradesh is tribale and rice is the major food crop for them. But productivity level is very low due to poor nutrient status of soil. Productivity of rice depends upon balanced application of nutrients. Thesoils of Arunachal Pradesh arepoor in macro and micronutrients due to continuous growing of crops in sloppy land without application of fertilizer. Further, the sloppy mountainous landforms with high intensity rainfall often result in extensive soil erosion and heavy losses of plant nutrients by runoff/ leaching. Moreover, farmers of the state haveapathy to use fertilizers in their farming system. Hence, the deficiencies of nutrients particularly micronutrientsare of critical importance for sustaining high productivity of rice in Arunachal Pradesh. Zinc plays an important role in different plant metabolic processes like development of cell wall, respiration, photosynthesis, chlorophyll formation, enzyme activity, fruits and seed setting, DNA synthesis, pollen grain formation, protein synthesis and other bio-chemical functions (Das, 2003 and Singh, 1984).

Widespread and extensive Zn deficiency has been reported in thelowland soils withrice cultivation in India, Bangladesh, Pakistan, Philippines, Burma, Indonesia, Japan, Korea, Taiwan and Thailand (IRRI, 1978). In North East India, 90 % of the soils are found to be deficient in micronutrients (Takkar *et al*., 1989).Studies on Zn fertilization proved that the application of Zn greatly influences growth, yield and quality of rice (Patnaik *et al*., 2011 and Rahman *et al*., 2007). The symptoms of Zn deficiency have been recorded on rice and other field crops including vegetables crops grown in Northeastern hill region. Realising the importance of Zn in plant growth and at the same time seriousness of their deficiency in rice growing soils and plants, an attempt was, therefore, being made to study the critical concentration of Zn in soils and ricecrop which is widely grown in Arunachal Pradesh to get maximum increase in productivity of rice.

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MATERIALS AND METHODS

Twenty four soil samples in bulk from plough layer (0-20 cm) were collected from different locations of cultivated soil of East Siang district ofArunachal Pradesh. The study area lying between $27^0 43^/$ to $29^0 20^/$Nlatitude and $94^0 42^/$ to $95^0 35^/$ Elongitude**.** These soils belong to theorder Inceptisols, Entisols and Alfisols(Poddar,1999**).**The collected soil samples were separately air dried, ground and passed through a 2 mm size sieve for laboratory analysis. Particle size distribution was done by the standard Bouyoucos hydrometer method (Gee and Bauder, 1986). Soil pH was determined by glass electrode with calomel as standard (Jakson, 1973). Organic carbon was estimated by wet digestion method of Walkey and Black (Jackon, 1973). The cation exchange capacity was determined by leaching the soil with 1 N NH_4^+OAC and subsequently displacing the adsorbed NH_4^+ following the methods of Schollenberger and Simon (1945). Available zinc content of the soil samples was determined when extracted with DTPA-TEA (pH 7.3) extractant following the method of Lindsay and Norvell (1978) and the concentration of Zn in the extracted solution were estimated with the help of Atomic Absorption Spectrophotometer (AAS).

A pot culture experiment was conducted in a greenhouse in polythene lined pots at the Instructional farm ($28^0 07^/$ N Latitude and $95^0 33^/$ E Longitude),Pasighat, Arunachal Pradesh. The polythene lining was rinsed in 0.1N HCI followed by deionized water. Four kg of each soil was transferred into each pot. Recommended doses of nitrogen, phosphorus and potassium @ 50, 25 and 25 mg kg ^{1} N, P_2O_5 and K_2O, respectively were applied as reagent grade i.e. Urea, KH_2PO_4 and KCl. Three 21 day old rice seedlings (variety-CAU-R1) were transplanted in each pot. Zinc was applied @ 0, 1.25, 2.5 and 5.0 mg kg ^{1} soil as reagent grade of Zinc sulphate ($ZnSO_4$, $7H_2O$) after 7 days of transplanting of rice seedling. Each treatment was replicated thrice in completely randomized design. Watering with deionized water and intercultural operations like weeds control and plant protection measures were adopted uniformly in each pot as and when required. Rice plants of above ground portion were harvested after 30 days of transplanting and washed in acidified solution, rinsed with deionized water, dried at 65^0C in a hot air oven and dry-matter yield was recorded. The dried rice plants and dried 3rd leaf samples of each pot were separately powdered in a warring stainless steel grinder. The dry powdered plant samples were digested in a mixture of 10:4:1 of HNO_3: $HClO_4$: H_2SO_4 on a hot plate and filtered through Whatman No.42 for estimation of Zn with the help of Atomic Absorption Spectrophotometer (AAS) (Singh *et al*. 1999). The critical value of DTPA-extractablezinc in soil and in plant were determined by plotting the Bray's percent yield against soil DTPA-extractable zinc content and separately against plant tissue zinc content respectively, following the method of Cate and Nelson (1965) and Cate and Nelson (1971).

$$\text{Bray's percent Yield} = \frac{\textit{Yield without Zn treatment}}{\textit{Yield without Zn treatment}}$$

Simple correlation analysis was carried out to establish the relationships between the Zn and soil properties.

RESULTS AND DISCUSSION

Soilsphysico-chemical properties

The data of DTPA-extractablezinc and relevant physical and chemical properties of the acid soilsof Arunachal Pradesh are presented in Table 1. The data revealed that soil texture varied from sandy loam to clay loam. The soils had pH values ranging from 5.2 to 6.7 with mean value of 5.8, indicating thatthesoilswere slightly acidic to strongly acidic in reaction. The organic carbon content of soil samples ranged from 9.2 to 17 g $kg^{-1}$with a mean value of 12.7 g kg^{-1}. In general, soils were medium to high in organic carbon content and more than95 per cent soils were found to be high in organic carbon. The range of values of cation exchange capacity was 7.5 to 32 cmol (p+) kg^{-1} with mean value of 15.87 cmol (p+) kg^{-1}. The resultsare in agreement with earlier works of Debnath *et al*. (2009) and Laxminarayan (2010).

Critical limits of zinc in soils and third leaf rice plant

The critical limit in plant refers to a level at or below which plant either develops deficiency symptoms or causes reduction in crop yield as compared to optimum yield. The available Zn content ranged from 0.54 to 0.95 mg kg^{-1} with mean value of 0.77 mg kg^{-1} (Table 1).The data revealed that Zn content in most of soils are low to medium. Similar results also reported by Mahata *et al.* (2012) andRaj *et al*. (2013).The percentof dry matter yield of rice ranged between 57.7-105.4 per cent with a mean value of 75.8 per cent. The value of Zn concentration in 3rd leaf of rice crop, total Zn in entire shoot and Zn uptake by rice shoot in no Zn applied pots were 16-39 mg kg^{-1}, 19-47 mg kg^{-1} and

Table 1. Soil properties and DTPA-extractable zinc of experimental soils

Locations / Districts East Siang	Physico-chemical properties of soils								Soil Order
	pH	Organic carbon (g kg^{-1})	Sand	Silt	Clay	Textural Classes	CEC C mol (p+)kg^{-1}	DTPA-extractable zinc (mg kg^{-1})	
Pasighat	5.3	9.2	57	27	16	Sl	9.5	0.60	Inceptisols
Berung	5.4	11.5	60	21	19	Sl	8.5	0.62	Inceptisols
Bilet	6.1	14	56	25	19	Sl	15.3	0.74	Inceptisols
Mirem	5.7	10.3	50	32	18	L	8.5	0.62	Entisols
Mikong	6.0	11.2	50	36.5	13.5	L	19.2	0.86	Inceptisols
Oyang	6.3	16.3	43	36	21	L	20.9	0.90	Entisols
Silly	5.4	14.2	60	26	14	Scl	12.5	0.65	Alfisols
Manguan	6.2	13.4	40	46	14	Sil	12.2	0.73	Entisols
Ruksin	5.5	11	55	26	19	Sl	16.4	0.71	Inceptisols
Rayang	6.5	17.0	30	41.5	28.5	Cl	18	0.95	Inceptisols
Ngorlung	5.7	13.6	51.5	33.5	15	L	16.4	0.82	Inceptisols
Nari	6.7	15.3	47	26	27	Scl	18.6	0.94	Alfisols
Detuk	6.1	14.2	52	30	18	L	14.8	0.86	Inceptisols
Koyu	5.6	14.1	56	28	16	Sl	18.1	0.74	Entisols
Sido	6.4	14.7	48	27	25	Scl	14.1	0.92	Entisols
Korang	6.2	11.3	60	21	19	Sl	19.9	0.80	Alfisols
Kaki	6.5	16.1	48	26	26	Scl	32	0.91	Entisols
Seren	5.2	10.3	48	25	27	Scl	12.6	0.7	Inceptisols
Mebo	6.6	15.5	49	27	24	L	20	0.94	Inceptisols
Ayeng	5.4	10.2	60	21	19	Sl	14.6	0.76	Inceptisols
Pangin	5.7	12.0	35	50	15	Sil	16.4	0.83	Entisols
Kebang	5.7	9.8	48	32	20	Scl	15.6	0.62	Entisols
Boleng	5.2	10.2	51	34	15	Scl	7.5	0.54	Alfisols
Rebo	6.0	11.2	52	30	18	L	19.5	0.72	Inceptisols
Range value	5.2-6.7	9.2-17	30-60	21-50	13.5-28.5		7.5-32	0.54-0.95	
Mean	5.8	12.7	50.3	30.3	19.4		15.87	0.77	

117.8- 646.8mg pot^{-1} with respective mean value of 24.8 mg kg^{-1}, 32.8 mg kg^{-1} and 339.3mg pot^{-1} (Table 2). The plot of Bray's per cent yield against soil available Zn and plant tissue Zn revealed 0.78and 27.0 mg kg^{-1}, respectively as the critical concentration of Zn in soils and plant (Fig. 1 & 2). These values are close to critical level of Zn (0.83 mg kg^{-1}) as observed by Muthukumararaja *et al.* (2012) and Gangwar and Chandra (1975). However, critical limit of DTPA-extractable Zn and plant tissue Zn was 0.82 mg kg^{-1} soil and 28.5 mg kg^{-1} reported by Mahata*et al.* (2013) for rice in Terai soil of West Bengal of India, below which appreciable responses to Zn application were observed. Based on the soil test, plant analysis and response of different crops to the application of Zn in greenhouse and field trial, the critical limit of Znof 0.60 g kg^{-1}(DTPA-extractable) for riceand wheat has so far been fixed for West Bengal (Das and Saha, 1999).

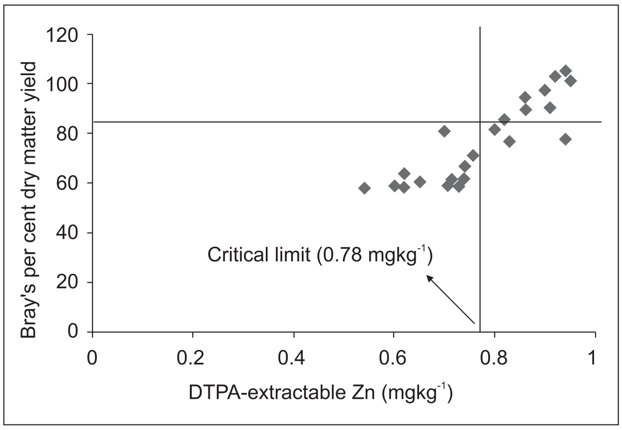

Fig. 1. Scatter diagram of DTPA-extractable zinc vs. percent dry matter yield of rice grown in soils of acid soil of Arunachal Pradesh

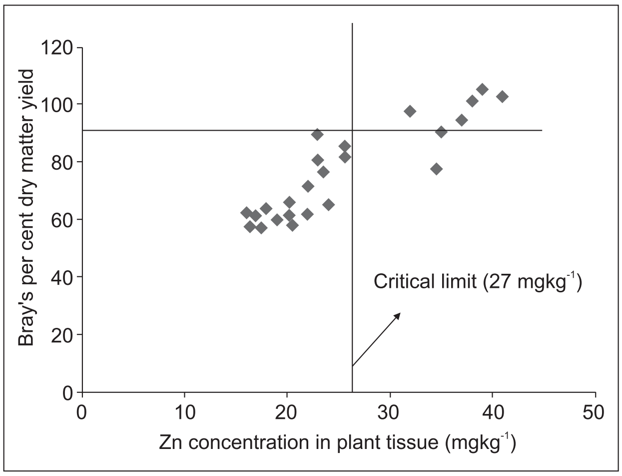

Fig. 2. Scatter diagram of third leaf zinc vs. percent dry matter yield of rice grown in acid soils of Arunachal Pradesh

Responses of rice dry matter yield to zinc application

Zinc is an important micronutrient which greatly influences the yield of rice due to its nutritional value in metabolism.The data presented in Table 3 reveals that the average response of rice in term of dry matter yield (%) at optimum level of applied Zn in soils below critical limit ranged from 23.8 to 72.5per cent.With increasing level of Zn content in soil above the critical limit, the percentage responses also decreased which varied from (-) 9.5 to 30.2 per cent. On the other hand, the application of Zn significantly increased the average shoot yield from 7.5 to 11.6 g pot^{-1} upto 5.0 mg Zn kg^{-1} soil below the critical value (Patnaikand Bhupal, 2001).The positive responses of Zn might be due to its beneficial effect on

Table 2. Effect of Zinc fertilization on dry-matter yield, Zn concentration in leaf and shoots and Zn uptake by rice

S.No.	Shoot weight (g pot $^{-1}$) Application of Zn (mg kg^{-1}soil)				Percent dry matter yield at optimum Zn level	Total Zn in the 3rd leaves of rice plants at no Zn pots (mg kg^{-1})	Total Zn in rice shoots at no. Zn pots (mg kg^{-1})	Zn uptake by rice shoots (ppm pot^{-1}) in no Zn pots
1.	0	1.25	2.50	5				
2.	6.3	8.4	9.6	10.7	58.8	16.7	21.0	132.3
3.	6.9	8.9	10.4	11.9	57.7	17.3	24.0	165.6
4.	6.8	8.0	9.7	11.0	61.8	17.4	27.0	139.2
5.	6.7	8.5	9.7	11.4	58.7	16.0	23.0	154.1
6.	12.2	13.6	13.0	12.1	89.7	23.0	38.0	463.6
7.	12.5	12.8	12.8	12.4	97.6	32.0	42.0	525
8.	7.1	9.0	10.9	11.7	60.6	16.8	26.0	184.6
9.	7.9	10.2	11.8	12.5	60.2	19.0	28.0	221.2
10.	7.2	9.5	11.5	12.2	59.0	20.5	25.0	180
11.	14.7	14.5	13.7	13.3	101.3	38.0	44.0	646.8
12.	12.4	13.4	14.6	13.4	85.5	25.6	37.0	458.8
13.	13.5	12.8	12.7	12.2	105.4	39.0	45.0	607.5
14.	12.1	12.8	12.6	12.3	94.5	37.0	43.0	520.3
15.	8.2	10.6	12.2	12.4	66.1	20.2	27.5	225.5
16.	13.6	13.2	12.8	12.5	103	38.5	46.0	625.6
17.	11.7	13.4	14.3	13.1	81.8	25.6	35.0	409.5
18.	12.5	13.8	13.5	13.2	90.5	35.0	41.0	512.5
19.	10.5	12.4	13.0	12.2	80.7	23.0	33.0	346.5
20.	10.4	13.4	13.3	13.1	77.6	34.5	47.0	488.8
21.	9.6	11.9	13.4	12.3	71.6	22.0	32.0	307.2
22.	10.9	13.0	14.2	12.0	76.7	23.5	33.0	359.7
23.	7.4	8.5	10.1	11.6	63.7	18.0	26.0	192.4
24.	6.2	8.4	9.6	10.7	57.9	16.7	19.0	117.8
25.	6.8	8.2	9.7	11.2	60.7	20.2	25.0	170
Mean value	9.7	11.2	12.0	12.2	75.8	24.8	32.8	339.3
Range value	6.2-14.7	8-14.5	9.6-14.6	10.7-13.4	57.7-105.4	16-39	19-47	117.8-646.8

Table 3. Response of rice crop to Zinc application

DTPA-extractable Zn ($mg\ kg^{-1}$)	No. of soils	Percentage of responding soils	Average dry matter yield ($g\ pot^{-1}$)				Average response in dry matter yield (%) at optimum level of applied Zn	
			Level of applied Zn ($mg\ kg^{-1}$)				Range	Mean
			0	1.25	2.5	5.0		
<0.78 (Deficient)	13	100	7.5	9.4	10.8	11.6	23.8-72.5	59.5
>0.78 (Adequate)	11	54.5	12.4	13.3	13.4	12.6	(-)9.5-30.2	11.05

A soil was classified as responsive to Zn where the per cent response was more than 10.

Table 4. Correlation coefficient (r-values) between DTPA-extractable Zinc and soil properties

Sl. No.	Variables	r- value
1.	Soil pH vs DTPA-extractable Zn	0.83**
2.	Organic carbon vs DTPA-extractable Zn	0.78**
3.	Clay vs DTPA-extractable Zn	0.52*
4.	Silt vs DTPA-extractable Zn	-0.16
5.	Sand vs DTPA-extractable Zn	-0.47
6.	CEC vs DTPA-extractable Zn	0.70**
7.	Bray's percentage yield vs DTPA-extractable Zn	0.87**
8.	Zn concentration in 3rd leaves vs DTPA-extractable Zn	0.90**
9.	Bray's percent yield and Zn concentration in plant tissues of 3rd leaf	0.91**
10.	Bray's percent yield and total Zn concentration in plant tissues	0.95**

** ® 1% level of significant, * ® 5% level of significant

metabolism (Rashid and Fox, 1992). Whereas, above the critical value, the application of Zn fertilizer increasedthe average shoot yield marginally from 12.4 to 13.4g pot^{-1} upto 2.5 mg Zn kg^{-1} soil. However, a substantial amount of average dry matter yield decreased with increasing levels of applied zinc fertilizer in the soils containing Zn above critical limit up to 5.0 mg Zn kg^{-1} soil. The decrease in dry matter yield at higher Zn levels may be ascribed to Zn toxicity in plant tissue (Singh,1984). Based on critical value of available Zn, soils were grouped into deficient and adequate classes (Table 3). Considering critical value of Zn in soils (0.78 mg kg^{-1}), 11 soils were rated to be adequate and 54.5% soils belonging to this category responding to Zn application. Whereas, 100% soils below the critical value showed the positive response to Zn application.However, closer examination indicated that the magnitude of mean percentage response due to 2.5 mg kg ^{1} level of Zn application over 0 mg kg ^{1} was found to be maximum (Table 2). This revealed that Zn can be applied for rice @2.5 mg kg ^{1} in the acidic soils ofArunachal Pradesh, where the Zn content was below 0.78 mg kg ^{1}. Naik and Das (2010) reported that the application of zinc as Zn-EDTA @ 1 kg / ha to low land rice soil of West Bengal gave in grain and straw yield of rice to the tune of 37.8% and 20.9 %, respectively, over the control.

Correlation among soil properties and zinc

The DTPA-extractable Zn exhibits significant positive correlation with pH (r = 0.83**), organic carbon (r = 0.78 **), Clay (r=0.52*), CEC(r =0.70**), Bray's percentage yield (r = 0.87**) and Zn concentration in 3rd leaves of the soils (Table 4), whereas, a negative relationship was also observed between silt (r= -0.16) and sand (r=-0.47).Such behaviour was also reported by Talukdar *et al*.(2009). This suggests that pH, organic matter, clay and CE Care the major factorsfor determining the Zn availability in soils. Further, Bray's percentage yield got significant and positive association with Zn concentration in plant tissues of 3rd leaf and (r =0.90**) and total Zn concentration in plant (r=0.95**). Similar correlation was also reported by Rahman *et al*. (2007).

CONCLUSION

The results indicate that the critical limit values of DTPA-extractable Zn in soil and third leaf of the rice plants were 0.78 and 27.0 mg kg^{-1}, respectively. It is evident from the study that Zn @ 2.5 mg kg^{-1} needs to be applied to obtained optimum yield for rice in the acidic soils of Arunachal Pradesh. The soils will likely respond to Zn application more when containing less than 0.78 mg kg^{-1} DTPA- extractable Zn.

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Exploring watershed approach to address agrarian distress: A case study in Vidarbha region of Maharashtra, India

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ABSTRACT

The study was designed to test the hypotheses that watershed approach of decentralized water harvesting and utilization is the remedy to overcome the agrarian stagnation suffered by the Vidarbha region which has been witnessing farmers' suicides. Participatory watershed management project funded by a development agency, NABARD was taken up as a case study. The watershed programme under taken in the region attempted to address the water shortage problem. The project emphasized on in-situ moisture conservation measures resulting in improved production. The selection of sites, design and execution of works played a crucial role. Better crop production and productivity change was attributed to design, execution and maintenance of conservation measures. This supported with production interventions resulted in increased income, poverty reduction and reduced migration from the village. The study has, however, argued that positive change in socio-economic condition of farmers notwithstanding more needs to be done to bring them out of misery. It was suggested to strengthen subsidiary input supply chain including market intelligence and remunerative prices of crop, in addition to intensified watershed plus activities in the region.

Key words: Distress, suicide, Vidarbha, watershed management

INTRODUCTION

Vidarbha has long had a strong sense of being discriminated against due to diminution in development efforts suffered by this region in the state of Maharashtra (Phansalkar, 2005). This resulted in negligence of irrigation development (Shah et al., 2012; Phansalkar, 2005) leading to poor agrarian development as compared to other parts of Maharashtra. The regional inequality, in literature, has been cited to be a complex interplay of factors viz., resource endowment, nature of population inhabiting the region, network of trade, history of investments on resource development and nature of polity (Frank, 1975; Amin, 2002, Phanslakar, 2005). Vidarbha region, historically, has fared poorly in these factors in comparison to similar neglected regions in other parts of the country such as Saurashtra in Gujarat. The region which was prosperous in terms of natural resources suffered from neglect of irrigation development leading to weak agrarian base over which subsequent agricultural development could not pick up (Phansalkar, 2003). There are various theories about Vidarbha's agrarian stagnation, each examined from different perspectives. Starting with lop sided irrigation development as documented by Phanslakar (2003), poor governance encompassing historical Zamindari system, development backlog and weak institutional base leading to poor agricultural development has been meticulously explored (Shah et al., 2012). The causes identified and the remedies suggested, by and large, point towards at least one common remedy, viz, decentralized water resource development apart from others. While the issue of governance plays a crucial role, the decentralized water resource development can be addressed by local stakeholders through

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watershed development approach of agricultural development.

Agricultural development in Vidarbha region

Vidarbha region lies between 18^0 45' and 21^0 45' north latitude and 76^0 0' and 81^0 0' east longitude in the eastern region of Maharashtra. The region occupies 31.6% of total area and holds 21.3% of total population of Maharashtra and is characterized by tropical/ semiarid and sub-humid monsoon type of climate. The annual rainfall varies between 760 mm to 1600 mm. The mean annual maximum and minimum temperatures vary from 30.9^0 C to 34.0^0 C and 20.3^0 C to 21.3^0 C. Soil is sandy loam to loam and has poor depth. Historically, Vidarbha has had subsistence farming similar to the common practice as elsewhere in the country. Subsequently, Vidarbha witnessed some growth due to expanded cotton cultivation (Mohanty, 2009). However, by and large, the region remained agriculturally backward owing to the absence of any irrigation. The region witnessed a substantial shortfall in actual expenditure for the irrigation sector as against excess expenditure in the rest of Maharashtra (Planning Commission, 2006). All this resulted in lower share (27% to 28%) of gross cropped area under irrigation in Vidarbha (Mohanty, 2009). Similar was the fate of agricultural credit flow for agricultural input and machinery. This had likely impact on use of high value inputs and thereby, agricultural production in the region. Cotton, the major crop of the region, was left to the vagaries of the monsoon in absence of sufficient irrigation infrastructure. Even after adoption of Bt cotton, which yields high under irrigation conditions, the crop was sown as rainfed (Shah et al., 2012). A rainfed cotton crop coupled with fluctuation in monsoon (Mohanty, 2001) resulted in repeated failure of cotton crop and became nemesis of Vidarbha (Shah et al., 2012). The increase in number of farmers' suicides in this region has been reported to be, by and large, the plight of cotton growers (Mohanty and Shroff, 2004; Mohanty 2005).The small holding size with rainfed subsistence farming and no credit and market support resulted in farmers' falling prey to vicious circle of poverty. Under these circumstances, it is argued that scientific management of basic resources such as land and water in combination with capacity building to sustain livelihood enterprises could minimize the impact of socio-economic and environmental causes (Arora et al, 2006). National Bank for Agricultural and Rural Development (NABARD) endeavored to address this through watershed management programme, called NABARD Supported Holistic Watershed Development Programme (NHWDP).

Watershed management programme in Vidarbha region

National Bank for Agricultural and Rural Development (NABARD) supported Holistic Watershed Development Programme (NHWDP) was launched on 2nd October 2006 in six distressed districts of Vidarbha. The programme, launched by the community, aimed not only at soil and water conservation measures but also support for overall development of families through integrated activities like livestock development, *wadi* (horticulture plantation), women's development and providing improved livelihood options to the landless families. A cluster of villages was considered a unit for implementation.

A socio-economic study was conducted in the region to examine the impact of the programme. The present paper explores the problems/issues of the region and discusses the impact brought about by the watershed in improving the conditions of the people in the region.

MATERIALS AND METHODS

Sample finalization and data collection

All the six clusters were selected for the study, viz., a) Dudhlam cluster, Taluka District Akola developed by Dilasa Janvikas Pratishthan, Akola, b) Asoli cluster, Taluka Ghatanji, District Yeovatmal developed by Maharashtra Institute of Technology Transfer for Rural Areas (MITRA), Nasik, c) Berala – Yeota cluster, Taluka Chikhli, District Buldana developed by Savata Mali Samaj Vikas Shaikshanik & Bahuddeshiya Mandal, Buldana & Berala-Yeota Cluster Level Watershed Committee, Buldana, d) Mothegaon cluster, Taluka Risod, District Washim, developed by SEVA, Ahmednagar, e) Dharampur cluster, Taluka Nangaon Khandeshwar, District Amravati developed by Sanjeevani Institute for Empowerment & Development (SIED), Aurangabad and f) Dahegaon cluster, Taluka Arvi, District Wardha. Both primary and secondary data were used to examine various socio-economic dimensions of local stakeholders. The secondary data was procured from various reports of the project implementing agencies. The primary data was collected through stakeholder's surveys following random sampling procedure. Data was collected during 2011-12 from a random sample of

151 farmers through detailed personnel survey. The data collected included socio-economic and bio-physical attributes such as demographic features, vegetation status, land use, soil fertility status, cropping pattern, geo-hydro-morphological features, input-output data on crops, income and employment and productivity. In addition, interaction was held with field functionaries following focus group and personal interviews. Besides the traditional survey techniques, use of geomatic tools such as remote sensing and GIS were relied upon to corroborate the information supplied by beneficiaries about the changes brought about due to watershed interventions.

Analytical technique

The standard evaluation approaches were used to assess the impact of watershed programme on different parameters. Before and after data comparison technique was adopted for all the socio-economic parameters. Statistical averages computed for the two periods were compared and analyzed for impact assessment at constant prices of the year 2006-07, the period of initiation of watershed management programmes. To assess change in land use and land cover, imageries of two points, with and without watershed intervention were used along with ground verification and survey. Assessment of water body, vegetation spread, green cover, crop acreage, irrigated area-dry season greenness was done following area-edge detection method.

RESULTS AND DISCUSSION

Land use pattern and watershed interventions

The land use pattern of the watershed clusters surveyed is given in Table 1. About 77% of the geographical area is under cultivation. The remaining land is fallow and unculturable land. Of the total cultivated area, 87% is rainfed and the remaining is under seasonal or perennial irrigation. However, there is variation in the land use pattern among the watershed clusters and the watershed interventions varied across micro watershed clusters. The expenditure on watershed interventions across micro watershed clusters also varied from Rs. 6 million to Rs 27 million.

Table 1. Land use pattern in the watershed clusters survyed

S. No.	Particulars	Total area (ha)
A. Watershed land use		
i	Forest Land	945.96
ii	Revenue Land	837.05
iii	Panchayat Land	679
iv	Gaothan (land occupied by household)	96.74
v	Summerged area under tank	262.2
	Sub-total	2820.95
B. Land privately owned		
i	Cropped Area	
a	Seasonally irrigated	1273.16
b	Perennially irrigated	62.93
c	Rainfed	9384.53
ii	Fallow Land	624.18
iii	Unculturable land	393.56
	Sub-total	11738.36
	Grand total	14559.31

Source: Project records of agencies involved in watershed programme

Among the interventions, highest expenditure was made on loose boulder structures followed by check dams and nala (local stream) bunds (Table 2).

Table 2. Expenditure on watershed interventions in Vidarbha

Proposed Land use	Total Expenditure (Rs)						
	Dudhalam	Dharampur	Berala-Yeota	Mothegaon	Dahegaon	Asoli	Total
Agro-forestry	4516093	-	-	1982462	2707295	-	9205850
Afforestation	341454	481624	-	-	-	-	823078
Crop Cultivation	5049055	7501912	9671729	15142229	2021135	7422834	46808894
Dry land Horticulture	173230	28500	389046	241189	44727	229857	1106549
Agri Horticulture	264551	265550	460000	176700	118753	5460684	6746238
Loose Boulder Structure	246961	-	63140	-	56879	13958625	14325605
Earthen Gully Plug	80880	-	-	-	-	-	80880
Gabion	172920				147009		319929
Check dam	107652		1259478	5395100	1344178		8106408
Cement Nala Bund	997349	-	34298	866800	-	-	1898447
Total	11950145	8277587	11877691	23804479	6439975	27071999	89421877

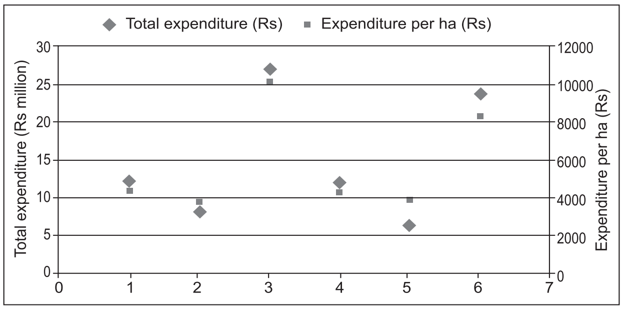
Source: Project records of agencies involved in watershed programme with Pigeon pea.

Socio-economic profile of farmers

Among the farmers, 15% were mar-ginal farmers, 39% are small farmers, 45% are medium farmers and just 1% are large farmers. Majority of the farmers belonged to weaker sections of society with low economic profile. The average family size was 4.73, with female to male ratio of 0.79. The major crops included cotton and soyabean in both pure as well as intercrop form. Livestock was not very well integrated in the production system. The average number of milch animal per household was 0.12. Working animal (bullock) constituted the highest number (50%) followed by indigenous cow (29%). Buffalo and cross bred cows constitute only 14% and 3% of the total standard cattle units, respectively.

Watershed intervention and expenditure

The various activities under the watershed management programme included drainage line treatment such as loose boulder structure, gully plug, earthen nala bund and cement nala bund. Conservation treatment in arable land included farm bund with outlet and in non-arable land, contour staggered and continuous trench. The production activities, under the programme, included improved crop cultivation, agri-horticulture and agro-forestry. Forest plantation and grass seeding was undertaken in non-arable land. The expenditure varied from Rs 3850 ha^{-1} to Rs. 10154 ha^{-1} across clusters (Fig 1).



1 – Dudhalam cluster 2 – Dharampur cluster
3 – Asoli cluster 4 – Berala-Yeota cluster
5 – Dahegam cluster 6 – Mothegaon cluster

Fig. 1. Expenditure pattern on different watershed activities across clusters in Vidarbha

Impact of watershed intervention

Crop area, production and productivity

The project interventions resulted in significant rise in area under rabi (winter) cultivation while kharif (rainy season) cultivated area did not show much change. Maximum increase in area under cultivation was recorded in Berla-Yeota cluster (572.94 ha) followed by Mothegaon cluster (254.14ha). Asoli cluster (3.49 ha) recorded minimum change in area under cultivation. The area under summer crops increased from 22.26 ha to 56.16 ha in Dudhlam cluster only. Similarly, the average change in cropping intensity was recorded as 8.42%, with maximum change in Berala-Yeota cluster (19%) and minimum change in Asoli cluster (1%). The average change in crop productivity was 35.4%. Among clusters, maximum increase in productivity was recorded in Berla Yeota cluster (70.28%) and least increase in productivity was recorded in Dahegaon cluster (15.82%). The reason for sharp increase in production in these clusters was increased availability of water due to soil & water conservation activities, introduction of Bt cotton and decrease in area under desi (local variety) cotton. The diverged area of cotton was used for cultivation of crops like soybean, mung and urd and the additional area under soybean, mung and urd was used for double cropping with rabi crops like wheat and gram, which ultimately resulted in increased crop production. The average change in crop production was 54.6%, the change varying from 25% in Mothegaon to 104% in Dharampur watershed cluster. The vegetative coverage in the region, similarly, increased from 4% in pre programme phase to 16% in post programme phase. The factors responsible for change in vegetation coverage included the conservation measures, rainfall being an important determinant.

Change in economic profile

a) Income and employment

As a result of the execution of watershed programme, the additional labour employment generated worked out to be 305,599 man days per annum for the six clusters. Different activities such as crop production, livestock, and horticulture accounted for 60%, 10% and 4%, respectively. The remaining employment was accounted for by other activities like micro enterprise (8%) and agricultural labour (18%). As a result, the change in income was observed to the tune of 38% (Fig. 2).

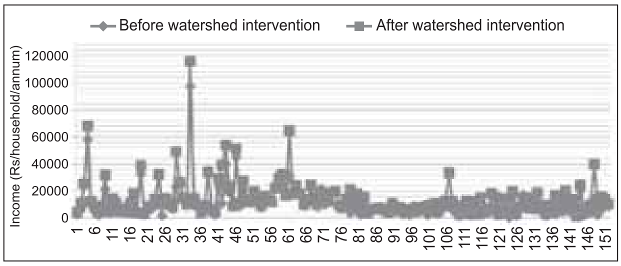


Fig. 2. Change in gross income of watershed beneficiaries (2006 prices)

Consumer durables and farm asset

The increased income was invested in creating farm asset, including pucca (permanent) house owned and consumer durables (Table 3).The investment on well increased by 25 per cent, which was a significant development. Similarly, per household investment on motor and pump owned before project was Rs. 15,003 and Rs. 11,391/- before programme implementation, it increased to Rs 18,558/- (24%) and Rs. 14,882/- (31%), respectively after programme implementation at constant prices. While the investment on bullock cart increased by 20.5%, the same in cattle shed increased by only 2.6%. The farm households of Vidarbha region also invested on house, cooking gas, refrigerator, television, telephone (mobile) and motor cycle.

There was increase in bullocks, cross breed cow, goat and poultry. The maximum increase (five times) was observed in cross bred cows, followed by goat (79%), poultry (78%) and bullocks (12%). The average income from milk production worked out to be Rs. 4115/year (1320-16800 Rs/annum).

Household indebtedness

Majority of the farmers availed short and medium terms loans. The short term loan was taken by 81 per cent farmers and the average amount of loan worked out to be Rs.54,138/, out of which 11.5% was repaid till the time of survey. Similarly, about 6% of the beneficiaries surveyed availed medium term loan, the average loan amount being Rs. 68,458/-. Only 2% of the loan amount could be paid till the time of survey. The whole amount of long term loan was yet to be paid as revealed by the farmers during the survey.

Change in migration profile

Only 2 per cent of the surveyed families reported about the family migration in the pre programme phase and this status reduced to 0.7% during post programme phase. However, the duration of migration reduced slightly. While the families migrated for an average of 4 months in a year prior to programme implementation, this reduced to 3 months/ year after the programmed implementation. Similarly, male migration declined from 3.3 per cent before the programme to 1.3 per cent after the programme. The seasonal migration was reported by only 0.7 per cent farmers prior to watershed programme. Across the clusters, Dharampur and Dahegaon reported high male migration as compared to other clusters. The whole family migration was about same in all the clusters except for Dharampur and Berala-Yeota. On the other hand, cluster like Berala-Yeota reported high incidence of seasonal migration, which was almost negligible in other clusters.

Table 3. Average value of asset owned before and after the watershed intervention

Asset		Average Value of asset (Rs/household)		
		Before programme*	After programme*	Per change*
A.	Farm asset			
	Well	61,137	77,530	24.7
	Motor	15,003	18,558	23.7
	Thresher	49,383	49,383	0.0
	Bullock cart	7,608	9,166	20.5
	Cattle shed	19,168	19,666	2.6
	Irrigation pump	11,391	14,882	30.6
B.	Consumer durables			
	House	54,718	56,656	3.5
	Cooking gas	3,198	5,510	72.3
	Refrigerator	4,689	8,078	72.3
	Television	4,492	5,238	16.6
	Motor cycle	27,717	29,936	8.0
	Telephone	1,262	2,336	85.0

(Source: Data collected from field) * At 2006 prices

Change in poverty level

About 46% of farmers surveyed were below the poverty line prior to watershed programme based on the sample survey data. This decreased to 29% after the programme implementation. The project had positive impact and helped people enhance income level, which increased per capita expenditure on consumption of pulses, which increased from 8% of total food expenditure in pre programme phase to 14% in post phase, leading to better nutritional security.

Vidarbha is mainly a rainfed farming region, the crops being dependent on vagaries of monsoon. The uneven distribution of annual precipitation (700mm) of the region, which is sufficient to support the production system, in absence of water conservation measures, remains un-utilizable. This has made living of the farmers unstable and difficult with uncertainty in yield and income. The region has been reeling under its worst agrarian crisis ever due to truant rainfall leading to massive crop failure in cotton, paddy, pulses and soybean. The low crop and animal productivity has resulted in low livelihood insecurity. This coupled with inadequate finance for agriculture, lack of supporting enterprises such as post harvest cottage and agro based industries and unavailability of good quality seed, timely availability of desirable fertilizers and pesticides has compounded the farmers' woes. Farmers' perception about suicide cases in the watershed clusters revealed that repeated crop failures and the resulting indebtedness mostly led to suicides (Fig. 3). Under these circumstances, watershed programme helped in availability of more irrigation water due to water storage structures which resulted in stabilization in production and improvement in crop income.

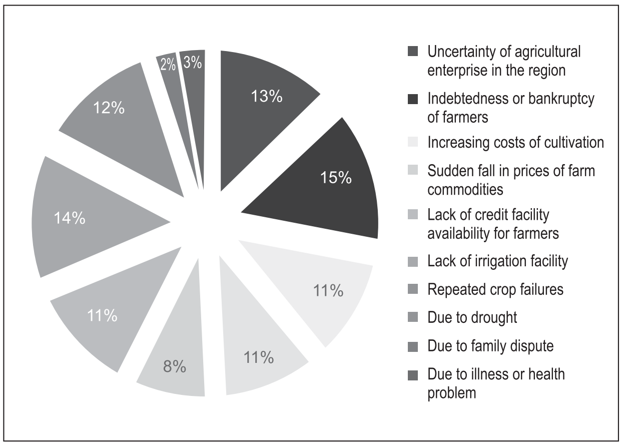


Fig. 3. Reasons of suicide as reported by farmers of the watershed clusters
(Source: Report submitted to NABARD by CS&WCR&TI, RC, Vasad)

This supplemented with income from enhanced milk production due to better vegetation status helped farmers improve their socio-economic conditions. Repayment of loans particularly the short term loans taken for purchasing of agricultural inputs for crop cultivation could be partly repaid as a resulted of the watershed management giving higher crop production.

The improved water conservation and resulted in increased area during summer in some clusters. The changes, however, were not uniform for all the watershed clusters studied and the differential impact of the programme was attributed to rainfall, natural resource endowment and the efficacy of the programme activities across the clusters in the region. In fact, selection of sites, design and execution of watershed activity played a crucial role. Despite same average rainfall, Asoli reported better crop production and productivity change as compared to Mothegaon. This could be attributed to better design, execution and maintenance of farm bunds with outlets. This was reflected in water availability including soil moisture regime. This supported with production interventions resulted in increased income, poverty reduction and reduced migration outside the village. Similarly, Berala-Yeota experienced improved cropping intensity and crop productivity post watershed programme due to better efficacy in execution of programme interventions like farm bunds with pipe outlet. Proper design, location and work execution of contour trenches in non arable land of Dahegaon, similarly, resulted in better vegetative coverage post monsoon. Little improvement in these aspects would further enhance the impact of the programme.

Despite positive change in socio-economic condition of farmers resulting from watershed programme, the economic gain from basic livelihood enterprise viz., agriculture was too little to push them out of the vicious circle of misery as reflected in minor changes in loan repayments and out-migration. This calls for strengthening subsidiary input supply chain like market intelligence and remunerative prices of crop through convergence of different programmes with watershed management programme. The apathy of development agencies in the past should be more than compensated by vigorously addressing the issues of inclusive growth of the local stakeholders in Vidarbha region. The watershed programme funded by development agency like NABARD is a sincere attempt. The impact of watershed management, though, was small, yet the change brought about on different socio-economic dimensions strengthens argument for its replication to entire region with more intensity. As per the estimate of the Commissionerate, Government of Maharashtra, only 27% of the area is available for watershed development, out of which 19% area has been treated with watershed intervention. Of the 9.04 lakh hectare available area for watershed treatment in Vidarbha region, about 3.3 lakh ha under DPAP and 0.44 lakh ha under dark and grey watershed area is under priority. The Government of Maharashtra has earmarked Rs 275000 crore for 12^{th} Five Year Plan with emphasis of water conservation and rainfed agriculture and allied sector. This includes interventions to protect dry land farming and consistent and predictable policy regime for pricing, marketing and export. It is recommended that high priority should be given to early completion of remaining area under watershed management programme.

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Effect of sowing dates and irrigation schedules on yield and quality of Indian mustard (*Brassica juncea* L.)

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ABSTRACT

A field experiment was conducted during the *rabi* seasons of 2010-11and 2011-12 to assess the effect of different dates of sowing and irrigation schedules on Indian mustard (*Brassica juncea* L.). The experiment was conducted with split plot design and replicated three times. Treatments consisted of three dates of sowing *viz.*, D_1 (30th October), D_2 (14th November) and D_3 (29th November) allotted to main-plot and four irrigation schedules *viz.*, I_1 (Irrigation at 0.5 IW / CPE ratio), I_2 (Irrigation at 0.7 IW / CPE ratio), I_3 (One irrigation at pre-bloom stage) and I_4 (Two irrigation at pre-bloom stage + pod filling stage) assigned to sub-plots. Results revealed that all the yield attributes increased significantly under 30th October sowing. Number of siliquae plant^{-1}, number of seeds siliqua^{-1}, length of siliqua (cm) and seed and stover yields were significantly higher with irrigation at 0.7 IW/ CPE ratio. Interaction between dates of sowing and irrigation schedules was significant on mustard seed yield. The highest seed yield (16.4 q ha^{-1}) was recorded with 0.7 IW / CPE ratio sown on 30th October. The highest net return and B:C ratio were recorded under 30th October sowing and irrigation at 0.7 IW / CPE ratio. The highest water-use efficiency (WUE) (146.5 kg ha^{-1} cm^{-1}) was recorded under 30th October sowing. Among irrigation scheduling, one irrigation given at pre-bloom stage resulted in the highest WUE (148.9 kg ha^{-1} cm^{-1}). 30th October sowing with irrigation at 0.7 IW / CPE ratio proved most remunerative and economically feasible for cultivation of Indian mustard under the agroclimatic conditions of eastern Uttar Pradesh.

Key words: Dates of sowing, irrigation scheduling, seed yield, quality, water-use efficiency and economics

INTRODUCTION

Mustard is the second most important edible oil-seed crop after groundnut. It plays an important role in the oil-seed economy of the country. India occupies the third position in mustard production in World after China and Canada. In India, during 2009-2010, the mustard crop had production of about 6.40 m t from an area of 6.45 m ha with an average productivity of 1184 kg ha^{-1}. However, in U.P it is grown in 0.82 m ha with production of 0.90 m t. The average productivity in U.P. is 1141 kg ha^{-1}, which is 3.6% lower than the national average productivity (Anonymous, 2010).

Among the different agronomic practices, optimum sowing time plays an important role to fully exploit the genetic potentiality of a variety as it provides optimum crop growing environment, such as temperature, humidity and light etc. Sowing time is one of the most important non monetary input which influences to a great extent on both the productivity of seed and oil. Mustard is usually sown by the end of September to first fortnight of October in north India when grown as a sole crop or sown as mixed or intercrop. But with the development of new varieties of crops and adoption of multiple cropping systems under irrigated conditions, it has become essential to extend their sowing from October to mid November or even later. Delayed sowing would influence adversely the crop performance. It necessitates developing suitable agro techniques to augment the productivity of the crop. Water is very precious and scarce input during winter, its efficient utilization is quite necessary. Efficient use of irrigation water aims at the utilization of available water resources to the maximum possible

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advantages in the crop production. As such, use of this costly and scarce input through efficient water management practices is very essential. Among the several recognized criteria of irrigation scheduling, the climatological approach (IW / CPE ratio) is very useful. Evapo-transpiration by a full crop cover is closely associated with the evaporation from an open pan. Information on optimum water requirement of mustard is not available under agro-climatic conditions of eastern U.P., which calls for a generating more information on the combined effect of mustard to the different dates of sowing and irrigation scheduling based on IW / CPE ratio for greater yields.

MATERIALS AND METHODS

The experiment was conducted at Agronomy Research Farm of N.D. University of Agriculture & Technology, Faizabad (U.P.) during *rabi* seasons of 2010-11 and 2011-12. Geographically experimental site is situated at 26^0 472 N latitude; 82^0 122 E longitude and an altitude of 113 m above MSL in the Indo-Gangetic regions of Eastern U.P. Soil of the experimental site was silt loam, having 0.32% organic carbon (Experimental soil was reclaimed having very low vegetation and high salt concentration and low percolation rate), 180.4 kg / ha available N, 18.4 kg / ha available P_2O_5, 290.0 kg / ha available K_2O, 7.9 pH and 0.33 dsm^{-1}EC. The experiment was conducted in a split-plot design replicated there times. Treatments consisted of three dates of sowing *viz.*, D_1 (30^{th} October), D_2 (14^{th} November) and D_3 (29^{th} November) allotted to main-plot and four irrigation schedules *viz.*, I_1 (Irrigation at 0.5 IW / CPE ratio), I_2 (Irrigation at 0.7 IW / CPE ratio), I_3 (One irrigation at pre-bloom stage) and I_4 (Two irrigation at pre-bloom stage + pod filling stage) assigned to sub-plots. Seeds were sown at 30 cm spacing with the help of *deshi* plough. Thinning was done twice at emergence stage at 10 days after sowing (DAS) and 20 DAS in order to maintain optimum plant to plant distance of 15 cm.

RESULTS AND DISCUSSION

Yield attributes

Number of siliquae $plant^{-1}$, length of siliqua, number of seeds $siliqua^{-1}$ and 1000-seed weight were decreased with delay in sowing from 14^{th} November to 29^{th} November (Table 1). However, the differences between 30^{th} October and 14^{th} November sowing were not significant. Late sowing (29^{th} November) restricted the growth duration and induced early flowering, delayed pod initiation and seed setting to the great extent as compared to 30^{th} October and 29^{th} November sowing due to low temperature during the months of December and January, which not only restricted the growth but also induced slow of pollination and flowering in late sown crop (Which is the confirmation of the study by Singh and Singh, 2002 and Dhaliwal *et al.*, 2008).

Number of siliquae $plant^{-1}$, length of siliqua and number of seeds $siliqua^{-1}$, influenced significantly due to different irrigation schedules. Higher values

Table 1. Effect of sowing dates and irrigation schedules on yield and yield attributes, and quality of mustard (*Brassica juncea* L.) (averaged over 2 years)

Treatment	No. of siliquae $plant^{-1}$	Length of siliqua (cm)	No. of seeds $siliqua^{-1}$	1000-seed weight (g)	Seed yield (q ha^{-1})	Stover yield (q ha^{-1})	Harvest index (%)	Oil content (%)	Protein content (%)
Dates of sowing									
D_1	400	5.4	13.5	4.7	14.7	45.0	24.6	40.1	20.2
D_2	365	5.2	13.1	4.7	12.8	40.0	24.2	39.2	19.0
D_3	310	4.6	11.5	3.7	10.0	30.2	24.9	37.9	18.7
SEm±	13.18	0.12	0.27	0.16	0.29	1.04	0.66	1.42	0.30
CD at 5%	51.75	0.46	1.04	0.64	1.15	4.08	NS	NS	1.16
Irrigation schedules									
I_1	321	4.8	12.0	4.3	10.5	33.9	23.7	38.4	18.7
I_2	399	5.3	13.5	4.5	14.5	45.6	25.6	39.8	19.9
I_3	333	4.9	12.3	4.3	11.0	35.7	23.6	38.6	18.9
I_4	379	5.2	13.0	4.4	13.9	41.5	25.4	39.4	19.7
SEm±	7.44	0.08	0.19	0.09	0.20	0.62	0.51	0.77	0.23
CD at 5%	22.10	0.23	0.56	NS	0.59	1.84	NS	NS	0.69

of these yield contributing characters were observed when crop was irrigated at 0.7 IW/CPE ratio. This might be due to the fact that as reproductive organs are determined much before the emergence of siliqua and largely governed by the vegetative growth and initiation of flower primordia. Better vegetative growth build ultimately into higher yield attributing characters due to increased absorption of mineral nutrients under adequate available soil moisture under adequate moisture condition growth characters were highest which contributed for highest yield attributes due to increased photosynthetic activity and translocation of photosynthates from source to sink.

Yield

Seed and stover yields of mustard were significantly affected due to date of sowing (Table 1). Crop sown on 30th October recorded significantly higher seed yield as compared to 14th November and 29th November sowing mainly due to better translocation of photosynthates from source to sink. But, it decreased drastically as the sowing was delayed further. A similar trend was also recorded in stover yield of mustard. This might be due to poor growth and translocation of photosynthates from source to sink. All the growth and yield attributes which determined the seed and stover yield of mustard crop, were adversely influenced when the sowing was delayed beyond 30th October. Crop sown later during first fortnight of November experienced comparatively cool climate, which reduced the rate of photosynthesis and other growth as well as development processes of plants resulting in reduced seed and stover yields. Significant reduction in seed and stover yields of mustard in delayed sowing, have also been reported by several other workers; (Panda *et al.*, 2004 and Khushu and Singh 2005).

Yield is the result of interplay of various growth characters and yield attributes. Seed and stover yields were significantly affected by different irrigation scheduling (Table 1). Higher seed and stover yields were recorded under irrigation given at 0.7 IW/CPE ratio might be due to better translocation of photosynthates from source to sink as the result of proper utilization of nutrients and led to higher yields. The findings of Sharma *et al.*, 2006 also confirms the result of present finding.

Quality

The quality of mustard seeds was measured in the term of oil and protein contents which were markedly influenced by dates of sowing (Table 1). Oil content was not significantly influenced due to dates of sowing. Protein content was significantly higher under 30th October sown crop as compared to 29th November sowing. Protein contents in seeds could increase as a result of decreased oil and carbohydrate content due to reduced dilution effect. The findings are in close proximity of Ghanbahadur *et al.*, (2006).

Oil content in seeds was not affected significantly due to irrigation scheduling. However, protein content was significantly influenced due to irrigation schedules (Table 1). Higher protein content was recorded with irrigation given at 0.7 IW/CPE ratio possibly due to higher N content in seeds as the result of better nutrient absorption under adequate availability of soil moisture.

Water-use efficiency

Water-use efficiency (WUE) was influenced by date of sowing (Table 2). Crop sown on 30th October recorded maximum WUE followed by 14th November sowing and then delayed sowing (29th November). Minimum WUE under delayed sowing ascribed due to proportionately lower yield to that of water used.

Table 2. Effect of sowing dates and irrigation schedules on water-use efficiency (averaged over 2 years)

Treatments	Seed yield (kg ha^{-1})	Total water received (cm)	Water use Efficiency (kg ha^{-1} cm^{-1})
Date of sowing			
D_1	1465	10.00	146.5
D_2	1279	10.65	120.09
D_3	1005	10.53	95.44
Irrigation scheduling			
I_1	1053	7.39	142.49
I_2	1452	13.39	108.44
I_3	1101	7.39	148.99
I_4	1394	13.39	104.11

Seed yield per unit of water applied decreased with increasing the number of irrigation mainly due to proportionately less increase in seed yield compared to water applied which led for decreased WUE under the higher number of irrigation (Table 2). Per unit increase of water under irrigated plots decreased the water use efficiency due to irrigation. Higher water use efficiency (148.99 kg ha^{-1} cm^{-1}) was recorded under one irrigation given at pre-bloom stage (I_3) followed by 0.5 IW/CPE ratio

Table 3. Effect of sowing dates and irrigation schedules on economics of various treatment combinations (averaged over 2 years)

Treatment combinations	Gross income (Rs. ha^{-1})	Total cost of cultivation (Rs. ha^{-1})	Net return (Rs ha^{-1})	B:C ratio
D_1I_1	32,748	19,740	13,008	0.66
D_1I_2	42,652	20,240	22,402	1.11
D_1I_3	36,589	19,740	16,849	0.85
D_1I_4	41,273	20,240	21,033	1.04
D_2I_1	28,251	19,740	8,511	0.43
D_2I_2	40,773	20,240	20,533	1.01
D_2I_3	27,180	19,740	7,440	0.38
D_2I_4	37,784	20,240	17,544	0.87
D_3I_1	21,937	19,740	2,199	0.11
D_3I_2	30,039	20,240	9,799	0.48
D_3I_3	22,994	19,740	3,254	0.16
D_3I_4	29,973	20,240	9,733	0.48

mainly due to proportionately higher increase in seed yield compared to water applied. The findings of Sarkar *et al.*, 2010 also confirms the result of present finding.

Economics

Variation in common cost was recorded due to cost of irrigation. The cost of cultivation increased with increasing levels of irrigation. The highest cost of cultivation Rs. 20240.00 ha^{-1}, might be due to increasing levels of irrigation. The highest net return (Rs. 22402.00 ha^{-1}) was recorded with crop sown on 30th October with irrigation given at 0.7 IW/CPE ratio followed by the same sowing date with two irrigation given at pre-bloom stage + pod filling stage (Rs 21033.00 ha^{-1}), might be due to highest seed yield under adequate moisture availability (Table 3). Similar trend was also noted in gross income. The highest net income per rupee invested *i.e.* (Rs. 1.11) was recorded with sowing on 30th October at 0.7 IW/CPE ratio which registered the highest net return ha^{-1}, yet failed to provide highest net income per rupee invested because of the highest cost of cultivation. The results are in close accordance with Irraddi and Mansur (2008).

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Nutrient availability for *eucalyptus tereticornis* and *acacia auriculiformis* tree plantations in a coal fly ash amended ultisol

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ABSTRACT

Electrostatic precipitator fly ash procured from Ballarpur Industries Ltd was used as a soil ameliorant for the rehabilitation of a 20 acre degraded land in Dhenkanal District of Orissa. The Ultisol soil of the selected area was amended with fly ash alone in one set of experiments and with fertilizers along with fly ash in another at concentrations ranging from 0, 6, 12, 18 and 24 % . Seedlings of multipurpose tree species namely *Eucalyptus tereticornis and Acacia auriculiformis* procured from Ballarpur nursery were planted according to split-plot design. No drastic change in pH, organic carbon, nitrogen, phosphorous and potassium were observed and the electrical conductivity showed an increase with rise in fly ash content in soil. The growth monitored over a period of four years showed faster establishment of herbaceous plants and 18 to 24 per cent fly ash was found beneficial for maintaining nutrient balance and growth of agroforestry species with *Eucalyptus tereticornis* performing better under hardy conditions.

Keywords: Multipurpose tree species, fertilizers, fly ash, nutrients, degraded lands.

INTRODUCTION

Nutrient recovery is the most important aspect of active rehabilitation of degraded lands, which in turn depends upon regeneration of the topsoil. Management of degraded lands site-specific depending upon geology, geography, land use pattern, climate and soil characteristics of the area (Palumbo *et al*., 2007; Akala and Lal, 2000). Plantations of fast-growing species managed in successive crops accumulate large amounts of nutrients in short periods of time and these in combination with appropriate soil ameliorants such as fly ash, fertilisers, organic manure etc. can lead to high productivity (Adholeya *et al*., 1998; Goyal *et al*., 2002; Cavaleri *et al*., 2004).

Balanced and optimal usage of organic manures / fertilizers (e.g. green manures, recyclable wastes, crop residues, and FYM), biofertilizers and solid wastes such as fly ash and soil amendments / ameliorants (EFP Reference Guide) influence crop growth and soil improvement according to crop requirements and agroclimatic considerations. Particular nutrients and counteract imbalances in soil are targeted and crop harvest achieves significance in terms of removal of nutrients (Walker *et al*., 2006; Malhi *et al*., 2008).

Plant growth is dependent upon a favourable combination of environmental factors including nutrients, water, specific temperature and the absence of detrimental factors such as extreme acidity or alkalinity, salinity, or high availability of potentially toxic metals (Brady, 1995). Crops need seventeen essential plant nutrients for growth and these are generally provided by the soil in sufficient quantity. These nutrients include three major (N, P, K), three secondary (Ca, Mg, S) and seven micronutrients (B, Cl, Cu, Fe, Mn, Mo, Zn). Quantities of N-P-K are usually applied in the greatest amounts to supplement the nutrients available from the soil to meet the crop need (Brady, 1995).

Coal is one of the most extensively used energy source which generates fly ash, as a major combustion product which needs careful eco-management since its disposal is an issue of concern. Fly ash has been used for neutralization

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of acidic mine spoils and restoration of nutrient balance in alkaline degraded lands (Adriano and Weber, 2001). Degraded lands are typically deficient in organic carbon and the success of any reclamation strategy is based on return of organic carbon to levels similar to that in undisturbed or normal cropland soil (Amonette *et al*., 2003). A combined application of fly ash at optimum dose and mineral fertilizers can augment and impart balanced plant nutrition and improve soil fertility (Uyovbisere and Elemo, 2000).

Apart from acting as a rich source of plant nutrients, the major benefit of fly ash for plant nutrition is the indirect effect of pH adjustment on nutrient availability (Yunusa *et al*., 2005). Most naturally existing elements can be found in fly ash and a number of investigators agree that many of the trace elements in fly ash show a definite concentration trend with decreasing particle size (Stehouwer *et al*.,1995 a, b; Taylor and Schuman, 1988). Fly ash addition to soil has generally shown a consistent and positive impact on plant production and nutrient profile of soil (Aitken and Bell, 1985).

MATERIALS AND METHODS

A plantation of *Eucalyptus tereticornis* and *Acacia auriculiformis* was established in July 1998, at village Durgaprasad, district Dhenkanal, Orissa, India in collaboration with Ballarpur Industries Ltd. The land was partially degraded with laterite rocks outcropping at several places in the plantation. The soil belonged to the order Ultisols and the texture ranged from light to heavy .Dhenkanal region is located at longitude 85°58' to 86°2' east and latitude 20°29' to 21°11' with a geographical area of 4452 km $^{2.}$ The area receives an annual rainfall of 1696 mm with minimum and maximum temperature ranging from 19.6°C to 33.3°C Electrostatic precipitator fly ash (ESP) for the experiment was procured from electrostatic precipitator of FBC boiler (source of coal: Talcher coal mines; F grade: 40per cent coal ash) and it was transported to the site in bulk. Bulk density of fly ash used was 0.9 Mg m^{-3} and the maximum water holding capacity was 67 per cent. Some physico-chemical characteristics of Electrostatic precipitator fly ash and experimental soil are given in Table 1.

Seedlings of two multipurpose tree species namely *Eucalyptus tereticornis and Acacia auriculiformis* were procured from Ballarpur nursery and planted for the experiment. The seedlings were 3-4 months old and 30 cm long. Two sets of experiments were conducted, one with each tree species. The experimental plantations were based on a split-plot design. Each block comprised of 7x7 plants with plant to plant and row to row distance of 2m. The main plot treatments comprised of (a) an unfertilized, control; and (b) fertilizing each plant with a mixture comprising of 17.5 g diammonium phosphate (DAP) , 5g muriate of potash (MOP) and 20g neem cake at the time of plantation followed by 50g urea after three months. The sub plot treatments comprised of applying fly ash in pits (30x45x45 cm) different concentrations namely 0, 6, 12, 18 and 24 per cent after mixing with soil and chemical fertilizers as per experimental plan. The rhizosphere soil was collected at yearly intervals from 2001 to 2004 to analyze for pH and electrical conductivity (Jackson, 1967), available phosphorous (Bray and Kurtz, 1945), available nitrogen (Subbiah and Asija, 1956) and available potassium (Merwin and Peech, 1951).

Table 1. Chemical characterization of soil and ESP fly ash (BILT, Choudwar) used in tree plantation of *Acacia auriculiformis* and *Eucalyptus tereticornis*.

Element	Soil	ESP ash (Electrostatic precipitator ash)
pH	5.82	5.30
EC (µS cm^{-1})	80	1140
N (%)	0.12	-
P (%)	0.011	0.108
K (%)	0.034	0.107
S (%)	0.00015	0.001
Ca (%)	0.17	0.34
Mg (%)	0.043	0.038
Na (%)	0.011	0.041
Fe (%)	2.95	0.676
Cu (ppm)	6	20
Zn (ppm)	73.5	79
Mn (ppm)	1061	739
Mo (ppm)	2.8	4.0
As (ppm)	3.5	6.2
Se (ppm)	2.35	3.6
Pb (ppm)	158	35
Ni (ppm)	33.3	13
Cd (ppm)	1.75	1.9
Cr (ppm)	51	330
Co (ppm)	108.2	58
Radioactivity in Bq kg^{-131}		
Ra^{226} (370)	31	100
Ac^{228} (2-40)	75	141
K^{40}(810-925)	260	376

(*Page *et al*., 1979 and Goyal *et al*., 2002) (*Values in parenthesis are permissible limits:* Pendias and Pendias (1984). *(N.A.: Not Available)*

RESULTS & DISCUSSION

pH and Electrical Conductivity

The pH of rhizosphere soil under various fly ash treatments of *Acacia* and *Eucalyptus* did not exhibit any marked difference over the study period indicating no detrimental effect of fly ash incorporation on soil pH. The pH ranged from acidic to neutral over the years with greater inclination towards acidity in fertilizer amended soil. The pH of rhizosphere control without fertilizer (F0T1) and fertilized control (F0T2) ranged from 5.36 to 6.35 and 5.62 to 6.20 respectively without any distinct variation with increased fly ash percentage.

Electrical conductivity (EC) in rhizosphere control (F0T1) of *Acacia* and *Eucalyptus* ranged from 70.0 to 166.7 and that of fertilized control (F0T2) varied from 40.0 to 136 dS m^{-1}. EC was observed to be slightly higher in fertilizer amended soil. Rhizosphere control soil (F4T1) amended with 24 % fly ash was observed to have highest EC corresponding to 128.5 and 80 dS m^{-1} for *Acacia* and *Eucalyptus* . A similar pattern was observed in F4T2 treatment of *Eucalyptus* where EC was maximum corresponding to 168.3 and 132.8 dS m^{-1} for 24 % fly ash amendment respectively.

Acacia auriculiformis

Organic carbon

Organic carbon showed marked increase with time in soil amended with fly ash alone and in conjunction with fertilizers. In F0T1 and F4T1 organic carbon ranged from 0.33 to 0.58 and 0.49 to 0.79 per cent respectively. In case of soil admixed with fly ash and chemical fertilizers organic carbon in F0T2 and F4T2 soil ranged from 0.55 to 0.76 and 0.65 to 0.83 per cent. In rhizospheric soil amended with 18per cent fly ash organic carbon increased up to 0.79 percent in F3T1, soil containing only fly ash and 1.00 in F3T2, soil containing fly ash and fertilizers both.

Nitrogen

Nitrogen in soil did not show any marked variation with addition of fly ash and in soil amended with fly ash and fertilizers both a similar pattern was observed. Nitrogen in rhizospheric soil analyzed over a period of four years did not exhibit any significant variation and ranged from 50 to 100 mg kg^{-1} in soil amended with fly ash alone (T1). In F0T1 and F4T1 nitrogen was 100 and 90 mg kg^{-1}. In soil amended with fly ash plus fertilizers (T2) nitrogen ranged from 20 to 100 mg kg^{-1}. In F0T2 and F4T2 nitrogen was 50 and 90 mg kg^{-1}.

Phosphorous

Phosphorous ranged from 0.16 to 63.0 mg kg^{-1} in soil amended with fly ash alone (T1). The control F0T1 was found to have 0.16 mg kg^{-1} phosphorous which increased to 3.97 mg kg^{-1} with fly ash dose up to 24 per cent, for F4T1 . Phosphorous ranged from 2.96 to 68.7 mg kg^{-1} in soil amended with fly ash plus chemical fertilizers alone (T2). The control F0T2 was found to have 4.55 mg kg^{-1} phosphorous which increased to 44.2 mg kg^{-1} with fly ash dose up to 24 per cent .

Potassium

Potassium ranged from 50 to 300 mg kg^{-1} in soil amended with fly ash alone (T1). The control F0T1 was found to have 103.7 mg kg^{-1} phosphorous which increased to 131.4 mg kg^{-1} with fly ash dose up to 24 per cent, for F4T1 . Potassium ranged from 60 to 335 mg kg^{-1} in soil amended with fly ash plus chemical fertilizers alone (T2). The control F0T2 was found to have 124.6 mg kg^{-1} potassium which increased to 335 mg kg^{-1} with fly ash dose up to 24 per cent .

Eucalyptus tereticornis

Organic carbon

Organic carbon showed marked increase with time in soil amended with fly ash alone and in conjunction with fertilizers. In F0T1 and F4T1 organic carbon ranged from 0.38 to 0.71 and 0.62 to 0.75 per cent respectively. In case of soil admixed with fly ash and chemical fertilizers organic carbon in F0T2 and F4T2 soil ranged from 0.32 to 0.61 and 0.45 to 1.12 per cent. In rhizospheric soil amended with 18 per cent fly ash organic carbon increased up to 0.92 percent in F3T1, soil containing only fly ash and 1.20 in F3T2, soil containing fly ash and fertilizers both.

Nitrogen

Nitrogen did not show any significant variation in soil amended with fly ash (T1) and fly ash plus fertilizers (T2) analyzed over a period of four years. Nitrogen ranged from 30 to 90 mg kg^{-1} in soil amended with fly ash alone. Increasing fly ash from 6 to 24 per cent in soil did not bring any change in the initially observed value of 80 mg kg^{-1} in F0T1 which continued till F4T1 over the years. Nitrogen ranged from 50 to 100 mg kg^{-1} in soil amended with fly ash and chemical fertilizers. Increasing fly ash percentage in soil did not bring any change in the initially observed value of 60 mg kg^{-1} in F0T2 which continued till F4T2 over the years.

Phosphorous

Phosphorous ranged from 0.6 to 54.5 mg kg^{-1} in soil amended with fly ash alone (T1). The control F0T1 was found to have 2.5 mg kg^{-1} phosphorous which increased to 3.8 mg kg^{-1} with fly ash dose up to 24 per cent, for F4T1 . Phosphorous ranged from 3.5 to 61.0 mg kg^{-1} in soil amended with fly ash plus chemical fertilizers alone (T2). The control F0T2 was found to have 3.5 mg kg^{-1} phosphorous which increased to 61.0 mg kg^{-1} with fly ash dose up to 24 per cent, for F4T1.

Potassium

Potassium ranged from 58 to 315 mg kg^{-1} in soil amended with fly ash alone (T1). The control F0T1 was found to have 104.2 mg kg^{-1} phosphorous which increased to 300 mg kg^{-1} with fly ash dose up to 24 per cent, for F4T1 . Potassium ranged from 62.6 to 340 mg kg^{-1} in soil amended with fly ash plus chemical fertilizers alone (T2). The control F0T2 was found to have 85.4 mg kg^{-1} phosphorous which increased to 70.9 mg kg^{-1} with fly ash dose up to 24 per cent .

Increasing fly ash percentage in soil up to 24 % did not have any detrimental effect on N, P, K . Nitrogen did not show any significant variation over the years for Acacia and Eucalyptus. Available phosphorus increased level in rhizosphere soil of *Acacia* compared to *Eucalyptus* for treatment T1 and T2. Overall 24 % fly ash amendment was favourable for available K, with increased K level in rhizosphere soil of *Acacia* compared to *Eucalyptus* for treatment T1 and T2.

Two-way ANOVA

Fly ash accounted for 5.14 and 2.78% of the total variance with a 78 and 91% chance of randomly observing the effect of fly ash on nitrogen in rhizospheric soil of *Acacia* and *Eucalyptus*. The percentage of total variance was 9.83 and 2.05 for the effect of fly ash on this experiment. Overall 2-way ANOVA of N, P, K showed that fly ash had no significant effect on concentration of nutrients with increased percentage in soil (Table 2).

Electrostatic precipitator (ESP) fly ash has the inherent potential of a soil ameliorant for rehabilitation of degraded lands alone and in conjunction with chemical fertilizers due to its heterogenous chemical nature. Fly ash when used at an appropriate dose benefits plant growth and soil as was observed in the present study. In turn multipurpose tree species of *Acacia auriculiformis* and *Eucalyptus tereticornis* would provide not only fuel and fodder in due course of time but also positively influence the nutrient profile of soil. The fly ash used in the study was observed to be rich in micronutrients which are beneficial for maintaining nutrient balance in soil (Aitken and Bell, 1984; Sikka and Kansal, 1994).

Typically Ultisols are red to yellow in color and are quite acidic, often having a pH of less than 5. The red and yellow colors result from the accumulation of iron oxide which is highly insoluble in water. Majority of nutrients are typically deficient in Ultisols, therefore fertilizers in combination with soil ameliorants such as fly ash facilitate proper nutrient management. Electrical conductivity of soil increased gradually with increase in percentage of fly ash (Kalra et al., 1997) and this was also observed here as electrical conductivity increased from 0.467 to 0.746 which could have been related to Fe-content of fly ash (Sikka and Kansal, 1994).

The addition of fly ash to degraded soil at the plantation site did not alter the pH greatly since the soil by nature was acidic with pH nearly same as that of the ESP ash used. The role played by the inherent buffering capacity of the soil might have

Table 2. Two-way ANOVA of nitrogen, phosphorous and potassium data in rhizosphere soil of *Acacia auriculiformis (A.a)* and *Eucalyptus tereticornis (E.t)* amended with 0-24% fly ash (v/v) without chemical fertilizers (T1) and with chemical fertilizers (T2).

		Fly ash		Treatment		Fly ash x Treatment	
		F	% Var	F	% Var	F	% Var
A.a	N	0.42^{a}	5.14	0.06^{a}	0.20	0.38^{a}	4.66
	P	0.12^{a}	1.55	0.22^{a}	0.74	0.06^{a}	0.89
	K	0.83^{a}	9.83	0.005^{a}	0.02	0.13^{a}	1.58
E.t	N	0.24^{a}	2.78	1.48^{a}	4.21	0.67^{a}	7.73
	P	0.66^{a}	7.87	0.62^{a}	1.87	0.08^{a}	1.01
	K	0.16^{a}	2.05	1.11^{a}	3.48	0.006^{a}	0.78

helped in resisting pH changes. The hydroxide and carbonate salts in fly ash have been reported to influence its principal beneficial chemical characteristics in terms of pH and electrical conductivity (Yunusa *et al*., 2005; Cetin and Pehlivan, 2007) which in turn influence available nutrients. A distinct rise in EC was observed especially in the rhizosphere soil of *Acacia auriculiformis*, with increasing fly ash percentage due to presence of soluble salts (Wong and Wong ,1989) and increased soluble major and micronutrients (Eary *et al*., 1990). Overall EC ranged from 20.0 to 260 dS m^{-1} in both tree species with highest observed in soil amended with 24 % fly ash over the four-year study period.

In order to understand the positive influence of fly ash on soil health and fertility in terms of organic carbon, respiration etc. it is essential to analyse the properties of fly ash and classify fly ash for use (Pillai and Chaturvedi, 2012; Kovacik et al. 2011). A combination of fly ash and chemical fertilizers for plantation of forestry species *Acacia auriculiformis* and *Eucalyptus tereticornis* proved beneficial for organic carbon with positive results corresponding to as much as 18 percent fly ash amendment over the years.

In the case of *Acacia* , organic carbon increased from 0.58 percent in F0TI (fly ash alone) to 0.79 percent in F3T1 (18 percent fly ash). In the presence of chemical fertilizers also a similar trend was observed in control and fly ash amended soil with organic carbon showing an increase from 0.76 per cent in F0T2 to 1.00 per cent in F3T2 respectively. In *Eucalyptus* organic carbon increased from 0.71 percent in F0TI (fly ash alone) to 0.92 percent in F3T1 (18 percent fly ash). In the presence of chemical fertilizers also a similar trend was observed in control and fly ash amended soil with organic carbon showing an increase from 0.61 per cent in F0T2 to 1.20 per cent in F3T2 respectively. The presence of organic matter in soil in the form of leaf litter, rhizospheric exudates etc. helps in lowering the C/N ratio and provides organic compounds, which enhance organic carbon and microbial proliferation (Wong and Wong, 1986; Pitchel and Hayes, 1990).

Nitrogen in rhizosphere soil of the two species remained consistent without any particular variation over the years, both for soil with and without fertilizers without any detrimental effect which can be attributed to decomposition of leaf litter, etc resulting in enzyme-aided nutrient mineralization carried out by the native microbial population (Stevenson,1994).

Acacia species plays a role in soil stabilization, wasteland reclamation and fixation of atmospheric nitrogen which is attributed to its spreading densely matted root system. Available P and K increased in rhizosphere soil amended with 24 % fly ash and these nutrients were more in rhizosphere soil of *Acacia* compared to *Eucalyptus* for treatment T1 and T2. A decline in phosphorous content for soil in second year of plantation was observed which may be attributed to interference by calcium and magnesium in the root-soil solution interface (Sikka and Kansal, 1995; Page *et al*., 1979).

Fertilizers such as diammonium phosphate (DAP) contains approximately 48% P_2O_5 and provides more fertilizer phosphorous than any other material in addition to simultaneous supply of nitrogen . Besides, many of the unavailable phosphates in this fertilizer become available under acidic conditions in soil, thereby increasing the available phosphorus content (Taylor and Schumann, 1988; Brady, 1995). In due course the indigenous population of phosphate solubilizers also help in increasing phosphorus availability along with the use of phosphatic fertilizers (Gaind and Gaur, 1991).

Phosphorous content also increased in soil with the increase in percentage of fly ash amendment. This can be attributed to fly ash itself and partly because of some native phosphate solubilizers (Klose *et al*, 2004). Positive effect of fly ash application on crop productivity and increased phosphorous uptake may be attributed to reduced soil crust strength, improved texture of soil and water holding capacity besides presence of organic matter (Gaind and Gaur, 1991).The compounds present in organic matter react with interfering compounds thereby leaving the phosphates free and also help in the adsorption of phosphorus on humic compounds and silicate clays thus protecting the phosphates from microbial attack (Sims *et al*, 1995).

Acacia and *Eucalyptus* based replenishment of nutrients in degraded Ultisol using optimum dosage of fly ash can be strengthened as an eco-friendly and soil benefaction strategy. The long-term benefits of trees on amended soil include binding of the soil with the help of massive root systems and establishment of an organic cover over the soil along with above-and below-ground biomass production (Stomp *et al*., 1993). The soil organic carbon level increases eventually, thus improving soil physical and chemical properties. Forestry species improve the chemical properties of soil and to a certain extent the microbial cycling of nutrients along with an increase in organic carbon, phosphorous and potassium level in the soil (Kang *et al*., 1999).

CONCLUSIONS

Soil ameliorants/amendments aid soil conservation by improving soil structure and replenishing secondary nutrients and micronutrients .Coupled with other complementary measures, effective nutrient and soil management can help to reclaim degraded lands for long-term use. In the long run this would be manifested as increased longevity and productivity of suitable agricultural land, reducing the solid waste disposal issues per se.

The fundamental knowledge available on bulk composition and modes of occurrence of elements in fly ash is sufficient to carry out advanced, effective and environmentally sound exercises for its appropriate utilization and for deriving maximum benefits in agriculture and forestry owing to its heterogenous chemistry. The primary approach for recovery of degraded lands is to control erosion through plant cover in the short term and development of a self-sustaining community through colonization of tree species in the long term. The problem of accelerated recovery in these degraded lands may be partially solved by a stepwise time bound restructuring of vegetation and manipulation of nutrient cycling rate by sustainable resource use. Many such rehabilitation programmes involving waste management need to be designed, which would provide a pathway for environmental pollution prevention and abatement.

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Agroclimatic situation and profitability study of traditional cropping pattern in Koraput district in eastern ghat region of Odisha

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ABSTRACT

Koraput is a backward and tribal dominant district located in the Eastern Ghats Region of Odisha. Land degradation, subsistence farming, poor crop harvest, low income from agriculture and lack of employment opportunities have resulted in to acute poverty in this region. A thorough investigation has been done to ascertain the agroclimatic situations and economics of existing cropping pattern in Koraput district. The total cultivable land, forest area, and barren & unculturable area of district is about 34.5, 21 and 24% of its geographical area respectively. Gross cropped area is 372.78 thousand ha and cropping intensity is about 139%. The climatic situation is congenial for crop growth with temperature varying from 12^o C to 38^o C and annual rainfall of 1567 mm occurs in 83.9 rainy days. Majority of farmers (78.5%) of the district come under marginal and small category with average per capita land holding size of 1.53 ha. Present study reveals that major cropping pattern (Paddy: 114.28 thousand ha, Finger millet: 73.02 thousand ha, Niger: 38.14 thousand ha, Maize: 18.85 thousand ha and Pigeon pea: 5.45 thousand ha) is not at all economic due to lower net returns and benefit cost ratio (BCR). Higher net returns are obtained from ginger cultivation (Rs 1,47,500) followed by sweet potato (Rs 1,02,125), vegetables-*rabi* (Rs 1,02,000), vegetables-*kharif* (Rs 88,000), pigeon pea (Rs 31000), horse gram (Rs 20,700) and green gram (Rs 10,800). Higher BCR is found in case of sweet potato (4.93) followed by horse gram (4.91), pigeon pea (3.58), vegetables-*rabi* (2.76), vegetables-*kharif* (2.69), green gram (2.60), ginger (1.88), black gram (1.72), field pea (1.63) and niger (1.54). In order to get maximum returns, crops having higher net returns and BCRs to be allocated more area. Therefore, limited area should be put under paddy, finger millet, niger and maize to meet the minimum food requirement of the district, and surplus area to be used for growing crops like ginger, sweet potato, vegetables, pigeon pea, turmeric, horse gram and mung (green gram) having higher BCRs and net returns to make the agriculture profitable and sustainable.

Key words: Eastern ghat region, land degradation, subsistence farming, cropping pattern, net return, benefit cost ratio (BCR)

INTRODUCTION

Eastern Ghats covering an area of 19.8 M ha spread over 4 states of India *i.e.*, Tamil Nadu, Karnataka, Andhra Pradesh and Odisha. Out of it, the Eastern Ghats region of Odisha alone comprises 4.87 m ha area spread over its 10 districts (Sikka *et al.*, 2000, Dass *et al.*, 2009). Land degradation, subsistence farming with poor crop harvest, low input uses and lack of employment opportunities have resulted in to poverty in Eastern Ghats of Odisha (Dass *et al.*, 2009). In addition, the rising population, limited land for agriculture and more food demand in the region have led to the extension of cultivation on steep slopes vulnerable to erosion. The backward and tribal dominant Koraput district of Odisha falls under this region and is a true representative of Easten Ghats (Sudhishri *et al.*, 2006). Shifting cultivation is a most acute problem responsible for land degradation and is prevalent among tribals in Koraput district of Odisha (Naik *et al*., 2013). This region is endowed with potentially rich natural resources but subjected to various inherent problems like undulating topography, intense rainfall, severe soil erosion, low fertility of

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soil, traditional farming practices, less intensive and low remunerating cropping systems, poor crop yield and low income from agriculture. Keeping in view the above and to find out a solution, a thorough investigation has been carried out to ascertain the existing land uses, climatic features, soil types, irrigation coverage, major crops / cropping pattern, crop wise investments and net returns, and crop economics (Benefit cost ratio) in respect of Koraput district.

MATERIALS AND METHODS

Koraput district is located in the extreme southern part of Odisha in the eastern plateau and hill region (Agro- Climatic Zone VII) in Eastern Ghats. The district lies between latitude of 17° 4' N to 20° 7' N and longitude of 81° 24'4"E to 84.2°E at altitude varies from 500 to 1600 m above mean sea level. It is bounded by Rayagada (Odisha) and Srikakulum (A.P) districts in the east, Malkangiri (Odisha) and Bastar (C.G) districts in the west, Nabarangapur and Rayagada districts in the north and Vizianagaram and Vizag (A.P) districts in the south. The district having 881 thousand ha of geographical area occupies 3rd rank in the state.

As per the 2011 census, the total population of the district is 13.79 lakh with population density 157 / km^2. The scheduled castes and scheduled tribes constitute 13.04% and 49.62% of the district population. The economy of Koraput district is primarily based upon agriculture and forestry (*http:// www. ordistricts. nic.in/ district_profile / aboutus. php*).

Information on land uses, land holding, climate, soil types, major crops, cropping pattern, productivity etc. are collected from available published reports i.e District Statistical Hand Book of Koraput, Odisha Agricultural Statistics, and from the internet in respect of Koraput district. Crop-wise investments details i.e expenditure towards land preparation, seed, farm yard manure, fertilizer, pesticides, plant protection, intercultural operation, harvesting etc. are collected from farmers, village agricultural workers (VAWs), line department officials and office of Deputy Director of Agriculture of the Koraput district. Minimum support price (MSP) of different crops is taken from the report "Price Policy for *kharif* Crops, 2013" published by the Commission for Agricultural Costs and Prices, Department of Agriculture & Cooperation Ministry of Agriculture Government of India New Delhi. Gross return from crop is calculated by multiplying MSP with total yield. Net return is computed by subtracting total cost of cultivation from gross return. Benefit cost ratio (BCR) is calculated by dividing gross return by production cost. All the data are critically analysed to have a better agricultural scenario of the Koraput district.

RESULTS AND DISCUSSION

Land uses

The land use details of the Koraput district is given in Table 1. The total cultivable area of the district is about 34.5% of total geographical area (881 thousand ha). The area under forest and barren & unculturable land is 21% and 24%, respectively. Gross cropped area is 372.78 thousand ha and cropping intensity is about 139%. Shifting cultivation is practised in 43.03 km^2 (0.5%) area of Koraput district (Naik *et al.*, 2013).

Table 1. Land use pattern of the Koraput district

Particulars	Area ('000 ha)
Net sown area	268
Forest area	188
Land put to non- agricultural use	54
Permanent pastures	45
Culturable waste	44
Land under misc. tree crops and groves	17
Barren and unculturable land	210
Current fallows	36
Other fallows	19
Total geographical area	881

Source : Odisha Agriculture Statistics 2010-11

The past land uses data reveals that the area under forest is continuously decreasing and it may be due to rapid urbanisation, large scale mining and deforestation. Increased area under barren and unculturalble land is a result of high soil erosion and land degradation problem. Shifting cultivation on steep slopes by tribal farmers is a major contributor towards it.

Land holding

As per the existing land holding pattern of Koraput district, majority of farmers (46.5%) comes under marginal (< 1 ha) category, 32% , 16% , 5%, 0.5% under small (1-2 ha), semi-medium (2-4 ha), medium (4-10 ha) and large (>10 ha) category, respectively with average land holding of 1.53 ha (Agril. Census, 2005-06).

Majority of farmers (78.5%) under marginal and small category, and decreasing size of land holding in district may be attributed to population rise and rapid fragmentation of land holding. Non availability of adequate land for cultivation and food demand is forcing tribal to go for shifting cultivation on the hills.

Climate

The climate is warm and humid with mean maximum and minimum temperatures of 38º C and 12º C respectively**.** The average annual rainfall in the district amounts to 1567 mm occurring in 83.9 rainy days. June to September is the usual wet period, where 79% rainfall is recorded in about 62.4 rainy days due to south west monsoon. The monthly distribution of rainfall and rainy days is given in Fig.1. Relative humidity varies from 67 to 96% in monsoon and 48 to 95% in off season. Bright sunshine hours vary from 1.8 to 6.4 in monsoon period and from 6.8 to 9.4 in post monsoon season. The mean wind velocity varies from 2.1 to 9.9 km / hr in monsoon period and from 2.1 to 13.7 km / hr in post monsoon period.

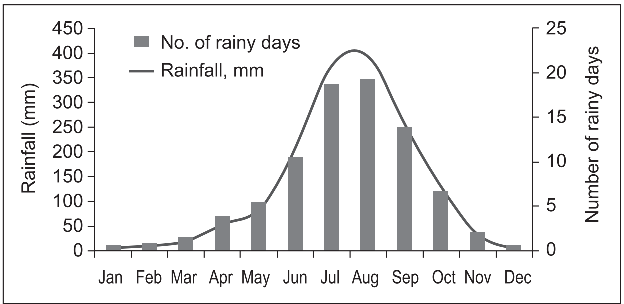

Fig.1. Monthly distribution of rainfall and rainy days of Koraput district

It reveals that overall climatic condition of the Koraput district is congenial for crop production, but it is suffering from soil erosion / land degradation and water scarcity problem due to undulating topography and high runoff.

Soil

Soils are predominantly red, mixed red and yellow having sandy loam to sandy clay loam texture. Soils are acidic with pH ranging from 4.5 to 6.2 having very low salt content (EC varying 0.184 to 0.321 dS / m). The area covered under major soil groups is given in Table 2. Patnaik et al., (2004) reported that soils of Koraput district are low in N, P and organic matter content and having low nutrient value index i.e., 1.63, 1.2, 1.1 and 2.77 for organic C, N and P respectively.

Table 2. Area covered under major soils in Koraput district.

Major Soils	Area ('000 ha)
Red soils	437.9
Alluvial soils	200.0
Mixed Red and Yellow soils	140.0
Red and black soils	60.0
Total	837.9

Source:*http://agricoop.nic.in/Agriculture% 20 Contingency% 20Plan/Odisha/*Odisha%2022- %20 Koraput% 2031.05.2011.pdf

Irrigation

The net and gross irrigated area of the district is 78.20 thousand ha and 131.93 thousand ha respectively. Total rainfed area of the district is 189.9 thousand ha. The major sources of irrigation are canals, tanks and ponds, and bore wells. Canals contribute about 60% of irrigated area. So far only 29% of net sown area of the Koraput district is under irrigation.

Major crops and cropping pattern

Major field crops grown in the district are paddy, finger millet, maize, niger and pigeon pea. During *kharif* paddy covers highest area of 114.28 thousand ha followed by finger millet (73.02 thousand ha), niger (38.14 thousand ha), maize (18.85 thousand ha) and pigeon pea (5.45 thousand ha). The details of cropping pattern of Korput district is given in Fig. 2.

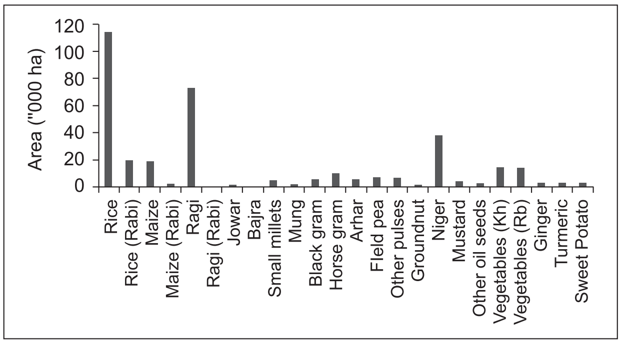

Fig. 2. Cropping pattern in *Kharif* and *Rabi* in Koraput district

It indicates that existing cropping pattern of Koraput district is rice, finger millet and niger dominant.

Cost of cultivation

Basing on expenditure incurred on inputs (seed cost, farm yard manure, fertilizer, pesticide, plant protection and labour), ginger cultivation involves the highest investment (Rs 1,67,500) followed by turmeric (Rs 1,07,500), vegetables-*rab*i (Rs 58,000), vegetables-*kharif* (Rs 52,000), groundnut (Rs 39,000), maize-*rabi* (Rs 34,000), maize-*kharif* (Rs 27,000), sweet potato (Rs 26,000) and rice-*rabi* (Rs 25,550) and rice-*kharif* (Rs 23,550). Cost of investment is lowest in case of small millets (Rs 4200). Crop-wise investment for different crops is shown in Fig. 3.

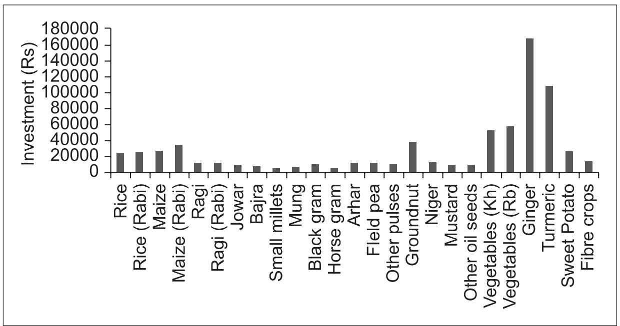

Fig. 3. Cost of cultivation of different crops in Koraput district

Crop productivity

The highest yield is obtained in case of vegetables-*rabi* (160 q / ha) followed by vegetables-*kharif* (140 q / ha), ginger (105 q / ha), sweet potato (102.5 q / ha), turmeric (34.5 q / ha), maize-*rabi* (31 q / ha) and rice-*rabi* (26 q / ha). Lowest yield is obtained in case of green gram and black gram (3.9 q / ha). Crop wise productivity of different crops is given in Fig. 4.

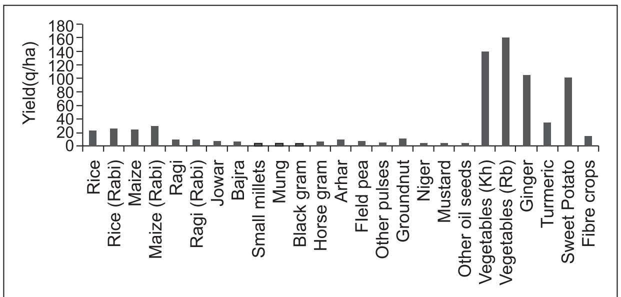

Fig. 4. Productivity of different crops in Koraput district

Net return

The highest net return is obtained from ginger cultivation (Rs 1,47,500) followed by sweet potato (Rs 1,02,125), vegetables-*rabi* (Rs 1,02,000), vegetables-*kharif* (Rs 88,000), pigeon pea (Rs 31,000), horse gram (Rs 20,700) and green gram (Rs 10,800). Lowest net return is obtained from small millet (Rs 600). The crop-wise net return is given in Fig. 5.

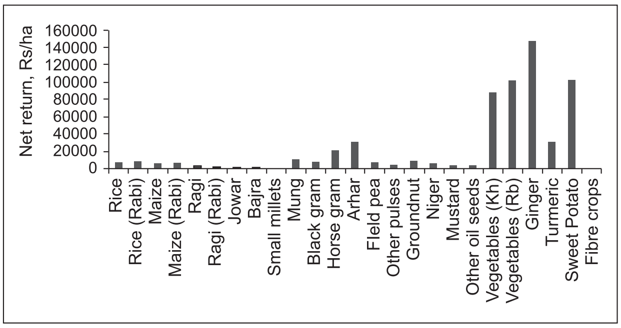

Fig. 5. Crop-wise net return in Koraput district

Benefit cost ratio

Benefit cost ratio (BCR) is found highest in case of sweet potato (4.93) followed by horse gram (4.91), pigeon pea (3.58), vegetables-*rabi* (2.76), vegetables-*kharif* (2.69), green gram (2.60), ginger (1.88), black gram (1.72), field pea (1.63) and niger (1.54). Crop wise benefit cost ratio (BCR) found is given in Fig. 6.

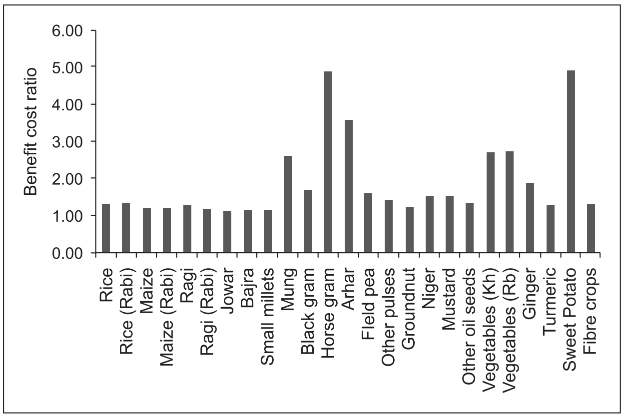

Fig. 6. Crop-wise Benefit cost ratio (BCR)

CONCLUSION

Proper quantitative identification of available resources and inherent problems of an area are highly essential for preparing any developmental plan. In the present study, most of the features i.e., socio economy, land use, land holding, rainfall, soil, irrigation, major crops, cropping pattern, crop-wise cost of cultivation, productivity, net return and BCR have been worked out taking in to account the actual scenario of the Koraput district. It is inferred that non availability of adequate land for cultivation and food demand is forcing tribal to go for shifting cultivation. Though climatic conditions of the Koraput district is congenial for crop production, suitable soil and water conservation measures are to be adopted to tackle the soil erosion /land degradation and water scarcity problem. As soils are low in N, P and organic matter content having low nutrient value index, adequate inputs may be used for maximisation of crop production. Only 29 % of net sown area is under irrigation and it has to be increased to grow more crops during off season to meet the food demand. As present cropping pattern is rice, finger millet and niger dominant, there is a urgent need of optimal land utilization through crop diversification in the district to maximise the production. Net return is higher in ginger, sweet potato, vegetables, pigeon pea, turmeric and horse gram cultivation. When crop wise BCR is compared, it is found highest in case of sweet potato (4.93) and lowest in case of bajra (1.09). As BCR is higher in sweet potato, horse gram, pigeon pea, vegetable, mung (green gram) and ginger cultivation, these crops may be grown to have maximum return. Under the existing cropping pattern, more area is allocated under rice, finger millet, niger and maize, which are not economical. Therefore, limited area should to be put under said crops which can meet the minimum food requirement, and surplus area should to be used for growing crops like ginger, sweet potato, vegetables, pigeon pea, turmeric, horse gram and mung. All this information will immensely help the farmers, policy makers, planners and researchers to prepare a comprehensive crop action plan for the backward Koraput district to make the agriculture profitable and sustainable.

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Joint forest management in Madhya Pradesh, India & implications in Bagdari village of Narsinghpur district - A case study

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ABSTRACT

Realizing the importance of people's participation in forest management the Join Forest Management (JFM) approach was implemented in village Bagdari brought gradual changes in the improvement of degraded forest and major changes in Socio-economic status of the villagers. The canopy cover or density of the forest increased from 0.4 to 0.7. Regeneration of trees was improved. The mixed trees species showed maximum regeneration from 17 to 145 per hectare. The study showed lower tree species richness as well as diversity values but higher stem density compared to the unprotected area. People's main preference was fuel wood in JFM areas and timber in the unprotected areas. The findings indicate the need for promoting regeneration of fast growing species and the development of fuel wood plantations particularly around centers of high consumption. The Socio-economic standard of the villagers improved after careful micro planning and implementation of JFM from 1997 to 2007.

Key words: Deforestation, rural communities, Joint Forest Management, species diversity

INTRODUCTION

The depletion of India's forest resources has brought into sharp focus for sustaining the forest resource base against the growing human and livestock population pressures, industrialization, urbanization and overall economic development activities. The crisis in Indian forestry relating to high rates of deforestation, and unregulated and unsustainable use of forest produce in the past, can be attributed to twin processes of erosion of customary resource management regimes and the acquisitive tendencies of the state in the period following independence.

Joint Forest Management, originated in West Bengal State at the Arabari Forest Range in West Midnapore, near Midnapore town in 1971. The major hardwood of Arabari is sal, a commercially profitable forest crop. Ajit K. Banerjee, a silviculturalist, working for the Forest Department as the Divisional Forest Officer, was conducting trials which were constantly being disturbed by grazing and illegal harvesting by the local populace. The experiment was successful and was expanded to other parts of the state in 1987. After the initial successes in West Bengal and Haryana, Involvement of rural communities living close to forests in protection and management of forest resources is enshrined in the National Forest Policy 1988. Translation of policy found expression in the resolution of Government of India, Ministry of Environment and Forests issued in June 1990. It envisaged that in lieu of the participation, the local communities will be entitled to sharing of unufructs in a manner specified by the concerned State Forest Departments. This led to the initiation of Joint Forest Management (JFM) programme. Importance of the programme is evident from the fact that the Government of India has constituted a "JFM Network" with the Inspector General of Forests, Government of India as the Chairman.

Joint Forest Management (JFM) is a concept of developing partnerships between fringe forest user groups and the Forest Department (FD) on the basis of mutual trust and jointly defined roles and responsibilities and with regard to forest protection and development. In JFM, the user (local communities) and the owner (Government) manage the resource and share the cost equally;

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however it is difficult to generalize the JFM concept and approach in the light of variations across the nation with respect to geography, resource base, socio-economic status, cultural diversity and pressures on forests. The effective and meaningful involvement of local communities has been attempted under the Joint Forest Management System in India by linking socio-economic incentives and forest development.

The Indian Forest Policy of 1988 and the subsequent government resolution on participatory forest management (MoEF, 1990) emphasize the need for people's participation in natural forest management. The policy document asserts that local communities should be motivated to identify themselves with the development and protection of the forests from which they derive benefits. Thus, the policy envisages a process of joint management of forests by the state government (which have nominal responsibility) and the local people, which would share both the responsibility for managing the resource and the benefits that accrue from this management.

Madhya Pradesh has the largest area under forest cover with a total of 94689.38 Sq. km area. Tropical climate and varied topography support rich bidoversity in the state. 13% of the total forest cover of India lies in the State. Madhya Pradesh is a pioneering state in implementing this programme. The government of Madhya Pradesh issued the first resolution in this regard in 1991. Based on the experience, the State Government revised JFM resolution in 1995, 2000 and 2001.

MATERIAL AND METHODS

To protect the degraded forests, Joint Forest Management schemes were launched at various places in Madhya Pradesh State. The study was conducted on 300 hectares of land near village Bagdari under Barman sub-forest of Narshinghpur forest range, district Narsimhapur was selected. Out of the total 300 hectare area, 100 hectares was barren and 200 hectares had forest cover. 100 sq.m quadrates were laid by random sampling method in the area of study. The density of trees, number of living stumps of cut down trees and frequency of grass was studied. The species diversity index was calculated following the formula of *Shannon and Weaver (1963)* and the growing stock was calculated using the species-specific volume equation (FSI, 1996). For those species where the specific volume equations was not available, the growing stock was calculated using the equation.Volume (m3)= 0.8 x D ^ 2 x H (D: Diameter at Breast Height,H: Height of tree in meter). The mean annual increment was obtained by dividing the growing stock in tones per hectare by the age of the plantation.

The present study was carried out in Bagdari village, which is situated 32 km away from Narsimhapur in north west direction along the NH-26 road. The village lies in Barman sub-forest of Narsimhapur forest range, district Narsimhapur, in Seoni forest circle, 7km away from the main road towards Sagar. The forest cover was very sparse. According to the sruvey conducted in 1995 the forest in this region was nearly11.7%. The forest type is of mixed deciduas type. Out of this 65% of the forest is in plain region and 35% are has a hilly tract. Hilly area of this region has the trees of Teak, (*Tectona grandis*) Bamboo (Dendrocalamus stictus), Saj (*Terminallia tomentosa*) Tendu (*Diosyros species*), Dhawda, (Anogeiosus latifolia), Lendia (*Lagerstromia species*) and plains area has Mahuwa, (*Madhuca longifolia*) Mangoes (*Mangifera indica*), khair (*Acaccia catechu*), Achar (*Buchnania lanzan*), Karonda (*Carissa carandans*), Harra (*Terminalia chebula*), Baheda (*Terminalia belerica*), are some of the prominent species. The total population of Bagdari village was 696, with 374 male and 322 female. More than 40% of the population was registered under criminal cases in the police records. There were 20 country liquor units operating in the village. Illegal felling of trees was very common. The village is situated adjacent to the forest. This village also forms the main entrance for the illegal cutting of wood in this region. The life of the villagers was very pathetic, criminal cases were registered against most of the villagers. To save the degraded forest in this region and to improve the socio-economic conditions of the people of this region, an attempt was made to introduce joint forest management scheme along with the help of the villagers in this region.

The forest is of degraded Teak forest. The density of the forest was less than 0.4, More than 30% of the forest land was total barren without any canopy cover. Trees with more than 30 cm Diameter at Breast Height (DBH) were only 11.2%. The bamboo was totally absent in the forest. The forest was prone to grazing and forest fires. Availability of grass in the forest was negligible. The forest area was also prone to soil erosion. Species availability of the forest shows that it has 60% Teak, 30% mixed wood which includes Lagerstromia species, Anogeisous species, Terminallia species , Diospyros species and 10% other species. Cattle grazing in the forest was the common practice, which caused maximum damage to young seedlings and slowed down the processes of regeneration. Agricultural practices were of primitive type, there were no irrigation facilities and farmers depended totally on rains and could get only one crop in a year. The agricultural implements used by the farmers were made out teak or mixed wood extracted from forest. Illegal mining of white soil for painting the houses and cleaning of clothes was a common practice in the forest. This also paved the way of cutting and illegal felling of trees.

The socio-economic structure as well as the dependency of the villagers on the forest was studied by Participatory Rural Appraisal (PRA) system. On the basis of climate dependent change studies time available for employment, availability of water, availability of crops, availability of minor forest produce in the area were calculated. On the basis of the above studies time of availability and dependency on the forest was studied. Open discussions with the village community was done to study the Socio-economic structure. Target groups were identified according to wealth ranking method. The priority target group was land less people with total dependency on the forests for their livelihood and the most affluent people of the village who were dependent on forest for various purposes were on the last. Since the forest adjoining the villages was degraded forest i.e. the canopy density of the forest was less than 0.4, hence the Village Forest Community (VFC) was constituted as per forest department instructions.

Micro planning for ten years starting from 1997-2007 was formulated using the PRA technique with an aim for restoration and conservation of degraded forests and improving the socio-economic structure of the villagers by involvement in Joint Forest Management. Clearing and planning of trees was planned for 300 hectares and generation of man days were estimated.

The restoration of degraded forest was initiated with a target of 30 hectares per year. Demarcation work of the forest area was initiated and *Agave species* plantation was done on the forest boundaries to protect the study area from grazing. Grass and Bamboo plantation was started in 50 hectares of irrigated land besides the construction of stop dams, contour bunds, brush wood bunds and cross bunds for conservation of runoff water and soil erosion. The activities initiated in the identified area are given in Table 1.

Five most affluent families of the village Bagdari were selected for the establishment of Bio-gas plants. A target of 30 families with more than 5 members in a family and also having more than 3 cattle in the house were identified for installation of Bio-Gas Plant in two years from 1997 to 1999. Smoke less ‘Chulas’ (Hearth) for the poor people were distributed. Villagers were also motivated for water shed management along with improved agricultural practices. Families having more than 3 acres of land were motivated for modern agricultural practices to use improved / hybrid seeds and iron implements of agricultural instead of wooden equipments. The farmers were motivated to create permanent source of irrigation by installing bore wells.

The families were also convinced for pegging of animals instead of sending the animals for grazing in the forest areas. Planning for grazing cycle and promotion of home feeding of cattle was initiated. 50 persons were selected for training in plantation and development of nurseries. *Bamboo, Dendrocalamus species, Eucalyptus, Acacia, Emblica species, Pidium species, Azairacta indica, Terminalia*

Table 1. Showing the work done for conservation of water & soil in the region

Year	Agave plantation	Contour bunds	Check dams	Contour trench	Resin tank	Cross bunds	Brushwood bunds
1997-98	2000	200	65	100	2	48	40
1998-99	3000	250	75	120	1	35	30
199-2000	1500	150	40	150	1	45	25
2000-2001	3500	100	80	170	2	35	20
2001-2002	2000	95	70	200	3	50	20
2002-2003	1000	1135	55	180	2	30	25
2003-2004	1500	85	65	175	3	50	20
2004-2005	2500	80	70	250	2	70	35
2005-2006	2500	95	50	200	1	30	20
2006-2007	2000	100	65	130	2	40	30
Total	21500	1290	645	1675	19	433	265

species and Citrus species were distributed for plantation on private lands with a target of 3000 plants in ten years. Clearing, barricading around young saplings was done and self regeneration of species was promoted in the forest. Proper measures were taken to curb the illegal felling of trees. Measures were also taken to protect forest fires. Controlled extraction of white soil from the forest was permitted. People were also motivated for self employment and scheme for giving loans for self employment was launched. 14 families were identified for promotion of self employment from the year 1997-2003. A loan of Rs. 76,000/- was distributed among these families for establishment of small business during the study period.

Observations

Observations on Diameter at Breast Height (DBH) of various trees in cms., was calculated in the five 100 x 100 meters sample plots in the study area are shown in the Table 2.

March during ten years as given in Table 3. The quadrate sampling also revealed the presence of about 880 living stumps per hectare in the study area. Frequency of grass in the study area was 23% which is less than normal 70%.

The extraction of fuel wood from the forest was about 5 carts per annum per family. Each cart carried about 5 quintals of wood. The families selected for establishment of bio-gas plants in the region used about 150 carts of wood i.e. 750 quintals of wood per annum. One cart of wood leads to the damage of 80 trees. Timber extraction for fencing, making of agricultural implements and other purposes was calculated about 20 quintals per family per annum. The extraction of fodder from forest was calculated about 10 quintals per family per annum. Availability of grass in the forest was negligible. The data were also recorded on change in dependency of forest produce from 1997-2007, the changes are shown in Table 4.

Table 2. Showing the classification of DBH of trees in sample plots (in centimeters).

Plot no.	DBH Classes								
	15-20 (cms)	21-30 (cms)	31-45 (cms)	46-60 (cms)	61-90 (cms)	90-120 (cms)	120-150 (cms)	150-above (cms)	Total
1	23	194	320	229	166	57	12	3	1004
2	59	190	310	220	90	13	6	2	890
3	49	363	344	152	5	3	-	-	963
4	43	255	327	201	91	25	7	2	951
5	34	201	207	142	31	2	-	-	617
	208	1203	1508	944	383	100	25	7	4434

Table 3. Regeneration of teak and mixed wood trees

Year	Regeneration No. of Teak in September-October	Regeneration of Teak in February-March	Regeneration of mixed wood in September-October	Regeneration of mixed wood in February-March
1997-98	308	105	17	17
1998-99	210	135	140	90
1999-2000	305	147	187	122
2000-2001	290	159	158	127
2006-2007	315	196	145	130

It takes about 40 years for a tree to stain the DBH of 40 and above. 34% trees were in the range of 31-45 cms of DBH and 0.15% in the range of 150 cms and above DBH. Only 4.6% plants were in regeneration stage. The density of the forest was found to be less than 0.4. The forest land without any canopy cover was found to be 30% .

The observation were also recorded on regeneration data of Teak and Mixed wood species in the months of September–October and February-

Table 4. The status of forest produce extraction by villagers

Produce extracted from forests by the villagers	1997-98	2006-07
Fire wood	750 Quintals	105 Quintals
Poles and timber	1080 Quintals	174 Quintals
Fodder & grass	10 Quintals	15.5 Quintals
Char (Buchnania) seeds	20 Kg	36 Kg
Beedi leaves	975 Kg	1040 Kg
Mahua flowers	22 Quintals	24 Quintals

Table 5. Impact on area under cultivation of agricultural crops and yield of crops

Crops	Area under cultivation in hectares 1997	Area under cultivation in 2007	Yield in quintals in 1997	Yield in quintals in 2007
Soyabean	30	69	150	641
Paddy	21	48	63	378
Jowar	10	05	32	46
Pulses	10	55	30	382
Wheat	20	45	200	584
Minor Millets	45	5	98	31
Chick pea	32	32	192	276

The observations were also recorded to study the impact on area under cultivation of agricultural crops and yield of crops as given in Table 5.

The data were also recorded for creating employment to the villagers. The data on man days created are given in Table 6.

Table 6. Showing man days created during the tenure of JFM

Year	Man days/annum
1997-98	260
1998-99	200
1999-2000	220
2000-2001	270
2001-2002	200
2002-2003	300
2003-2004	150
2004-2005	240
2005-2006	100
2006-2007	270
	2210

RESULTS AND DISCUSSION

Implementation of Join Forest Management program in Bagdari brought gradual changes in the improvement of degraded forest and major changes in Socio-economic status of the villagers. The study showed that the canopy cover or density of the forest increased from 0.4 to 0.7. The regeneration of trees was in the months of September and October (after monsoon season) as compared to February & March months for both teak and mixed trees as given in Table 3. The mixed trees species showed maximum regeneration from 17 to 145 per hectare. Due to increased regeneration of grass, the villagers could get the 15.5 quintals of grass in 2006-07 against 10 quintals in 1997-98 in the JFM area. With support under JFM, the dependence of villagers for fire wood reduced from 750 quintals per annum in 1997-98 to 105 quintals in 2006-07 According to the field survey conducted each family used to extract 25 quintals per annum fire wood which required lopping of 80 trees. 30 families lopped about 12000 trees per annum. This could have lead for destruction of about 1,20,000 trees in 30 years and a total loss of revenue of Rs. 11,25,000/- which has been minimized by establishing the bio-gas plants. With the protection of study area, the supply of beedi leaves also increased which resulted in increased income to the villagers. Higher percentage of individuals in <15 cm DBH class were found JFM protected area. 4434 trees were counted with the >15 DBH in the selected five plots of JFM, the same were protected during the study period. The sustainability of JFM work was ensured with plantation of 21500 agave plants, 1290 contour bunds, 645 check dams, 1675 contour trenches, 19 resin tanks, 433 cross bunds and 265 brushwood bunds. The support for establishment of nursery also resulted in raising 63000 plants which generated Rs. 1,55,000/- revenue per annum from 2003-04 JFM project. The JFM project also undertook cleaning of old wells for availability of drinking water to the villagers.

Various water shed management programs improved the ground water table helped the villagers in increasing the area of cultivation and change in the crop patterns as shown in Table-5. Two crops per year could be grown instead of one after the water shed management. Distribution of hybrid seeds and improved agricultural implements had an added benefit in the agricultural economy of the villagers. The area under soybean increased from 30 hectares to 69 hectares . Similarly, paddy area increased from 21 hectares to 48 hectares, In wheat, area increased from 20hectares to 45 hectare. The yield of all the crops increased. With increased availability of water farmers shifted from millets to other profitable crops.

The number of criminal cases registered against the villagers in 1997 also reduced from 67 to 03 in 2006-07. The country liquor units in 1997 were 20 which have come down to 2 in 2006-07. Several self employment schemes were launched for social uplift of the villagers. Several schemes like ponds for fisheries, grinding mills, grosser shops, vegetable business, leaf plate making, rope making, tea stalls, cycle shops and several small works were initiated. Women's participation in JFM was also promoted by employing women in forest village committee and also in patrolling party.

The collection of Non Timber Forest Produce (NTFP) from forest was also allowed for poor people and the proper cost was decided by the VFCs and saving their money in bank accounts. The handicraft work like making of ropes, leaf plates, baskets and other forest produce items besides increased registration of children in schools. The findings indicate the need for promoting regeneration of fast growing species and the development of fuel wood plantations particularly around the centres of high consumption. The institutional support in development activities has made promising impact on biophysical and socio-economic environment of the JFM area.

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Soil sulphur status and response of crops in foothill region of J&K

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ABSTRACT

Sulphur (S) deficiency is emerging and different crops respond significantly to S application. Sulphur deficiency in coarse textured foothill soils of J&K state is also becoming quite common as has also been revealed by crop responses to its application. It has been reported that total S contents of the soils were in the range of 139-226 ppm with an average value of 183 ppm. Apart from agricultural crops, oilseeds and fruit plants like mango and apple are also prone to S deficiency in the state and declining productivity.

Key words: Soil sulphur, sulphate, deficiency, oilseed, erosion prone soil

INTRODUCTION

Soil health has been a cause of concern for sustainable agricultural production in the new millennium. During the past four decades, continuous use of nitrogen and phosphatic fertilizers has resulted in the mining of secondary and micronutrient reserves. This skewed fertilization application pattern has resulted in nutrient imbalance in the soils. Soil health, however, calls for a balanced application of the requisite nutrients for sustaining productivity of the land. The balanced crop nutrition must include the application and management of all those nutrients which are deficient in soils and not available to crops in adequate quantity. Sulphur deficiencies were not common before the introduction of high yielding varieties. Surveys made to delineate S deficient areas in different parts of the country revealed that S deficiency varies from 5 to 83 % with an overall average of 41 % (Singh, 2001).

The role of sulphur in plant growth is well recognized. Sulphur is an essential nutrient for plant development and growth, as it is a constituent of S-containing amino acids (cysteine, cystine, methionine) and enzymes, and it is required for the synthesis of proteins, chlorophyll, oil and vitamins. It increases crop yield besides improving quality of produce.

Different crops respond significantly to S application. S uptake by crops can range from 5 to 80 kg S ha^{-1} $year^{-1}$ depending on type of crop, yield and cropping intensity. There are research data to show the beneficial effects of S application on more than 40 crops under field conditions (Tandon and Messick, 2007). However, oilseed crops were the first to show deficiency of S in the country in view of their greater S requirement (Aulakh, 2003). J&K state also covers a sizeable portion of oilseed crops and among the various agro-techniques that can enhance productivity of oilseeds, adequate nutrition ranks the highest. However in the fertilization scheduling emphasis is given on nitrogen, phosphorus and potassium inspite of sulphur fertilization being an inexpensive option. This is largely due to the ignorance regarding the benefits of S application. Besides oilseeds, other crops such as cereals and pulses also respond favorably to S application. Sulphur deficiency in J&K is also becoming quite common as has also been revealed by crop responses to its application. An effort has, therefore been made to summarise the workdone in the state regarding status of S in soils and response of crops to S application and to identify research gaps.

Soil sulphur status of J&K

There were wide variations in available soil S in different districts of J&K, which subsequently varied widely within blocks, depending upon variation in cropping systems, fertilizer use pattern, and soil characteristics. Generally, soil available-S

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was lower in light textured soils than in medium and heavy textured soils. Recognizing the need to delineate S-deficient areas in J&K, Kher and Singh (1993) conducted studies on surface soil samples of north Kashmir and reported that 50 % samples were deficient in available sulphur and the percent deficiency was likely to increase with time. However, total S contents of the soils were in the range of 139-226 ppm with an average value of 183 ppm in different locations and among different sulphur forms, organic S is the major fraction of total S and constituted 43.6 to 71.3 % of total sulphur. Koul (1997) also observed organic S as the dominant form of all forms of S in different Brassica growing soils of Jammu region and it ranged between 26.0 to 114.0 ppm in the surface soils, whereas total S varied from 51.00 to 146.00 ppm and it decreased with increasing depth. Among the different forms, sulphate S (available S) constituted the lowest component of inorganic S comprising 5.76 % of total S with average value of 5.38 and 4.03 ppm respectively for surface and subsurface samples and was found to be positively and significantly correlated with organic carbon and clay component. Thus brassica growing region of Jammu needs optimum sulphur application for increasing the yield and oil content as majority of the soils are deficient in sulphur.

Gupta and Sumbria (1997) studied districtwise available S in 455 surface soil samples of different districts of Jammu region. Available S content in soils of Jammu region of J&K varied from 3.2 to 78.2 ppm with an average value of 24.17 ppm. Soils in Jammu, Kathua, Udhampur, Doda, Rajouri and Poonch districts respectively were found deficient in available sulphur in 24.2, 18.0, 9.3, 6.25, 17.0 and 16.4 % samples, respectively (Fig 1). The major reasons for S deficiency in the soils of Jammu region may be low organic matter status of soils, intensive cultivation, the use of high analysis fertilizers, continuous crop removal and non-replenishment of S (negative S return) and lack of irrigation.

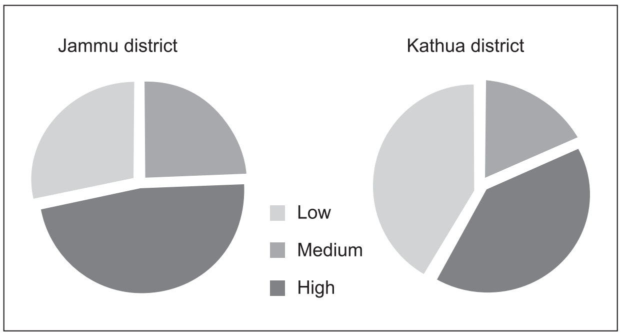

Fig. 1. Sulphur deficiency in soils of Jammu and Kathua districts

Distribution of sulphur in major soil groups of Jammu region from two depths and observed highest average total sulphur content (141.9 ppm) in Haplaquent soil group followed in order by Ustifluvent (123.9 ppm), Ustorthents (113.1 ppm) and Eutrochrepts (95.1 ppm) in surface soils and the pattern of distribution was similar in subsoils were reported by Singh (1998). Soils of mango orchards of Jammu region were surveyed by Jalali *et al.* (2002) to ascertain the cause of declining yields and 35 % of the soils were found to be deficient in available sulphur. Available S content in these orchards ranged from 8.10 to 19.80 mg kg^{-1}. However, Jalali *et al.* (2004) while conducting studies on nutrient status of major fruit crops of Jammu region reported inadequacies of N, P, K, S and Zn, in both soil and leaf samples of fruit orchards. Thus application of N, P, K, S and Zn through fertilizers is essential for improving the productivity and growth of fruit orchards.

Table 1. Available sulphur status in different fruit growing soils of Jammu region

Soil Type	Range	Mean
Mango orchard	8.10-19.80	11.25
Guava orchard	8.40-17.6	11.95
Ber orchard	8.4-12.0	10.80
Citrus orchard	7.3-17.60	10.90

The available S in surface soils of apple orchards of Kashmir varied from 9.30 to 12.10 ppm whereas in subsurface layers, it varied from 7.8 to 12.0 ppm (Najar *et al.* 2005). The S content in leaf samples of apple ranged from 0.20 to 0.52 % with an average of 0.34 % and all the orchards surveyed were found to be adequate in S which may be due to spraying of S based fungicides and insecticides against the diseases and pests. A detailed study based on different land use patterns had been conducted by Gupta *et al.* (2005) of Jammu region and indicated that available S was low in uncultivated barren and cultivated unmanaged lands and varied from 4.6 to 11.4 ppm and 5.9 to 17.3 ppm, respectively whereas soils under cultivated well managed and forest lands were rich in available S status and its amount varied from 9.5 to 24.5 and 14.3 to 44.3 ppm respectively, irrespective of surface and subsurface strata. About 90 % of soil samples of barren uncultivated lands were found to be deficient in available S, taking 10 ppm available S as a general critical limit.

Different forms of S in soils of three agro-climatic zones of Jammu region was estimated by

Kour and Jalali (2008) and it was observed that total S was highest in temperate zone soils followed by intermediate zone soils and then followed by sub-tropical soils. Subtropical soils also showed maximum deficiency of available sulphur whereas soils of intermediate and temperate zone fall in medium to high S containing soils (Fig. 2).

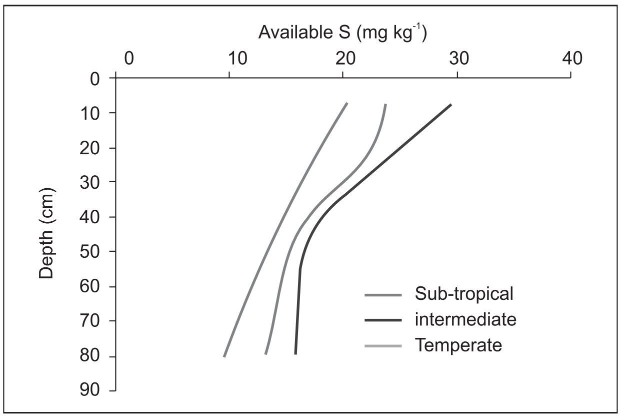

Fig. 2. Available sulphur content in agro-climatic zones of Jammu region

Sulphate sulphur availability in soils of cultivated locations of intermediate midhill zone of Jammu region was studied by Kour *et. al* (2010) and the inorganic sulphur was found to be the lowest fraction of all forms of S contributing least to the total S (0.93 to 11.98%) and recorded to be in the range of 5.5 to 43.7 mg kg^{-1}.

Relationship between sulphur deficiency and soil properties

The sulphate fraction, most important from the plant nutrition point of view may prove a suitable index in evaluating the amount of sulphur available to plants and it is dependent upon different chemical and physical soil properties. The relationship between soil properties and sulphur deficiency was established based on 125 soil samples from Kashmir (Kher and Singh, 1993), 64 soil samples from Jammu region (Gupta *et al.*2005) and 40 soil samples from different districts of Jammu region (Koul,1997). Overall, S deficiency increased with decreasing clay and organic carbon content. However, S deficiency did not correlate with soil pH. Organic carbon, clay, silt content and cation exchange capacity correlated with S content. Thus, fertile soils rich in organic carbon, P and K content provide adequate S supplies. Gupta *et al.* (2005) established relationship of surface and subsurface soil samples from 32 different locations of Jammu district and reported that available S correlated with organic carbon (r= 0.790**), clay (r=0.754**) and cation exchange capacity, thereby indicating that the availability of S in these soils is a function of organic matter, clay contents and cation exchange capacity. Kour and Jalali (2006) observed positive association of available S with organic carbon in hilly tract soils of Jammu region. Kour *et al.* (2007) also analysed depthwise samples of subtropical soils of Jammu region and observed positive correlation of all forms of sulphur with organic carbon and silt content.

Crop response to sulphur in J&K

Crop responses to S fertilizer is dependent upon soil available S content. Sulphur applied to crops grown on S deficient soils not only increases crop yield but also favorably affects crop quality. Sulphur fertilization influences the composition of oil, acetyl-CoA and acetyl-CoA carboxylase in oilseeds. However sulphur responses differed widely among crops and their cultivars because of wide variations in sensitivity to S stress and soil types.Yield responses to S vary from 12 to 48 % under irrigated and 25 to 124 % under dryland conditions (Tandon, 1991). In Jammu, Gupta *et al.* (1996) observed that application of sulphur @ 50 kg ha^{-1} in the form of gypsum and borax @ 10 kg ha^{-1} on an average increased seed yield of mustard by 22-25 % and oil content by 2-3% in the clay loam soils having low status of sulphur and boron. (Table 2).

Brassica growing soils of subtropical zone of Jammu region were largely deficient in sulphur and thus about 30 % of plant samples of that area were found to be deficient in sulphur Koul (1997). Leaf S content exhibited a definite relationship with the available soil S status. Significant increase in plant height, bulb diameter, sulphur concentration, S uptake and bulb yield of onion crop in Jammu region was observed by Singh (1998). Increased bulb yield by 20 and 14.6 % over control was recorded with the application of S in the form of gypsum @ 45 and 35 kg ha^{-1} in light and heavy textured soils respectively. Wani (2000) observed increased rice yield with increased doses of sulphur in Kashmir soils. Singh (2001) reported that applying 20 kg S ha^{-1} increased all the yield attributes of barley viz. plant height, dry matter production, and effective tillers and per metre row length, earhead length, number of grains per earhead and 1000-grain weight. Improved grain and straw yield and total uptake of S up to 20 kg S ha^{-1} had also been observed. Jalali *et al.* (2002) observed that 44 % leaf samples of mango orchards of Jammu region were deficient in S whereas leaf S

Table 2. Effect of zinc, boron and sulphur on yield and oil content of rapeseed mustard

Treatment	GSL-1		Pusa bold		RL-1359	
	Yield (q ha^{-1})	Oil content (%)	Yield (q ha^{-1})	Oil content (%)	Yield (qha^{-1})	Oil content (%)
$N_oP_oK_0$	6.24	36.2	5.17	35.4	5.07	35.8
$N_{60}P_{30}K_{20}$(RD)	11.73	38.4	9.85	37.7	9.87	37.6
RD+Zn_{10}	12.02	39.1	10.61	38.4	10.15	38.3
RD+Zn_{20}	12.90	39.4	10.65	38.7	10.31	38.5
RD+S_{25}	13.24	39.4	11.69	38.9	11.26	38.9
RD+S_{50}	14.34	39.7	12.76	39.2	12.36	39.0
RD+B_{10}	12.82	39.5	13.02	38.7	12.39	38.9
RD+B_{20}	13.44	39.5	13.33	38.9	12.53	38.9

content was significantly correlated with S content in soil at all the four depths.

Oilseed response to sulphur application was studied by Wani (2005) and significant increase in seed yield and protein content of mustard with increase in sulphur level upto 80 kg S ha^{-1} was observed where as oil content and oil yield increased significantly up to 60 kg S ha^{-1} in silty clay soils of Kashmir. Also gypsum had an edge over pyrite application in terms of average yield and protein content and thus can efficiently be used as plant mobilizer and co-fertilizer to supply S and Ca to plants in S-deficient soils (Table 3).

Table 3. Effect of sulphur application on seed yield (q ha^{-1}) and protein content (%) of mustard

Sulphur levels	Average yield (q ha^{-1})	% increase	Protein content (%)
Control	11.72	-	16.65
20	13.69	16.81	18.79
40	14.68	25.26	19.14
60	15.22	29.86	19.41
80	15.72	34.13	20.15
C.D(0.05)	0.50	-	0.36
Sources of sulphur			
Gypsum	16.23		19.57
Pyrite	15.43		19.38
C.D(0.05)	0.28		0.25

Sharma and Arora (2008) observed significant increase in S content, S uptake, oil content and yield of mustard through gypsum or pyrite over the control under rainfed conditions of Jammu region. Sulphur application at 50 kg S ha^{-1} of ground gypsum recorded significantly highest mean seed yield of 20.30 and 18.01 q ha^{-1} in the first and second year, respectively.

The critical level of soil S is commonly reported as 10 mg kg^{-1} however S responses in soils are higher as well as lower than this. Nad and Goswami (1986) reported S response in soils as high as 41 mg $kg^{-1}$of available sulphur whereas Iswari and Tewari (1987) obtained satisfactory crop yield without S applications in soils containing as low as 4.5 mg S kg^{-1}.Thus different crops respond differently to sulphur. This aspect of field based soil test research remains neglected in J&K state and requires immediate attention. Therefore, soil surveys and calibration studies need to be conducted systemically to assess the status of soils throughout J&K state and the relationship correlating available S and crop responses in different agro-climatic zones within J&K.

Fertilizer S utilization efficiency

Wani (2005) reported maximum fertilizer S utilization efficiency at 20 kg S ha^{-1} in mustard crop in Kashmir soils. S utilization efficiency was 10.70 % at 20 kg S ha^{-1}application and it decreased with increasing S application with 6.78 % at 80 kg S ha^{-1}. Kour (2006) reported maximum S utilization efficiency at 15 kg S ha^{-1} and decreased with increasing S doses with minimum value of 5.08 % at 60 kg S ha^{-1} in mustard crop grown in subtropical soils of Jammu region. (Fig. 3)

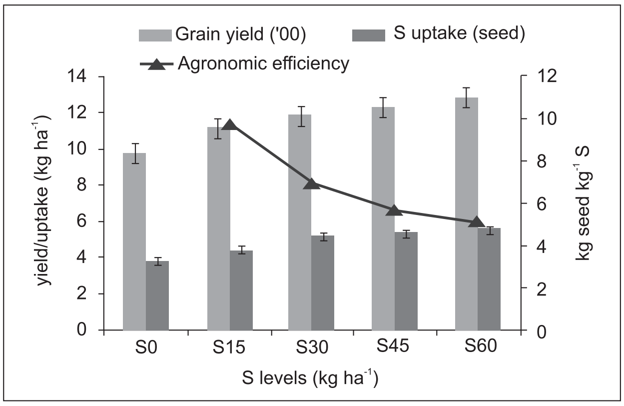

Fig. 3. Effect of sulphur application on grain yield, S uptake by mustard and agronomic efficency. (Error bars depict the C.D. values at P<0.005).

CONCLUSION

Although limited, available data in J&K show that sulphur deficiencies were recorded in all districts of J&K, however the magnitude differed depending upon soil characteristics, crops grown, climatic conditions and fertilizer use patterns. The severity of S deficiency was associated with soil characteristics, fertilizer use pattern and cropping intensity.

Sulphur, therefore, must be included in fertilizer recommendations based on the systematic delineation of S-deficient areas and cropping pattern as areas growing pulses and oilseeds need more S than areas growing cereals. Thus balanced fertilization of crops, including S is necessary for high yield in S-deficient areas.

Systematic information about status, forms and distribution of available S for all major soil groups, agro-climatic regions and districts, as well as their relationship with soil properties, must be given priority and organized on a collective basis.

Horticultural crops cover a sizeable area of J&K state however; data on S nutrition for these crops are minimal or negligible. Research is needed to evaluate the S status of these areas, i.e effect of S fertilization on crop yield and quality and better diagnosis techniques must be developed.

Long term studies to improve the S utilization efficiency of applied S for optimal rate and frequency, residual availability and crop performance under different soil-crop management situations are needed.

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Effective tools for management and dissemination of agricultural information

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ABSTRACT

The Information and Communication Technology (ICT) is playing a key role in agricultural growth and development in the country by providing timely and useful information in a demand-driven mode. As a commitment to deliver cost-effective and production-oriented technologies for the welfare of farming community, the ICAR has adopted ICT based information dissemination system. Apart from increasing trends in e-publishing in agricultural sector in the country, it has been noticed that number of print publication has also been increased. The Indian Council of Agricultural Research is leading the country in the area of agricultural research, education and extension through its wide network of Research Institutes, Krishi Vigyan Kendra and Agricultural Universities (SAUs). In the era of information explosion, Information and Communication Technology is progressively replacing the old methods of information collection, storage and retrieval. The ICAR has initiated projects realted to ICT like e-Journals, e-Courses, CeRA, Agroweb, Mobilising Mass Media and interactive multimedia advisory system in order to enhance the overall efficiency of the management and dissemination of agricultural knowledge to different stakeholders of the society.

Key words: Knowledge dissemination, CeRA, ICT, Virtual Networks, e-Journals, e-Courses, Agroweb

INTRODUCTION

Application of appropriate ICT tools for the management and dissemination of agricultural technologies has transform the overall delivery of information to public. Information and communication technologies (ICTs), are re shaping many aspects of the economies, governments and societies. Now, it is right time to harnessing the transformative power of ICTs to make public services more efficient, to grow agri-businesses, and to strengthen agricultural research and extension for development. ICT has facilitated the much needed community empowerment and development by meeting their information needs. ICT is also an important enabler in research activities to accomplish tasks at faster rate with higher efficiency. It holds as much potential for development of agriculture sector as contributing in other sectors in India.

Several ICT initiatives have been taken by the Indian Council of Agricultural Research for agricultural research in the country under various projects including the World Bank funded projects like National Agricultural Research Project (NARP) and National Agricultural Technology Project (NATP).

Information, communication and dissemination system

The main focus of ICDS is to strengthen the infrastructure related to information and communication technologies (ICT) and its application for greater dialogue and interaction within the system and among the stakeholders. This has helped in enhancing public awareness capacity and improved knowledge sharing using modern ICT tools and mass media communication strategies.

Comunication management and knowledge sharing

Communication management has been improved leading to wider dissemination of events and achievements of NARS by both print and electronic media. A standard web-based, user-friendly e-publishing portal has been implemented for ICAR Journals and this facility is offered to other agricultural research societies publishing

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their research journals. The dream of any Indian extension professional to provide the right information at the right time and context and even many local languages to the ever Information-Hungry farmers is realized through Agropedia (portal for crop information) and Rice Knowledge Management Portal (www.rkmp.co.in) - the one stop shop for rice related information.

Knowledge creation and management through ICT platforms has brought out global visibility and recognition for agricultural technologies. The viewership of ICAR journals has created new records. The impact factors of the journals of both ICAR and the professional societies have enhanced and overall production time of many journals has come down to 2-3 months.

Engaging farmers, enriching knowledge

An agricultural knowledge management portal-Agropedia available at http://www.agropedia.iitk.ac.in was developed. The Agropedia, led by IIT-Kanpur in partnership with ICRISAT-Hyderabad, IIM-Calcutta, ICAR-ZPD Zone-IV-Kanpur and UAS- Raichur, is an open platform which facilitates exchange and delivery of information between the agricultural community through a web portal and mobile phone networks accessible to phones with limited data capability. The development of the Agropedia was carried out in two phases, with the first phase focusing on content and development of the web platform and the second phase on providing a delivery platform for extension services. Various crop knowledge models, content aggregation around the models, web-based query and response system that linked to farmers through mobile telephones (SMS and voice) have been developed.

The platform integrates a variety of digital information and services for a variety of extension related purposes. The knowledge dissemination was followed in multiple languages such as English, Hindi and Telegu through appropriate interfaces to users categorized as anonymous, authentic users and editors. Agropedia has become very popular in many parts of the country as extension trainers are getting access to the information for solving crop related problems at farmers' fields.

The key elements of the Agropedia system are knowledge objects and knowledge models. Knowledge objects describe agricultural resources such as documents / information in the form of text, image, audio, video, etc. Knowledge models are used to organize, search and navigate agricultural content. Knowledge models are visual representations of important concepts in agriculture with appropriate relationships defined between them. The content and knowledge repository which was hitherto restricted to certified content, an interaction space, and crop based knowledge models was supplemented with a service delivery platform called vKVK. The vKVK is an ICT tool that connects KVKs with farmers through internet and mobile technology and bridges the gap between the farmers and the KVK expert. The interaction in the form of alerts and advisories can now happen over a mobile instrument either through text based SMS or a voice format. It has brought a much desired convenience to the extension expert and reduces the gaps in terms of time, money and knowledge quality as vKVK is two way facility, both as expert to farmer and farmer to expert. The vKVK service is cutting across all the service providers and can be accessed flawlessly on even low end mobile handsets. All vKVK services were free of cost to the farmers. Initially, the service was started in 24 KVKs and further up-scaled in 191 KVKs covering more than 35,000 farmers.

Strengthening ICT infrastructure and its application

The key to successful research today demands live consultations, data sharing and resource sharing. Therefore, in order to optimally utilize the potential of institutions engaged in generation and dissemination of knowledge in different areas of agriculture, it is important to connect them through a high speed broadband network. Presently, there are more than 15000 internet connected nodes in the NARS institutions. Out of 99 institutions of ICAR and 69 agricultural universities, connectivity of high speed internet with a bandwidth of 1.0 Gbps have been provided to 57 (70 %) institutes of ICAR and 19 (30 %) state agricultural universities. These networks now support overlay networks, dedicated networks, and virtual networks. The entire network is seamlessly integrated with the global scientific community at multiple gigabits per second speed. Such a knowledge network goes to the very core of the country's quest to build quality institutions with requisite research facilities and create a pool of highly trained persons in agriculture and its allied areas. The National Knowledge Network connectivity, while impacting the existing academic and student community, has started to alter the research and developmental landscape for future generations.

ICAR central data centre

In recent years, the importance of data as a primary research output is recognised. New technology has made it possible to create, store and reuse data sets, either for new analysis or for combination with other data in order to respond to different queries. To address the rising requirements of ICAR institutes for online services and at the same time launch of a number of e-governance and research projects, data centre requirements are growing exponentially. Based on the latest cutting edge technology being followed globally, a centralized and well-established Data Center was the long requirement of the ICT infrastructure of ICAR. Initially, the existing ICT infrastructure at various ICAR institutes was developed to meet their basic IT needs. The services running using the existing infrastructure are susceptible to security threats, slow speed, and non-conformity to standards and lacks in feature of interoperability.

ICT-mediated knowledge management

The Agricultural Knowledge Management Consortium was formed to test various information and communication technology platforms to find new and viable ways to build linkages between research-derived information sources, extension staff and farmers. It brought together SAUs and ICT resource institutions for design, comprehensive testing and capacity strengthening of various stakeholders in the farmer-research institution continuum. Over the period of its activity, the consortium took up activities that led to creation of crop knowledge models, content aggregation around the models, web-based query and response system that linked to farmers through mobile telephones (SMS and voice), variety of methods to harness GIS products and platforms in support of decision-making at farm level besides carrying out capacity building efforts.

Mobilizing mass media support for sharing Agro-information

The capacity of information development of ICAR in different media was strengthened through the sub-project Mobilizing Mass Media Support for Sharing Agro-Information with lead centre at DKMA, New Delhi along with 10 partner institutes in 8 states as media centre from the NARS. The major emphasis was to enhance the agricultural communication and awareness in the country at grass-root level; build up and harness synergy of inter-institutional communication platform in participatory mode; and capacity building for agricultural communication in different modes and media by using effective communication and information tools. The focus was to develop the overall interactive and effective communication system to reach farming community, policy planners, scientists, students, media persons and public at large.

Various communication activities were integrated on a single platform to achieve the objectives. Regular interactions with media followed by field visits helped to develop linkages and trustworthy relations for enhanced visibility of agricultural research in the national and regional media (print and electronic media). Regular news feeds to media in the press-friendly format also contributed in achieving the targets. Activities at all the media centers developed a communication system in seven languages (Hindi, Tamil, Malayalam, Punjabi, Gujarati, Kannada and English) for various stakeholders by using appropriate media vehicles.

As a part of strategy for strengthening of agricultural communication through print media, initiatives were taken such as regular press releases, visits of media persons to laboratories and interactions with scientists. As a result, more than 4600 news items on agricultural technologies appeared in Hindi, Gujarati, Tamil, Malayalam, Punjabi, Kannada and English language at national and regional level. This endeavour culminated into enhancement of visibility and branding of agricultural research at national and regional level. Media meets were conducted across the country to facilitate direct interface of the press with scientists and technology developers. In this regard, 114 media meets and field visits and interaction were organized, in which over 1000 media persons participated.

Dissemination of agricultural technologies in electronic media: In view of increasing importance of electronic media in the overall communication scenario, the project laid emphasis on use of this important communication tool in dissemination of agricultural technologies and success stories. Around 160 video films/capsules and audio capsules were produced under the project targeting the farming community and entrepreneurs. These products were broadcasted and telecasted on various national/regional/local TV channels and also posted on ICAR website. Videos uploaded on YouTube on agricultural innovations of NAIP inspired the farmers, especially the youngsters. Introduction of innovatiove knowledge dissemination through several social media (Facebook, Youtube and Blogs) were introduced in NARS.

Coverage of News Event and Success Stories on ICAR Website: The project played a central role in content management of the ICAR website by regularly updating news and success stories in the desired format. Events held at New Delhi were widely covered by the project, while News/ Success stories from across the nation were also designed and packaged under the project. During the project, hits and visits on ICAR website increased up to 160%. Simultaneously, in 2009 ICAR website was seen in 45 countries and presently numbers of visiting countries is 172.

Dissemination of Information through Social Media: Realizing the importance of social media for quick and effective communication, the Facebook page of ICAR was launched in February, 2013. Now, this page has more than 30,000 likes and the numbers are increasing every day. This page is being used for dissemination of information about the latest happenings in NARS, career opportunities in agriculture, videos of interest and to create a direct interface with stakeholders. The significant achievements made under different sub-projects under NAIP were highlighted.

Showcasing of Agricultural Technologies: To build up and harness synergy of inter- institutional communication platform in participatory mode, linkages were developed with farmers associations, SAUs, NGOs, KVKs and other organizations for dissemination of technologies. Showcasing of technologies (54) was organized at various urban and rural locations for farmers and entrepreneurs. It provided the opportunity to the farmers for direct interaction with technology developers thus facilitating the adoption of technologies. These events were also covered by local and the regional press.

Capacity building for agricultural communication: Short-term courses on Knowledge Management for agricultural scientists were organized to enhance capacity building for agricultural communication in different modes and media, at Indian Institute of Management (IIM), Lucknow.

Publishing of scientific journals for Indian NARS

The sub-project entitled e-Publishing and Knowledge System in Agricultural Research with Lead Centre at Directorate of Knowledge Management in Agriculture (DKMA), New Delhi made a significant impact on the publishing process and manuscript management of research journals through the implementation of ICT in journal publishing. Implementation of e-publishing resulted in making the entire research journal publishing process quick, transparent and paperless leading in improvement of overall efficiency. Online availability of research journals through internet also improved the quality of research, enhanced visibility, and impact factor. Now many research papers are being cited by researchers internationally in reputed journals and compilations. More than 1500 researchers/ managers were sensitized about Open Access in scholarly publishing and its benefits for the researchers, quality of research and society as a whole. Twenty research journals are being published using the developed ICT enabled platform and available online now. Open Access policy in ICAR for enhanced dissemination and sharing of Indian agricultural research was one of the major outcomes of the initiative.

Impact of e-Publishing of Scientific Journals: After adopting e-publishing research article submission-to-publication period reduced considerably from 18-24 months earlier to 4-6 months now. Thus, automation helped in reducing the time lag in research paper publication.

*Efficient and reliable record keeping: I*n the E-Publishing System, 35-40 predefined email templates are available for all possible situations like "Acknowledge of manuscript submission", "Request to referee", "Acceptance of reviewing request", "Auto Reminder to Author", "Auto Reminder to Referee", "Copy edit Request to Author" etc. which are available during the workflow to various users like Reviewers, Editor, Author, Copy Editor, which help in more effective and fast email based communication. Records of research papers and all editorial correspondence are stored automatically in the entire process on computer servers and databases. This resulted in online tracking of the progress by authors themselves and hence no paper based communication. This has helped in saving on postal cost which is a big amount considering that both journals, viz. IJAS and IJANS are receiving more than 3000 articles per year (2012-13) (e.g. average postage cost Rs. 100 per article leads to expenditure of Rs. 3,00,000 per year). This has also saved on secretarial manpower associated with the journals.

Green publishing: In the new e-publishing system, article manuscript submission by author is completely online, all correspondence carried out between editor-author-referees is via email and online both and complete editorial office process is also carried out through email and online, hence it has been possible to eliminate the use of paper in DKMA in research journal publishing. Now our journals are 'Green Journals' as we are saving nearly 3.0 lakh A4 size paper per year if we consider total articles submissions (3,000) only from 2 research journals. The figure will be much higher if two semi-popular journals and society journals are taken into account.

E-Publishing of professional agricultural research society journals: Society journals namely, Fisheries Technology, Journal of Medicinal and Aromatic Plants, Indian Phytopathology, Journal of Indian Society of Agricultural Statistics, Journal of Horticultural Sciences, Potato Journal, Journal of Agricultural Engineering, Journal of Indian Society of Soil Science, Indian Journal of Dairy Science, Indian Journal of Veterinary Anatomy, Indian Journal of Veterinary Medicine, Journal of Wheat Research, Journal of Cotton Research and Development, Annals of Agricultural Research and Indian Journal of Hill Farming, were made online using e-publishing System. The agricultural research societies were given training at DKMA. E-Publishing has enhanced visibility and readership of Indian agricultural research knowledge in many folds.

Open Access of agricultural research journals online resulted in enhanced discoverability of the research published in ICAR's Journals. Independent information analyzing agency Scopus database has shown improvement over period in performance of both ICAR's journals.

e-Publishing Analytics

Year	Visits	Unique Visitors	Page Views	Article downloads	Abstract Views	Count-ries
2011-12	1,44,258	74,442	965,179	10987	85937	181
2012-13	1,94,344	99,634	1,203,798	65903	337467	178
2013-14	2,12,223	1,11,436	1,253,025	154343	942177	192

Source: Google Analytics

E-publishing and open access enhanced Impact factor of the ICAR journals : Impact factor of Indian Journal of Agricultural Sciences increased from 0.088 in 2010 to 0.177 in 2014 and there was a significant increase in the impact factor of Indian Journal of Fisheries from 0.040 in 2013 to 0.195 in 2014. The Indian Journal of Agricultural Sciences and Indian Journal of Animal Sciences are being e-published online since March 2010 and are available in Open Access since then.

Total registered users on the ICAR e-publishing platform of research journals are more than 50,000 out of which those registered users 40,022 have registered as readers. Two top ranking ICAR research journals. The Indian Journal of Agricultural Sciences and The Indian Journal of Animal Sciences have about 17,000 registered readers. There are total of 16,171 full text articles in the archive.

Consortium for e-resources in agriculture

The CeRA sub-project is the first of its kind for facilitating 24x7 online accesses of select journals in agricultural and allied sciences to all researchers in NARS through IP authentication. At present, there are 147 members (along with regional stations, KVKs and colleges) in CeRA comprising ICAR Institutes, SAUs, NRCs, PDs, etc. in NARS. About 3,490 journals were made accessible in CeRA which includes consortium subscribed (2,046), Open Access- (501) and Library subscribed- (905) in addition to two databases; CABI and Web of Science. CeRA is now the most sought after online platform by scientists/ teachers in NARS for literature search for their professional pursuit. The subscription of journal was obtained at one place instead of subscribing individually. This process provided an effective and efficient way of subscription of research journal under NARS in terms of time, space and budget.

The usage of CeRA (http://cera.iari.res.in & http://www.jgateplus.com) has improved steadily and the monthly average downloads of full text articles is about 0.15 million (1.5 lakhs). The number of visitors to CeRA website reached more than 3.5 million (35 lakhs) and the total downloads of full text articles more than 8.5 million (85 lakhs). Based on the number of downloads and the consortium subscribed costs to Publishers, there is more than 80 per cent savings, in addition to easiness with which a researcher can have the access to full text articles right on their tables. Due to CeRA, significant time and energy associated with visiting libraries and searching literature by researchers were saved besides reduction in subscription costs. Many Libraries were not in position to subscribe several journals due to the high subscription cost or remote location, now empowered to access through CeRA.

During the past five years, more than 50,000 articles have been distributed among all CeRA members under the Document Delivery Request System, a novel method of sharing knowledge. The number of publishers for subscription is seventeen namely, Annual Reviews, Elsevier, Taylor & Francis, ISHS-Acta Horticulturae, Nature, BioOne, AAS-Science, American Society of Microbiology, informatics, Indian Journals, Oxford University Press, Thomson Reuters(Web of Knowledge), Springer, International Water Association, CAB International(CABI), EzProxy (for remote access) and American Society of Agronomy.

Strengthening of digital library and information management

Emergence of digital resources along with digital services and access technologies has created new challenges and expectations from library and information services. The demand for fast access to authentic and credible digital information sources have also risen in agriculture sector. End to end value chain development requires quick access to diverse type of information. A successful attempt has been made to create a digital library by connecting 37 libraries of NARS under the sub-project Strengthening of Digital Library and Information Management under NARS: e-Granth with lead centre at IARI, New Delhi and 36 consortia partners from the NARS. This facilitates researchers, teachers, students and extension professionals. Infrastructure facilities along with KOHA software at 36 partner's institution were created to bring under the same network. An open source Library Management Software called KOHA was identified and implemented in all partners' libraries with expert support. This has provided uniform Library Management across the NARS library through KOHA, which also supports in integrating all libraries with standard protocols in a unified approach.

Indian agricultural doctoral dissertations repository

To overcome the duplication of research work through doctoral dissertation, under the sub-project entitled Indian Agricultural Doctoral Dissertations Repository - KrishiPrabha at CCS HAU, Hisar was established. The KrishiPrabha was envisaged to develop and maintain a repository of Indian Agricultural Doctoral Dissertations in electronic form. The uniqueness of this work lies in the fact that the repository was made online accessible. A database of metadata and abstracts of about 7,627 dissertations and more than 6,000 dissertations having full text for the period 2000-13 was created.

Full text data is also accessible to all the consortia partners through IP authentication only for viewing. Copying and printing of full text is restricted for prevention of plagiarism. However, metadata and abstracts are available to non-members world over and can be copied and printed. Facility and standard format to submit soft copies of the dissertation from remote have been developed. The KrishiPrabha platform was further up-scaled and merged with e-Granth sub-project at IARI, New Delhi. The activity of the Krishi Prabha has been sustained in 12th Plan under the financial support of the Education Division of ICAR during post NAIP period.

Interactive multimedia agriculture advisory system

Farmer-specific agriculture advisory call centre was developed under the sub-project entitled Development of ICT based Tools/Technology towards an Interactive Multimedia Agriculture Advisory System that conveys information pertaining to that farmer, farm and specific crop being grown and displays any images that may have been uploaded by the farmer. Based on this information, the expert can provide advice which may also be recorded for future reference. The dashboard is updated by the expert while in conversation with the farmer. The multi-party conferencing system allows the expert to connect to an off-site expert if faced with questions that cannot be answered by the local expert.

The system was built with an interactive voice response system developed in the English and local language (Tamil) using which farmer can update his crop data. The change in data was instantly aimed to reflect in the central database. In Call-center system, when the farmer calls, the call lands onto the call-center advisory system, prompting the specific dashboard of the farmer to open up. This helps the expert to quickly provide farmer and crop-specific advisory. Interactions between the farmer and the expert can be recorded by the expert forming a regularly updated advisory timeline which helps the expert in tracking issues and concerns raised by farmer. Farmer can very quickly capture images of any infestation or potential problem areas of crops and upload it through Pest and Disease Image Upload Application (PDIU) to a database real-time and will obtain immediate advisory from expert. A comprehensive farm plot historian database system has been developed for nearly 1200 farmers; this includes farmer details, plot details including GIS images of plot contours and various other plot parameters such as area, soil fertility, previous crops grown and current inputs that have been used.

e-Courses

The demand and supply gap of manpower requirement for graduates in the field of agriculture and its allied areas is increasing significantly in India. The traditional methods of educating the diverse masses in diverse geographical areas are becoming difficult in the new context of problems, which puts greater demand on current and future knowledge. Besides, the new generation of students are tech-savvy and believe in blogging, podcasting, SMSing and net-centric in the connected world. Therefore use of new technologies in education like e-course, ODLs, cloud computing and virtual teaching are need of the present requirement. e-Learning is the current trend in synchronous classroom education as well as asynchronous distance education.

e-Courses for the degree level programmes in seven disciplines was developed for the disciplines; Agriculture Science, Fisheries Science, Dairy Science, Veterinary and Animal Husbandry, Horticulture Science, Home Science and Agricultural Engineering. The entire course modules were developed by renowned subject matter specialists, teaching in respective disciplines and course contents were as per the syllabus approved by ICAR.

Open and Distance Learning System

Open and Distance Learning (ODL) system has been recognised as successful tool due to its capacity to reach the unreached. Knowledge modules and small learning chunks were developed in the form of Reusable Learning Objects (RLOs) under the sub-project Innovations in Technology Mediated Learning: An Institutional Capacity building in Using Re-Usable Learning Objects in Agro-horticulture with Indira Gandhi National Open University (IGNOU), New Delhi as the Lead Partner along with TNAU, Coimbatore and YCMOU, Nashik. A framework of modules synchronized with units and sub-units was developed using the technique of Re-usable Learning Objects (RLO) and Open Educational Resources (OER) philosophy. Multi-modal deliveries using online availability of RLOs, CD and Self Instruction Materials (SIM) were prepared to facilitate the modules. The learning materials developed covered five major themes viz., nursery management, high value crop production technology, integrated nutrients management, integrated pest management and post-harvest management and value addition in agro-horticulture including rice, potato, mango, banana, grapes and tomato etc. Altogether, 500 Reusable Learning Objects (RLOs) under these themes for six crops were integrated with the modules.

Rice knowledge management portal

The consortia helped in strengthening communications infrastructure among the stakeholders, improving tools for collecting data and information, nurturing scientific communities in the field of rice, providing platform for collaborative action and information sharing, initiated steps for integrating information systems, and improving the knowledge sharing culture throughout various key players and stakeholders in the rice sector of India. The project was aimed at developing and maintaining a rice knowledge management portal to strengthen research, extension, farmers, and private subsystems, partnerships and networks, for the better flow of rice knowledge and information contributing to the overall rice development in the country.

The RKMP serves as an information highway for rice sector in sharing rice knowledge through latest ICT tools including mobile telephony. It also helps agricultural departments' ongoing activities in reaching out to the farmers through extension advisory services, in most effective way.

The largest rice database of location specific content also helps the farmers to know about the soil health and fertilizer recommendation system through online Fertimeter application. The exclusive and exhaustive information on weeds helps to make wise decisions in weed management.

As Indian Agriculture is highly dependent on vagaries of weather and 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. For having the first hand information, any farmer is given assistance in spotting the nearest research station, extension office, KVK, dealer. To enhance the export opportunities for rice from India, Trade Information System of RKMP delivers the trade information at different markets all over the world and exports and imports information of rice.

Strengthening of communication and public awareness capacity

For strengthening the communication and public awareness capacity to provide the required value-added information support for the accelerated and sustainable transformation of the Indian agriculture through print and electronic modes were formulated. The objective of the project was to provide viable media communication system models in the NARS and communication links among public research organizations, farmers' groups, private sector and other stakeholders, to achieve poverty alleviation, food security and income generation for the farmers.

Agroweb-digital dissemination system for Indian agricultural research

One of the major activities of our NARS institutions is to create knowledge repository and provide information on agriculture, horticulture, resource management, animal sciences, agricultural engineering, fisheries, agricultural extension and agricultural education. The aim of the project is to provide uniform content, format and domain name and updating mechanism. A common gateway was created for the institutes to act as a one-stop window for getting access to all the information about National Agricultural Research and Education Systems in India.

Under this project, Website Uniformity Guidelines for ICAR was developed and disseminated which outlined the Standards and Content Management Strategies (CMS) to be employed by all ICAR institutes. Model websites of all the eight consortium partners (including ICAR) were developed using latest web 2.0 technologies and open source CMS such as Joomla and Drupal. The website contain role-based dynamic updating mechanism which enables the web administrator to upload the contents from anywhere in the network, using secured access. The layout was also made compact but informative, with quick links to most demanded after information. Other new features include Calendar of Events, Feedback, RSS modules, embedded videos and flash objects and bilingual options.

Capacity building in development and management of websites was carried out. Several participants from various ICAR institutions have been trained in new generation web technologies, design, development and management of websites. The modules of Online submission of ICAR award applications, intellectual property rights management system application of ICAR, tender document application of ICAR, and online admissions system of PG School (IARI) were implemented with critical input from the users.

The ICAR web portal is a web based application with the concept of web content management, content publishing using intensive role based process and workflow and federated search across the ICAR organizations, business process integration, knowledge management and integration of online application systems. The portal provides a single point of access to all modules such as Users Registration, Award System, Tenders Information, Online Admission System, IPR Management System, latest News and Events, Institutes Information, Speeches, circulars, ICAR success stories and Innovations etc. The system provides intensive web 2.0 features of sharing on social portals, commenting, emailing, printing and rating on various ICAR articles. The feature of most rated and most viewed articles have associated with various categories like success stories and innovations.

CONCLUSION

The emergence of Information and Communication Technologies (ICT) 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. The ultimate objectives of agriculture knowledge management system was to come up with results that can advance research more in certain areas, and engender technologies that stakeholders can use to increase production, conserve the environment, etc.

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Types of contribution

Papers should mainly be based on original works/experience or ideology on any aspect of soil and water conservation including the generation and interpretation of basic data for these programmes.

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Manuscripts are required neat and clean in Laser Print or Letter Quality in font size 10/12 point on Bond Paper in English with one Photocopy double spaced, with wide margins and along with one soft copy should be sent to the Cheif Editor, Soil Conservation Society of India, National Societies Block A/G-4, National Agricultural Science Centre Complex, Pusa Campus, New Delhi 110 012. Only two copies of illustrations and plates need to be sent.
Papers should have the following sequence of heads: title, followed by the name(s) of author(s) with affiliation(s). Abstract, Introduction, Text of the paper with sub-heads, if necessary, Summary, Conclusions, Acknowledgement and References. Tables should be compiled separately on separate sheets.

The text should suitably be subdivided; the main heading has to be in capital letters, secondary heading also in capitals but in side position and tertiary heading should be normal typescript in side position. Underline only those words that should be in italics. Use the metric system. The abstract should not be exceed 200 words; it should highlight only techniques ans significant finding and thus be more concise than a regular 'Summary'. References should be written in the form as given below:

Ahuja R L, Garalapuri V N, Manchanda M L and Khanna S S. 1978. Physiography and Soil Association of Haryana, J. Ind. Soc. Soil Sc. 26:261.

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These should be kept to the absolute minimum in view of the high cost of reproduction.

Line diagrams and maps should neatly be drawn in Black ink on tracing paper of drawing paper. The original drawings should ordinarily be not more than 35 x 25 cm in size with letter size and spacing so arranged as to permit easy 2/3 reduction.

All photographs should be of good quality, original or printed on glossy paper and should not exceed page (21 x 13 cm.) They should preferably by in squares or rectangles.

If annotated air photos of India are sent, the author(s) should send a certificate tot the effect that Defence Clearance has been obtained for printing.

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