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Contents

Pledge

J.S. Bali

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

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INMS: A tool to retrieve soil health

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ABSTRACT

Over exploitation and degradation of soil resources in the quest of food security has made the soil deficient in macro as well as micro nutrients. On an all India basis 41% soil samples have been found deficient in S, 47% in Zn, 35% in B, 13% in Fe, 7% in Mo and less than 5% in Cu and Mn. Percentage of nutrient deficient samples in India is increasing tremendously. It is due to avoidance of organic matter incorporation in our soil during the post green revolution era. Organic sources of plant nutrients are important as they improve physical, chemical and biological health of soils. However, the chemical fertilizers are also an important input to obtain the high output from less fertile soils because sudden replacement of chemical fertilizer by manures/ composts/ bio-fertilizers may cause noticeable yield decrease. Thus, an integrated nutrient management system (INMS) may prove a useful tool to achieve food security on sustainable soil health consideration.

Key words: INMS, food security, sustainable soil health, chemical fertilizers, organic sources of plant nutrients

INTRODUCTION

India has the onerous task of feeding almost 17 percent of the global human and 11 percent of the livestock population on only 2.3 percent of the world's land. It is estimated that by 2025, India would require 338 million tons of food grains to feed it's teeming millions population (Parama and Biswas 2009). This target has to be met under the constraint of decreasing net cultivated area due to utilization of cultivated area for residential, transport and industrialization purposes and impairing soil fertility. It has been estimated that the area of cultivated land in India will decrease to 100 million hectare and human population will become 1.4 billion by 2025. To feed the ever increasing population from shrinking cultivated land, it will be necessary to use 30-35 Mt of NPK from various sources. In addition, the experts on horticulture, vegetable, plantation crops, sugarcane, cotton, oilseeds and potato have projected that by the year 2025, the demand for fertilizers for these high value crops, will rise to 3.0, 2.0, 0.9, 3.1, 1.5, and 1.0 million tonnes, respectively (Tiwari, 2008).This adds to the total nutrient needs by another 14-15 million tonnes NPK. Thus, from both inorganic and organic sources, the country will require to arrange for the supply of about 40-45 million tonnes of nutrients by the year 2025. However, present consumption of NPK and production of $N+P_2O_5+K_20$ in our country are only 22.57 million tonnes Bhumbla (2010) and 16.42 million tonnes FAI (2008) respectively.

As a result of over exploitation of the soil resource in post green revolution era, most of our soils have become deficient in some secondary and micro nutrient elements. The number of deficient nutrients in Indian soils continue to increase sharply (fig. 1). Not only this, but the physical, chemical and biological properties of soils have also been found deteriorated (Rattan *et al*, 2009). Thus, there is an urgent need of organic matter incorporation in soil to restore it's health. Though, organic matter incorporation improves physical, chemical and biological properties of soils, but it can't be used for sudden replacement of chemical fertilizers. Thus, it should be integrated with chemical

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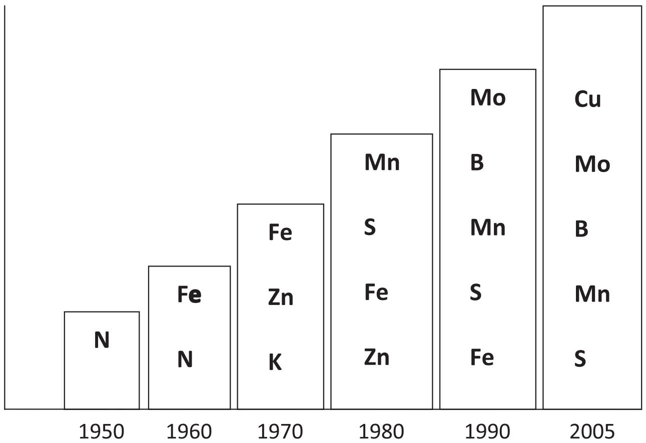

Fig. 1: Progressive increase in deficient nutrient elements in India (source; Rattan et.al, 2009)

fertilizers to assure food security without impairing our soil fertility.

Organic carbon vs. soil health

The quality and health of soils not only determines agricultural sustainability but also the environmental quality and plant, animal and human health (Sharma and Mandal, 2009). Organic carbon status of the soil is an important biological indicator of soil health and its contribution on physical, chemical and biological properties in sustaining the productivity is being appreciated since the dawn of human civilization. It has been estimated that land use change resulted in the transfer of 1 X 10^8 - 2 X 10^8 Mt C/yr from terrestrial ecosystem to the atmosphere of which 15-17 percent carbon is contributed by decomposition of soil organic carbon (Houghton and Hackler, 1994). Organic carbon in Indian soils was estimated at 23.4 X 10^8 - 27.1 X 10^8 Mt (Dhadhwal and Nayak, 1993). The amount of soil organic carbon in Indian soils under intensive cropping systems is relatively low, ranging from 0.1 to 1% and typically less than 0.5% which influences the soil fertility and physical condition (Swarup and Singh, 2009). The organic carbon content of Indian soils is decreeing very sharply and as a result physical, chemical and biological properties of soils are deteriorating gradually due to unfavorable shift of mineralization and immobilization. So, there is a need to improve organic carbon status of the soil to assure the nutrient requirement of crops through organic or inorganic sources.

In general, four important chemical and biochemical processes, often working simultaneously, are involved in influencing the dynamics of nutrients in soil system. These are: dissolution-precipitation, sorption-desorption, mineralization-immobilization and oxidation-reduction and most of the dynamic behavior of soil nutrients can be explained by one or combination of these processes. These all processes are governed by organic carbon status of the soil. Thus, there is a need to apply organic matter in combination with inorganic fertilizers to sustain fertility and productivity of the soils.

Nutritional status of Indian soils

There is a definite gap between nutrient removal and supply leading to nutrient depletion from soils. There exists a gap of about 10 Mt between additions of nutrients through fertilizers and their removal by crops in India (Tandon, 1997). As a result, the growth rates of production and productivity of principal crops started showing stagnation or a declining trend in the post green revolution era. Poor nutritional status of Indian soils due to imbalanced use of nutrient elements is one of the important factors responsible for this declining trend in crop yield. On an all India basis, out of 36,50,004 soil samples, 63, 42 and 13 % samples were found to be deficient in nitrogen, phosphorus and potassium respectively (Table 1). However, it has been reported by Subba Rao *et. al*.(2009) and Vasuki (2010) that out of 2,50,000 soil samples 40-41% soil samples were deficient in S, 47% in Zn, 35% in B, 13% in Fe, 7% in Mo and less than 5% for Cu and Mn (Table 2). Zinc deficiency in soil is expected to increase from 49% to 63% by the year 2025.This situation can possibly be restored by full exploitation of the potential of alternative sources of plant nutrients (Tiwari, 2008). Complementary use of available renewable sources of organic and biological sources of plant nutrients along with mineral fertilizers is of great importance for the maintenance of soil productivity, preferably in a

Table 1. Extent of macronutrient deficiencies in India

Nutrient	Number of samples analyzed	Status of nutrient (%)		
		Low	Medium	High
N	36,50,004	63	26	11
P	36,50,004	42	38	20
K	36,50,004	13	37	50
S	27,000	40	35	25

Source: Singh, 2010

Table 2. Extent of micronutrient deficiency in soils of different states and union territories

States	Per cent soil samples deficient					
	Zn	Cu	Fe	Mn	B	Mo
Andhra Pradesh	51	<1	2	20	-	-
Assam	34	-	-	-	17	-
Bihar	54	3	6	2	39	-
Delhi	20	-	-	-	-	-
Gujrat	24	4	8	4	2.5	10
Haryana	61	2	20	4	-	-
Jammu & Kashmir	12	-	-	-	-	-
Karnatka	78	5	39	19	32	-
Kerala	34	31	<1	-	-	-
Madhya Pradesh	63	-	3	3	2	18
Meghalaya	57	2	-	23	-	-
Orissa	54	-	-	-	69	-
Pondicherry	8	4	2	3	-	-
Punjab	47	<1	14	2	-	-
Rajasthan	21	-	-	-	-	-
Tamil Nadu	53	3	18	8	-	-
Uttar Pradesh	45	<1	6	3	24	-
West Bengal	36	-	-	3	68	-
Overall	47	2	13	4	35	7

Source: (Vasuki, 2010)

balanced way (Singh, 2008). This integrated nutrient management system (INMS) is the need of the day and for future in agriculture for sustainable soil health and food security (Singh, 2001).

Integrated Nutrient Management System Concept

The basic concept underlying with INMS is the maintenance and adjustment of soil fertility to supply an optimum level of plant nutrient through all possible sources in an integrated manner. The appropriate combination of mineral fertilizers, organic manures, crop residues, vermicompost or bio-fertilizers according to the system of land use and ecological / social and economic conditions is the basic aim of INMS. The INMS involves a low to medium external chemical inputs approach.

Although, INMS is an age old concept but its importance was not realized earlier. It has now assumed a great importance because of the present negative nutrient balance (nutrient mining). The INMS helps not only to restore and sustain the soil fertility and crop productivity, but also enables the emerging deficiency of nutrients other than N, P, and K. INMS favorably affects the physical, chemical and biological environment of soils and increases the efficiencies of fertilizers.

Components of INMS

Different components of INMS are discussed below:

Fertilizers: Fertilizers are one of the most important components of INMS. The response of the major crops to the applied fertilizers has been decreasing for the country as a whole and as a result fertilizer consumption in India is increasing very sharply (Table 3). Fertilizer use efficiency is required to be improved. The causes of low efficiency are as under:

- Sub optimal and imbalanced use of fertilizers (NPK)
- Excessive use of fertilizer in some commercial and horticultural crops
- Inappropriate methods and time of fertilizer application
- Deficiency of secondary and micronutrients
- Deteriorating soil health.
- Poor water management system
- Faulty plant protection and weed control measures.
- Faulty agronomic practices
- Poor organic carbon status of majority of the soils

Table 3. Consumption of fertilizer ('000 tonnes of nutrients) in India

Year	N	P	K	Total
1960-61	210	53	29	292
1970-71	1487	462	228	2177
1980-81	3678	1214	624	5516
1990-91	7997	3221	1328	12546
2000-01	10920	4215	1567	19702
2007-08	14490	5515	2636	25570

Source: GOI, Economic Survey, 2009-10

Organic manure: Organic manure is another important input for INMS. It can potentially deliver 19.419 million tonnes of NPK (Table 4) but there exists a wide gap between potential and actual supply. It appears that only 30% of the estimated potential is actually available for agricultural use. Improved recycling techniques can increase the potential availability of nutrients from organic resources.

The long term fertilizer experiments conducted at different locations in the country indicated that the plots receiving organic manure (FYM) along with NPK sustained the soil fertility and productivity. In contrast, in the absence of FYM, application of even 50 percent higher dose of recommended NPK could not hold on the initial rise in productivity (Nambiar and Ghosh, 1984). Additional response to organic manures over NPK is attributed to correction of some other nutrient deficiencies and improvement of soil physical properties. Even in short term studies involving rice-wheat rotation, FYM (12t ha^{-1}) produced a residual effect equivalent to 30 kg each of N and P_2O_5 ha^{-1} (Tiwari, 2008). The organic manures used with fertilizers, besides improving soil physico- chemical properties also improved the use efficiencies. Physical, chemical and biological properties of soil also improved in long term fertility experiments due to application of INM in different cropping systems (Table 5).

Table 4. Nutrient potentiality of various organic resources

Types of organic resources	Availa-bility	Total Nutrient(Mt/Year)			
		N	P_2O_5	K_2O	Total
Crop residues	273	1.28	1.97	3.91	7.16
Cattle manure	280	2.81	2.00	2.07	6.88
Rural compost	285	1.43	0.86	1.42	3.71
Forest litter	19	0.10	0.04	0.10	0.24
City garbage	15	0.23	0.15	0.23	0.61
Press mud	03	0.03	0.079	0.055	0.164
Sewage	6351	0.32	0.14	0.19	0.65
Industrial waste	66	0.003	0.001	0.001	0.005
Total		6.203	5.20	7.976	19.419

Source: Bhardwaj, 1995; Tandon, 1997

The crop residues with high C: N and C: P ratios can not be directly applied to soil as a source of nutrient. They have to be composted in order to convert the nutrient contained there in to become plant usable forms. Technologies to upgrade the nutrient content of compost and also to hasten the process of composting by use of efficient cellulolytic and lignolytic cultures have been developed (Tiwari *et al.*, 1989). The technologies for preparation of enriched compost, vermicompost, enriched vermicompost and biodynamic fertilizers in India have been standardized. The main limitation in the way of composting is the consumption of 75% of total dung for domestic fuel purposes and wastage of livestock urine. However, wider adoptability of INMS requires proper utilization of cattle dung and urine for composting.

Green manures/ Brown manures: Green manure has long been known to be beneficial for sustainable crop production. The studies in India indicate that

Table 5. Effect of INMS on physical, chemical and biological properties of soils in long term fertility experiments

Location	Treatment	Soil organic carbon (g Kg^{-1})	Av.N (Kg ha^{-1})	Av. P (Kg ha^{-1})	Av. K (Kg ha^{-1})	Bulk Density (Mg m^{-3})	Hydraulic conductivity (cm hr^{-1})	Bacteria (X $10^6 g^{-1}$ soil)	Fungi (X 10^3 g^{-1} soil)	Actino-mycetes (X 10^4 g^{-1} soil)
Ludhiana	NPK	3.6	126	86	99	1.53	-	-	-	-
NPK + FYM	5.2	132	99	114	1.49	-	-	-	-	
New Delhi	NPK	4.4	-	35	287	1.48	0.69	-	-	-
NPK + FYM	5.5	-	41	316	1.41	0.76	-	-	-	
Palampur	NPK	9.7	317	103	156	1.17	-	11.5	7.8	20.3
NPK + FYM	13.0	335	194	215	1.13	-	28.0	2.8	7.3	
Bangalore	NPK	4.9	308	113	173	1.52	0.96	16.7	9.0	3.0
NPK + FYM	5.7	316	195	206	1.45	0.59	24.0	15.0	4.3	
Jabalpur	NPK	7.4	263	29	266	1.28	0.50	-	-	-
NPK + FYM	9.6	315	39	313	1.25	1.40	-	-	-	
Pantnagar	NPK	8.7	242	19	140	1.35	0.74	-	-	-
NPK + FYM	16.0	328	35	154	1.20	0.80	-	-	-	-

Source: Singh, 2010

the green manure is able to replace 60 KgN/ha (Tiwari *et al*., 2008). A fertilized green manure crop would substitute more mineral fertilizer N than an unfertilized green manure crop. With the increasing cost of fertilizer and growing awareness of ecological impact of using agro- chemicals, green manuring has a special place in view of the limited availability of other organic manures. Incorporation of summer green gram into the soil after first picking also saved 60 kg N ha^{-1} (Tiwari, 1980). Being deep rooted and leguminous, green manuring crops improve the availability of other plant nutrients beside nitrogen. Physical properties of soil also improve due to practice of green manuring of *Sesbania* before rice crop (Table 6).

Bio-fertilizer: Biological organism used as a fertilizer is known as bio-fertilizer. Bio-fertilizers can be grouped into nitrogen fixer, phosphate solubilizer, mycorrhiza and nutrient transformer but last one is neither produced nor utilized in India. However, all kind of nitrogen fixers (symbiotic, associative and free living) are being utilized to fix substantial amount of nitrogen biologically (Table 7).

Rhizobium: Rhizobia, a soil bacteriam has an ability to fix atmospheric nitrogen in symbiotic association with legumes and certain non-legumes like parasponia. Organic matter, temperature, sunlight, moisture and nutritional factors affect the nitrogen fixation abilities of rhizobial species and strains. *Rhizobium* is host specific. The new system of classification of root nodule bacteria and host specificity has been presented in Table 8. As native rhizobial population is not sufficient in Indian soils for maximum N_{2-} fixation, so legume seeds are inoculated with synthetic cultures adopting the principle of F.I.R. (Fungicide-Insecticide-*Rhizobium*).

Azospirillum/Azotobacter: Multilocational trials with pearl millet, sorghum, finger millet, barley and vegetables have shown significantly increased yield due to inoculation with *Azospirillum* and *Azotobacter*, the effects of inoculation being more conspicuous under low levels of added nitrogen (SubbaRao *et al*., 1982). Apart from nitrogen fixing ability, *Azospirillum* is known to produce auxins, cytokinins and gibberellins. *Azospirillum* and *Azotobacter* are also applied through seed inoculation, seedling treatment, tuber treatment or soil application.

Blue green algae: Extensive field trials conducted in many parts of India on the use of the blue green algae in rice fields indicated that one third of the recommended N fertilizer could be conserved without affecting crop productivity through inoculation (Goyal, 1993). These algae are known to provide the crop plant with many other useful organic substances like growth factors, vitamins etc. Normally, continuous inoculation for 3-4 consecutive cropping seasons results in an appreciable population build up without any further inoculation unless some unfavorable ecological conditions supervene.

Azolla: *Azolla* is a tiny floating fresh water fern and is omnipresent in nature. The dorsal lobe of *Azolla* has blue green algal symbiont (*Anabalna azollae*) within a central cavity. The heterocyst of the microsymbiont is the site of nitrogen fixation. The increase in yield of rice due to *Azolla* application has been reported to be varying from 18-47 percent depending on the cultivar of rice used (Singh, 1977). Further, field experiments have shown that consistent increase in yield of rice could be obtained by the use of *Azolla* as a green manure in *conjunction* with fertilizer N (Tilak , 1998) . It has been estimated that a saving of at least 30Kg N / ha for rice could be obtained by the use of *Azolla* biofertilizer beside residual effect for the succeeding crops.

Phosphate Solubilizers: Phosphate solubilizers include various bacterial, fungal and actinomycetes. They help to convert insoluble inorganic phosphate into simple and soluble forms. Field experiments conducted with phosphate solubilizers significantly increased the yield of various crops like wheat, rice, cowpea etc. In the presence of rock phosphate,

Table 6. Effect of green manuring of *Sesbania* on physical properties of soils

Reference	Study duration (Years)	Treatment	Water stable aggregates (%)			Bulk density ($Mg\ m^{-3}$)
			0.25-0.1mm	0.5-0.25mm	0.5-1mm	
Kumar *et al*. (1992)	6	- GM	6.3	7.5	8.0	1.54
		+ GM	11.1	10.7	7.8	1.45
Boparai *et al*. (1992)	2	- GM	10.5	9.4	3.9	1.56
		+ GM	17.3	12.8	4.6	1.50

Table 7. Typical level of fixed-N in different systems

Crop / plant	Associated organism	Fixed-N(kg N/ha/yr)
(A) Symbiotic Legumes		
Medicago sativa (Alfalafa)	*Rhizobium*	90-386
Trifolium pratense (Clover)	*Rhizobium*	69-373
Pisum sativum (Pea)	*Rhizobium*	17-244
Lupinus sp. (Lupin)	*Rhizobium*	32-288
Lens esculenta (Lentil)	*Rhizobium*	10-192
Vicia vilbosa (Vetch)	*Rhizobium*	53-330
Vicia faba (Faba bean))	*Rhizobium*	53-330
Lupinus agustifolius(Lupin)	*Rhizobium*	32-228
Cicer aritenum (Gram)	*Rhizobium*	3-141
Phaseolus vulgaris (Bean)	*Rhizobium*	0-125
Leucena leucocepnala	*Rhizobium*	98-230
Vigna unguiculata (Cowpea)	*Bradyrhizobium*	9-201
Vigna radiata (Green Gram)	*Bradyrhizobium*	9-112
Vigna mungo (Black Gram)	*Bradyrhizobium*	21-140
Arachis hypogea (Peanut)	*Bradyrhizobium*	37-206
Glycin max (Soybean)	*Bradyrhizobium*	0-450
Cajunus cajan (Pigeon pea)	*Bradyrhizobium*	7-235
Pueraria (Kudzu)	*Bradyrhizobium*	100-140
(B) Symbiotic non legumes		
Alnus	*Frankia*	50-150
Gunnera	Not well defined	10-20
Casurina equisetfolia	*Frankia*	9-440
Giricidia sepium	Not well defined	86-309
Calopogonium/Peuraria spp	Not well defined	150
(C) Non legumes (Non nodulated)		
Pangola grass*(Degetaria decumbans)*	*Azospirillum*	5-30
Bahai grass*(Pasalum notatum)*	*Azotobacter*	5-30
Azolla	*BGA*	150-300
(**D) Free living**		
Hetrotrophic	Microbes	0.1-0.5
Autotrophic	Microbes	25.0

Source: Peoples *et al*., 1995; Marschner, 1986; Singh, 1989

inoculation of phosphate solubilizers saved 30kg P_2O_5 ha^{-1} (Gaur, 1985).

VAM Fungi: Vesicular arbuscular mycorrhiza (VAM) is the mutually beneficial association between certain fungi and the roots of higher plants. Mycorrhiza greatly enhance the ability of plants to take up phosphorus and other nutrients that are relatively immobile and present in lower concentrations in the soil solution. Water uptake may also be improved by mycorrhiza making plants more resistant to drought, pests and diseases.

Table 8. New system of classification of root nodule bacteria

Species	Biovar	Host
Rhizobium leguminosarm	*a. viciae*	Vicia
	b. *trifolii*	*Trifolium*
	c. *phaseoli*	*Phaseolus*
R . meliloti	-	*Medicago*
R . loti	-	Lotus
R . friedii	-	*Glycine*
Bradyrhizobium Japonicum	-	*Glycine*
Bradyrhizobium sp.	-	*Cicer, Cajanus,Vigna*

CONCLUSION

Fertilizer is the most costly input used for crop production. Demand of chemical fertilizers has been increasing tremendously over the years due to the introduction of high nutrient responsive crops and declining fertility of the soil. Still, the gap between removal and addition of nutrients through fertilizers is constant i.e. 10 million tones of nutrients per annum. The plant nutrient imbalance in quest of increasing food grain production target would further aggravate through over exploitation.

Balanced use of nutrient will not only improve crop productivity but it reduce large scale depletion of soil nutrients .The entire nutrient needs of the crops to take care of nutrient removal by crops can not be met either through chemical fertilizers alone or through organics alone. Integrated nutrient supply and management based on soil test would be the most practically viable technique which holds the key to sustain crop yield and quality of soil without adversely affecting the environment. Addition of organic sources can again increase the yield by increasing the soil productivity and fertilizer use efficiency. Thus sustainable agriculture in years to come should ideally be based on integrated plant nutrient supply system. Locally adopted INMS should be technically sound, environmentally friendly, economically reliable, socially acceptable and practically feasible and these are yet to be developed on priority basis.

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Effect of rates, methods, and schedules of N application on growth, and yield in upland rice under unfavourable environments

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ABSTRACT

A field study was conducted to find out the optimum time and application rates, methods and schedules of N fertilizers and characterize their effects on the growth, dry matter accumulation, yield and its components and for improving its response in upland rice under rain fed ecosystem. Results revealed that for achieving the highest grain productivity in rain fed upland environment, application of 40 kg N ha^{-1} applied in two equal splits at 20 and 40 DAS and 2% urea spray at 2 weeks after flowering while for highest productivity of straw ,60 kg N ha^{-1} applied in two equal splits at 20 and 40 DAS and 4% urea spray at 1 week after flowering is essential.

Key words: fertilizers, productivity, flowering and DAS

INTRODUCTION

Typical upland soils of Eastern India is generally deficient in nitrogen & phosphorus and there is toxicity of Al and Mn. Traditional rice cultivars were non-responsive to chemical fertilizers but with the development of fertilizer responsive cultivars, it is essential to determine the rates, methods and schedules of N fertilization for achieving higher use efficiency or response (Newton *et al*., 2001) due to leaching, denitrification, volatilization and run off losses. For upland rice, the recommended rates of N varies from 40-60 kg ha^{-1} (Kumar *et al*., 2002) which should be applied in 2-3 equal splits at sowing, flowering and panicle initiation for achieving higher use efficiency (Singh and Modgal, 1979). But in the event of severe water deficit when soil becomes too dry then it becomes impossible to apply nitrogenous fertilizer by top dressingdue to higher dentrification / voltalization losses. Under such situations, nitrogenous fertilizers solution can be sprayed (Singh and Modgal, 1979) which resulted in higher yield due to direct absorption of N by the leaves. In view of the above, a field study was conducted to find out the optimum time and application rates, methods and schedules of N fertilizers and characterize their effects on the growth, dry matter accumulation, yield and its components and for improving its response in upland rice under rain fed ecosystem.

Field study was conducted at Central Rain fed Upland Rice Research Station, Hazaribag, Jharkhand during kharif season with promising upland rice (cv. Kalinga III) as test crop with two levels of nitrogen viz., 40 and 60 kg ha^{-1}, two concentrations of urea spray (2 and 4 %) and two timings of spray (1 and 2 week after flowering-WAF). Eleven treatment combinations viz., T1- N_0 (control), T2- 40 kg N ha^{-1}, T3-60 kg N ha^{-1}, T4: T2+ 2 % urea spray 1 WAF, T5 : T2+ 2 % urea spray 2 WAF, T6 : T2+ 4 % urea spray 1 WAF, T7 : T2+ 4 % urea spray 2 WAF , T8 : T3+ 2 % urea spray 1 WAF, T9 : T3+ 2 % urea spray 2 WAF , T10: T3+ 4 % urea spray 1 WAF and T11: T3+ 4 % urea spray 2 WAF were tested in RBD replicated thrice. The soil belongs to *Alfisol* order having the characteristics: sand-32.1%, silt-46.6% and clay-21.3%, pH-5.8, OC-0.36%, CEC-14 meq / 100g, total N-0.04%, available P-5.5 ppm, and K-129 ppm, rolling topography and very sloppy. Total long-term average rain fall of the study area is 1298.5 mm. However, during the

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crop growing season, a total 926.6 mm rain fall was received. Crop was sown @ 100 kg ha^{-1} (direct seeding) in 20 cm row spacing. Recommended dose of fertilizers P_2O_5:K_2O-30:20 kg ha^{-1} was applied as basal . Half of N was applied at 20 DAS (after first hand weeding) and ½ at 40 DAS. Periodic data on plant height was recorded during the growing season for studying the growth profile of the crop. Representative plant samples using destructive method were collected from 50 cm row length during crop growing seasons to compute dry matter accumulation. Nitrogen response expressed as agronomic nitrogen use efficiency (ANUE) was computed by dividing the increase in grain yield over control by the amount of nitrogen applied in the crop. Yield and its components were recorded and analyzed statistically .

Crop growth expressed as plant height and total dry matter accumulation was appreciably affected by rates, methods as well as application schedule of N (Table 1) in upland condition. Among various treatments, the differential rates of increase in plant height was recorded during the growing season (22 to 81 DAS). At any stage, tallest plants were found in T10 (30.0 cm on 22 DAS and 101.4 cm on 81 DAS) and shortest in T1 (25.1 cm on 22 DAS and 86.0 cm on 81 DAS). Maximum percent increase in plant height in most of the treatments, except in T2 ,T3 and T6, was found on 39 DAS (24.4% in T7 to 34.5% in T10) but in T2 ,T3 and T6 it was found on 53 DAS (T2-14.5% and T6-18.2%) compared to control. A gradual decline in percent increase in height was observed between 53 to 81 DAS, which reflects the growth profile of each treatment. Similarly, highest dry matter accumulation was found in T10 during the growing season (5.6 g on 22 DAS and 53.4 g on 81 DAS) and the lowest in control T1 (3.3 g on 22 DAS and 26.8 g on 81 DAS). In all the treatments, except in T3 and T6, maximum increase in dry matter accumulation (45.5% in T7 and 119.7% in T10) was observed on 39 DAS while in T2,T3 and T6, it was observed on 22 DAS. On 53 DAS, it declined gradually in all the treatments. But, a differential rate of increase and decrease in dry matter accumulation was observed on 67 and 81 DAS indicating the variable impacts of treatments on dry matter accumulation. This reflects that 39 DAS is the most active stage of growth in upland rice expressed in terms of plant height and dry matter accumulation which might be due to maximum physiological and biochemical activities like cell division and elongation in the plants.

Yield components viz., panicle length, grains/ panicle, total and effective tillers, 1000-grain and panicle weight, of rice under rain fed environment were considerably affected by N fertilization (Table 2). Maximum panicle length was found in T1 (19.7 cm) which was 5.9% higher than the control - T1(18.6 cm). Highest number of grains / panicle was obtained in T11 (74) which were 21.3% higher than the control (T1)(61). The percent increase was 9.8 and 16.4%, in T2 and T3, respectively . Maximum total tillers were found in T11 (467) which were 26.2% higher than the control (370). The percent increases in T2 and T3 was 16.5 and 22.7 % , respectively. Similarly effective tillers

Table 1. Effect of N fertilization on plant height and dry matter accumulation in rain fed upland rice

Treat-		Plant height (cm)					Total dry matter (g)			
ments	22	39	53	67	81	22	39	53	67	81
T_1	25.1	40.6	61.4	83.5	86.0	3.3	6.6	13.6	20.8	26.8
T_2	25.7	43.1	70.3	86.0	86.5	3.9	7.4	15.7	21.5	30.3
T_3	26.0	45.2	70.3	87.9	91.2	4.4	7.9	16.2	22.1	33.0
T_4	26.5	52.0	74.3	93.4	98.1	4.7	10.2	17.3	26.5	35.2
T_5	26.6	52.1	75.2	94.4	98.1	4.8	10.8	17.6	32.2	38.6
T_6	26.1	46.9	72.6	91.9	94.4	4.5	8.4	17.0	22.4	33.7
T_7	26.4	50.5	73.0	93.1	96.6	4.6	9.6	17.1	23.7	34.4
T_8	27.0	52.8	75.4	94.8	98.4	5.4	12.0	18.3	34.3	44.5
T_9	28.9	54.3	75.8	95.4	99.4	5.5	13.6	18.4	34.4	50.3
T_{10}	30.0	54.6	78.0	98.3	101.4	5.6	14.5	22.8	38.5	53.4
T_{11}	27.0	52.6	75.4	94.6	98.4	5.2	10.9	18.0	34.3	38.7

Table 2. Effect of N fertilization on ANUE, yield and yield components of rain fed upland rice

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	ANUEkg grain / kg N applied	Panicle length (cm)	Grains / panicle	Total tillers (m^{-2})	Effective tillers (m^{-2})	1000-grain weight (g)	Panicle weight (g)
T_1	1.74	1.89	-	18.6	61	370	346	21.8	1.35
T_2	2.20	2.41	11.5	19.2	67	431	413	23.1	1.56
T_3	2.25	2.54	8.5	19.5	71	454	436	23.4	1.60
T_4	2.39	2.79	14.3	19.3	68	437	416	23.2	1.45
T_5	2.41	2.86	14.7	19.3	69	439	418	23.3	1.46
T_6	2.31	2.71	11.2	19.4	69	440	421	23.6	1.42
T_7	2.31	2.76	11.2	19.4	70	442	426	23.9	1.43
T_8	2.46	2.96	11.0	19.5	73	460	441	23.5	1.43
T_9	2.58	2.97	12.8	19.5	73	462	445	23.7	1.44
T_{10}	2.09	2.98	4.9	19.6	74	465	449	23.8	1.41
T_{11}	2.34	2.95	8.6	19.7	74	467	451	24.0	1.42
SEM±	0.16	0.17							
C.D.(5%)	0.33	0.37							

were also highest in T11 (451) which were 30.3% higher than control (T1)(346). Minimum percent increase was found in T2 (19.4%). Highest 1000-grain weight was found in T11 (24.0 g) which was 10.1% higher than the control (T1)(21.8 g) and minimum percent increase was 6.0% in T2. Highest panicle weight was recorded in T3 (1.6 g) which was 18.5 % more than the control (T1) (1.35 g) and minimum increase in panicle weight was found in T10 (4.4%).

Agronomic nitrogen use efficiency was substantially affected by N fertilization (Table 2). Highest ANUE was obtained in T5 (14.7 kg grain / kg N applied) which was 200% higher than T10. Almost, similar ANUE was found in T11 (8.6 kg grain / kg N applied) and T3 (8.5 kg grain / kg N applied) which was 75.5 and 73.5% higher in T11 and T3, respectively than T10. Same ANUE was recorded in T6 and T7 (11.2 kg grain / kg N applied) which was 128.6% higher than T10. The values for other treatments falls in between.

Nitrogen management in upland rice has significantly influenced the rice productivity (Table 2). Highest grain yield was recorded in T9 (2.58 t ha^{-1}) which was at par with T8, T5, T4, T11, T7, T6 and T3 but significantly higher than other treatments (T2 and T10) including the control T1 (1.74 t ha^{-1}). Maximum percent increase in grain yield was found in T9 (48.3%) and the minimum in T10 (20.1%) over control (T1). On the other hand, maximum straw yield was recorded in T10 (2.98 t ha^{-1}) which was at par with T9, T8, T11**,** T5, T4, T7 and T6 but significantly higher than T3, T2 and control (T1). The percent increase in straw yield of other treatments was 57.1% in T9, 56.6% in T8, 56.1% in T11, 51.3% in T5, 47.6% in T4, 46.0 % in T7, 43.4% in T6, and 34.4% in T3. This indicates that there was more diversion of photosynthates towards dry matter accumulation in T10 while in T9 there was more diversion of photosynthates for grain formation.

It can be concluded that for achieving the highest grain productivity in rain fed upland environment, application of 40 kg N ha^{-1} applied in two equal splits at 20 and 40 DAS and 2% urea spray at 2 weeks after flowering while for highest productivity of straw ,60 kg N ha^{-1} applied in two equal splits at 20 and 40 DAS and 4% urea spray at 1 week after flowering is essential.

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Efficient use of geotextiles as soil conditioner to increase potato productivity on inceptisol of West Bengal

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ABSTRACT

A field experiment was conducted at the University farm of Regional Research Station, New Alluvial zone of Bidhan Chandra Krishi Viswavidyalaya, Gayespur under Nadia district of West Bengal to investigate the effect of various geotextile on change of soil properties including yield and size of the tubers. Four treatment combinations viz. T_1 – farmers practices (control), T_2 – non oven jute geotextile, T_3- non oven coco coir geotextile, T_4 – vetiver root geotextile ware applied @ 5 ton / ha for each of the geotextile along with the levels of N-P-K at 100- 75- 75 kg / ha and replicated thrice. Yield of potato tuber responded by jute, coco coir and vetiver were 68, 86, and 89.5% respectively. Application of geotextile reduce the number of small size tuber by an average 40% and increased sharply the medium and large sized tubers 26 and 34% respectively favoring better yield of tubers in treated plots. These also improved moisture use efficiency, in general, by 81.5% over control. Decreasing bulk density with simultaneous increasing of porosity under each treatment also improved the moisture retention capacity in soil. Better aggregation and their stabilization occurred with applied treatments. Results under vetiver root geotextiles were found most effective in all the above respects followed by jute and coco coir geotextiles.

Key words: Geotextile, Bulk Density, Porosity and Moisture use efficiency.

INTRODUCTION

Potato (S*olanum tuberossum L.*) is the world's fourth important food crop after wheat, rice and maize because of its great yield potential and high nutritive value which constitutes nearly half of the world annual output of all root and tuber crops. With an annual global production of about 328.87 million tons over an area of about 19.13 mha, potatoes are grown in about 150 countries and more than a billion of people worldwide consume potato as staple food. Although India ranks 3rd , covering an area of 1.75 mha of potato cultivation and becomes the 3rd largest country in the world with its production of 34 million tones, but it have the lowest per capita consumption (14.8 kg / head / year) in the world hardly where 1% of the potatoes are processed (Anonymous 2010). The region of Indo-Gangetic plains in the country covers 90% potato cultivation of which the state of West Bengal occupies 3rd rank in terms of area and production. However, the productivity of the crop gradually decreases due to declining soil fertility status and inadequate availabilities of water and non-availability of good quality of seeds. Naturally occurring geotextile are ecofriendly and biodegradable products which act as surface cover materials and useful ameliorative to eliminate soil related constraints to crop production (Yong *et al.* 2000). It also helps to protect the most vital natural resources against various degradation processes and promotes vegetation cover through accelerated seed germination and seedling emergence (Bhattacharya *et al.* 2010). Adequate information on the efficiencies of geotextiles as soil conditioners towards improving crop productivity are lacking. Viewed the above consideration, the present study

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was undertaken to compare the efficiencies of geotextiles of different nature on soil quality changes and improvement of tuber yield of potato crops.

MATERIALS AND METHODS

The present investigation has been carried out at the university farm of Regional Research Station, New Alluvial Zone, Bidhan Chandra Krishi Viswavidyalaya, Gayeshpur, Nadia District, West Bengal represented by sub-tropical climatic region. The area lies between $21^0 51^/$ N latitude and $86^0 22^/$ E longitude with an altitude of 10 m above MSL having average rainfall of 1500 to 1600 mm / year with variation of temperature between 10^0 to 38^0 C. The soils of the area are characterized as acidic in nature, low in organic carbon and medium fertility status. The experiment was conducted with following treatments:

T_1 : farmer's practice (control), NPK @ 200-150-150 kg / ha

T_2 : nonwoven jute fiber geotextiles, 5 tons +NPK @ 100-75-75 kg / ha

T_3 : nonwoven coco coir fiber geotextiles, 5 tons +NPK @ 100-75-75 kg / ha

T_4 : nonwoven vetiver root geotextiles, 5 tons +NPK @ 100-75-75 kg / ha

The above treatments were replicated thrice in RBD design with growing potato (var-Kufri Chandra Mukhi) as test crop were grown on 1st week of November consecutively for 2005-06 to 2008-09. The area of each plots were maintained by 20 sq.m with spacing of 50 cm between row to row and 20 cm between plants to plants. The recommended packages of practices were adopted for growing of the crop. Each year crops were harvested in 1st week of February, tubers of the crop were graded into different sizes and the yields of tuber from each plot were recorded. Surface soil samples from each plot were collected for the analysis of relevant physical and chemical properties in soil. Bulk density and porosity in soil were determined by the normal procedure as described by Black (1965). Soil moisture contents of surface layer at 7 days interval from each plot during seedling emergence to harvesting were determined by Theta Probe Moisture Meter. The size distribution of aggregates in soil like mean weight diameter, geometric mean diameter representing structural indices, structural coefficients and aggregate stability percentage were evaluated by the methods as proposed by Piper (1966). The pH, organic carbon, availabilities of phosphorous and potassium were determined by the standard procedure of Jackson (1965). Cost benefit ratios was calculated by the ratio of total economic return (Rs) and total cost (Rs). Moisture use efficiency was calculated by the relationship as: MUE (Kg / mm / ha) = Total tuber yield (kg / ha) / Consumptive use of water (mm). Necessary stastical analysis was worked out to interpret the effects of treatments as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Size and yields of potato tubers

The results of effects of various kinds of geotextiles on yields of potato tubers presented in Table 1 showed that irrespective of the nature of geotextiles the yields of potato tubers increased over control. The response of tuber yield in each treatment were increased by 97.5, 122.5 127.5 q / ha respectively for jute, coco-coir and vetiver root with corresponding values of 68%, 86%and 89.5%. The yield and its response over control were maximum in the treatments of vetiver root geotextiles than all other treatments. The results of size distribution of potato tubers also showed that in control plots the tubers yields were mostly constituted with small sized grades having 60% distribution with these whereas the medium and large sized tubers were constituted with remaining 40% with equal distribution of each of around 20%. Highest distribution of small sized tubers in control plots reflected the lowest tuber yield. Application of geotextiles dropped the distribution of small sized tubers by an average of 40% and increased sharply the medium and large sized tubers 26 and 34% respectively and an average of 20% due to applied treatments over control which directed to quantitative increase in yields of potato tubers in these treatments. The results thus revealed that the increase of tuber yield were associated with enlargement of tuber size and better utilization of soil moisture favored by the geotextiles treatments. The benefit cost ratio of potato crop under the treatments also showed similar results the maximum of which found under vetiver root treatments. The above results find supported by Paza (2007).

Physical and chemical properties of soil

The results of the effects of various geotextiles on the changes of physical and chemical properties of soil are presented in Table 2. Bulk density of soil were decreased by 4.5%, 3.7% and 6.0% with simultaneous increased of porosity by 13.6%, 11.7% and 19.1% respectively by jute, coco-coir and vetiver root geotextiles over control. The vetiver root geotextiles were found more effective in this respect. The results further indicated that significantly increased availability of phosphorous and potassium. The results also reveal that increased of organic carbon by 100%, 95.9% and 124.5%, respectively by jute fiber, coco-coir and vetiver geotextiles over control. Similar to the effects of yields vetiver root geotextiles also showed prominence towards increasing fertility in soil. The above results also supported by Dutta and Chaktaborty (1995).

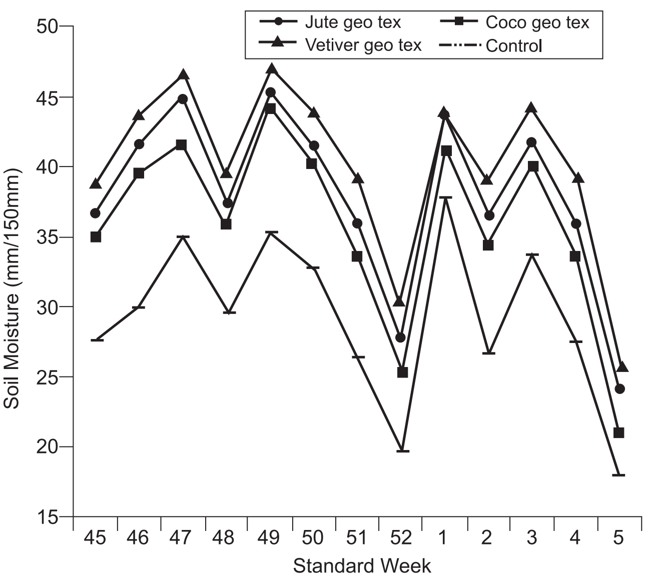

Fig. 1. Changes of soil moisture at 7 days interval as influenced by various geo textiles

Soil moisture use efficiencies

Soil moisture changes at 7 days interval for the enter growing period of potato under various geotextiles have been depictured in figure 1. Soil moisture content at every stage was higher under each of the treatment over control. It was found maximum under vetiver root geotextiles than other treatments. Results followed the following order of soil moisture contents: vetiver geotextile > jute geotextile > coco coir geotextile > control. The changes of soil moisture content due to the treatment might be attributed by bulk density and porosity in soil towards increasing moisture retention capacity in soil. The data further showed that the moisture use efficiencies of the crop, generally, increased by 81.5% due to the treatments of geotextiles over control, the highest 89.6% of which occurred under vetiver root geotextiles (table 1). The above results supported by Nag *et al.* (2008).

Soil aggregation

Results of the effect of various geotextile on the changes of various indices of soil structure and their stabilization were presented in table 3. Results clearly revealed much variation of all the indices of soil structure and their stability due to application various treatment. The values of mean weight diameter (MWD), geometric mean diameter (GMD), structural coefficient (SC) and water stable aggregates (WSP) were found highest under vetiver root followed by coco coir and jute geotextiles. These indicated that vetiver root geotextile could be effective ameliorative towards improving stability soil structure. The above results also supported by Smets and Poesen (2009).

Table 1. Effect of different geotextile management practices on potato tuber yield, MUE and BC ratio.

Treatments	Percentage of tuber			Yield (kg/ha)	Moisture use efficiency (kg/ha/mm)	Costbenefit ratio (B:C)
	A (>100gm)	B (50-100 gm)	C (<50 gm)			
(T_1) Control (farmers practices)	19	21	60	142.5	35.6	1.2:1
(T_2) Non woven jute fibre geo textile	35	24	41	240.0	60.0	2:1
(T_3) Non woven coco coir geo textile	35	25	40	265.0	66.3	2.2:1
(T_4) Non woven vetiver root geo textile	32	29	39	270.0	67.5	2.3:1
SE(m)$\pm$	0.799	0.645	0.764	1.236	3.232	
CD(0.05)	2.766	2.234	2.643	4.277	11.183	

Table 2. Effect of different geotextile management practices on soil physical and chemical properties

Treatments	Bulk Density (mg/m^3)	Porosity (%)	pH (1:2)	Organic Carbon (%)	Total Nitrogen (%)	Available P(kg/ha)	Available K(kg/ha)
(T_1) Control (farmers practices)	1.34	41.8	6.3	0.49	0.06	16.9	152
(T_2) Non woven jute fibre geo textile	1.28	47.5	6.7	o.98	0.19	26.6	219
(T_3) Non woven coco coir geo textile	1.29	46.7	6.7	0.96	0.14	24.9	306
(T_4) Non woven vetiver root geo textile	1.26	49.8	6.8	1.10	0.16	29.7	230
SE(m)$\pm$	0.005	0.389	o.082	0.032	0.006	0.497	2.646
CD(0.05)	0.017	1.346	0.283	0.111	0.020	1.721	9.156

Table 3. Effect of different geotextile management practices on soil structure and their stabilization.

Treatments	Mean Weight Diameter (mm)	Structure Coefficient	Geometric Mean Diameter (mm)	WSA >0.25 (%)	WSA <0.25 (%)
(T_1) Control (farmers practices)	0.706	0.514	0.426	58.47	41.53
(T_2) Non woven jute fibre geo textile	1.568	0.769	0.698	78.56	21.44
(T_3) Non woven coco coir geo textile	1.872	0.861	0.705	81.99	18.01
(T_4) Non woven vetiver root geo textile	2.979	0.912	0.868	82.38	17.62
SE(m)$\pm$	0.03	0.01	0.03	0.99	0.99
CD(0.05)	0.10	0.03	0.12	3.43	3.43

CONCLUSION

Geotextiles of various natures due to its effects as surface cover materials have potentials for maintaining soil quality and protecting the soil against any form of degradation. Efficiencies of different kinds of geotextiles on the improvements of soil properties attributing yield and quality of potato tubers have been investigated in the present study. Each of the geotextiles increased the size of potato tubers leading to its higher yield associated with much increase of organic carbon and availability of phosphorous and potassium. Sharp improvements of bulk density, porosity, moisture use efficiency as well as better aggregation and well stabilization of soil aggregates occurred due to application of each geotextiles, of which vetiver root showed most prominent effect in all such respect. The result thus lead to suggest that vetiver root geotextiles could be effectively utilized for making favorable soil structure along with other soil properties towards development of larger size tubers and better utilization soil moisture facilitating in yield and quality of potato tubers.

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Irrigation water use and availability in India: changing growth trends and implications

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ABSTRACT

Per capita availability of water resources in India more particularly irrigation water availability is on the decline vis-à-vis an increase in the annual irrigation water requirement, which may have an adverse impact on the food security. Importance given to irrigation sector during five year plans and efforts made for irrigation development as well as favourable policy with respect to irrigation investment has helped a great deal in making stupendous achievements in agricultural production. Minor irrigation system, the tubewell technology has been given so much importance that it has led to mushrooming of tubewells in the country. However, excessive extraction of groundwater raises sustainability issues in various regions across the country and many blocks in the north west belt of the Indo-Gangetic Plains are already designated as over exploited zones and hence may have a dent on agriculture production, more specifically, on the production of food grain crops on which food security largely depends. Strenuous efforts are therefore required to reverse the trend, while the current trend being decline in area under surface water sources and increase in area irrigated by groundwater sources. It is important to encourage conjunctive use of water, which can be practiced with the help of further water augmentation and potential creation from surface water sources. Revival of age old tank irrigation system and proper maintenance and monitoring of canal irrigation system can promote conjunctive use of water. Increase in groundwater recharge through rain water harvesting and adoption of water-saving irrigation technologies will be useful for matching supply and demand of irrigation water and helpful in achieving the sustainable food production in the country. In the face of achieving the 4 per cent growth in agriculture, irrigation sector needs to be accorded higher emphasis in the context of declining water table conditions and changing climate scenario. While aiming at achieving inclusive growth in agriculture, it is important to reorient the irrigation policy in favour of marginal farmers because of their lion's share in cultivation.

Key words: Water availability, growth trends, irrigated agriculture, groundwater development, source of irrigation, implications

INTRODUCTION

Irrigation water is one of the critical inputs for agricultural production. In the beginning of five year plan periods, priority has been in favor of surface irrigation development. However of late, due to the inherent weaknesses in surface water irrigation system and conflicts on distribution and use of surface water both at micro and macro level, groundwater development has taken a rapid pace. As a result, over a period of three decades surface water irrigated area particularly tank irrigation has declined while ground water use registered prominence in agriculture. Favorable policies on energy and credit facilitated farmers' access to the technology for enhancing crop productivity.

Groundwater plays a supplementing and stabilizing role when surface water supplies fluctuate both within and between years. Though it facilitates increasing farm production, mushrooming of tubewells with excessive extraction of ground water threatens sustainability of fresh water resources. Command and control approach to regulate groundwater would not work in a democratic set up as in India, where market-

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based economic instruments can play a pivotal role in managing this precious water resource more efficiently and equitably. Small farmers may be the beneficiaries because they are unable to make investments in tube-well installation. Generally, the possession of tube-wells is highly skewed in favour of large farmers. Though ground water market is functioning informally in many places, emergence of formal groundwater market is still at nascent stage in India. Such a market can benefit both the buyers and sellers of water and the small and marginal farmers can have access to irrigation water without making huge initial investment. It is an informal institutional arrangement in which private tube-well owners sell surplus irrigation water to the neighbors who don't own wells. However, the flip side is that sellers can exercise monopoly in charging and supplying water to non-owners of tube wells. In such cases, buyers can be exploited and become the losers. While discussing the ground water transaction and development in India, overall trends in irrigation development, availability and future demand for water is also discussed in this paper.

Water availability and demand

Water is becoming scarce and per capita availability of water resources is declining due to rapid population growth, economic development and urbanization. According to the irrigation census 2001, per capita availability of water resources was around 1900 cu.m in 2001 while it was 2300 cu.m a decade ago (Figure 1). It is going to further decline when the estimates are made on the basis of population projections assuming the availability of water shall not change in future. Based on these projections, per capita availability of surface water

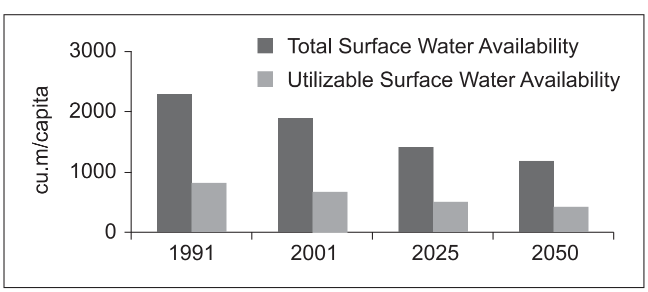

Figure 1. Per capita availability of water in India

Source: Based on data from Ministry of Statistics and Programme Implementation, GOI(2010)

would be around 1400 cu.m and 1200 cu.m by 2025 and 2050, respectively.

The utilizable surface water availability will be still less than the total and it would also follow the same declining trend. While the per capita availability of water is declining, water requirement has been increasing over the years and it is predicted that water requirement will further soar up in future (Figure 2). Irrigation sector is by far the largest consumer of water among various sectors including industry and energy sectors. Domestic sector's requirement is very less when compared to irrigation sector, however, the requirement for domestic sector will also increase because of population growth unless there is a check in population.

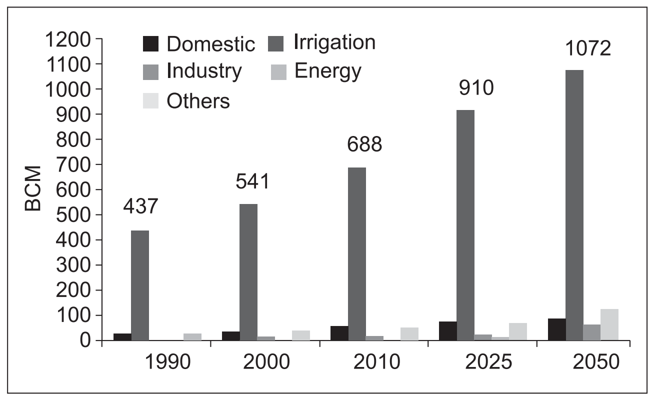

Figure 2. Sector-wise Water Requirement in India

Source: Based on data from Ministry of Statistics and Programme Implementation, GOI (2010)

Favourable policy prevailed in India with respect to irrigation investment on development has provided a solid platform for Indian agriculture to flourish. It acts like a complementary input for adoption of modern varieties and large scale application of fertilizer. The efforts and importance accorded to irrigation sector in the past, has no doubt brought in more area under irrigation and the yields also increased quite significantly on existing cropland. It has allowed multiple cropping and therefore gross area irrigated also increased with supplemental irrigation. This provided more stability to the production system in comparison to rain-fed agriculture. Rains are more uncertain at the time of sowing and drought occur frequently even during rainy season (Biwalkar *et al.*, 2007). It is evident that to achieve the food grain production demand of 281 MT by 2020, more food needs to be produced with less amount of water. Irrigation assumes greater significance while aiming at achieving 4 per cent growth in agriculture in sustainable and inclusive manner. It is a matter of concern that water use in agriculture is not efficient because of several reasons including distribution and conveyance losses. The losses occur at basin scale as well as field scale at micro level. These losses need to be minimized by more investment in distribution networks and channels and the overall irrigation efficiency should be improved.

Each stakeholder in an irrigation system confronts with different kinds of problems spanning from scarcity to plenty with different consequences. Water logging and salinity problems are often in the head region of a system and water dearth in the tail region. Water conflicts, both intra and inter basins, trans-boundary issues are common and longstanding and these conflicts need to be resolved in an amiable manner in order to achieve the inclusive growth. At basin scale, activities in the upstream decide the fate of the community downstream. These issues need to be sorted out at basin scale and more importantly collective action for water distribution and use will benefit the community at large.

To achieve the sustainable and inclusive growth, it is important to pay more emphasis on both supply and demand fronts. Efforts on water augmentation and creation of awareness on optimal use of water will be the key to bring in water supply and demand match and also to achieve the set target of agricultural production. But the annual increase of irrigation water requirement and the deficit in its availability (supply) will have an impact on agricultural production. The overall cost for water augmentation and minimizing water losses may soar up in future in addition to the present costs. There is a need for completing the incomplete irrigation projects which can be done through the existing Accelerated Irrigation Benefits Program (AIBP). There are substantial costs for construction of water projects in the form of capital and for reduction of environmental degradation. The growth in irrigated lands also emanates externalities either directly or indirectly. When the irrigation potential is increased, there are a few associated problems such as population displacement, soil erosion, deterioration in water quality, increase in waterborne diseases and adverse impact on biodiversity.

Trends in irrigation development, investments and coverage

Starting from I FYP, major and medium irrigation programmes contributed around two-third of the additional irrigation potential created (Table 1). Minor irrigation programmes contributed the remaining one-third. This emphasis was gradually changing from III FYP and completely reversed from IV FYP onwards extending up to IX FYP. This could have been due to a shift in the funding source for minor irrigation development, which might have provided the fillip for increased share of minor irrigation in the additional irrigation potential created from IV FYP onwards.

Table 1. Plan wise Irrigation Potential Created and Utilized in India (‘000 ha)

V Year Plan	Major & Medium Irrigation		Minor Irrigation		Total	
	IPC	IPU	IPC	IPU	IPC	IPU
I	2486	1280	1159	1159	3645	2439
II	2143	2067	671	671	2814	2738
III	2231	2123	2269	2269	4500	4392
IV	2608	1937	4380	4380	6988	6317
V	4014	2475	3900	3900	7914	6375
VI	1083	929	7521	5249	8604	6178
VII	2225	1893	9086	7871	11311	9764
VIII	2216	2126	7545	6252	9761	8378
IX	4097	3079	12935	4544	17032	7623
X	5296	3410	5572	3871	10867	7281
XI*	9000	-	7000		16000	-

Source: CWC, GOI (2010)
IPC and IPU denote Irrigation Potential Created and Utilized respectively.
**Target*

In the IX Plan, the share of minor irrigation increased noticeably around 3/4th of the total while the remaining by the major and medium irrigation projects. However, in the X plan, the gap reduced in terms of potential created between major and minor irrigation systems. As a result of this, both surface and ground water resources were harnessed at varying levels across space and time. Overall, the gap between irrigation potential created and utilized continues to remain wide although in the middle of the FYP, the gap gets abridged to a certain extent. In the X Plan, the total investment made in irrigation infrastructure was Rs. 1,06,743 crore. Government investment in irrigation has been rising over the years and has received a further boost in the recent years (Ramanayya, et al., 2008). Investment in irrigation infrastructure is a critical part of rural infrastructure. It remains a public sector activity only because the sector is nowhere near being commercially viable since water charges account for only about 20 per cent of operating costs.

Source-wise area irrigated and its trends are shown in Figure 3. Expansion of minor irrigation especially tubewell irrigation has witnessed exponential growth, which obviously contributed significantly towards agriculture production growth in India. As seen from the Figure, canal irrigated area in India showed declining trend after 90’s but area irrigated by minor irrigation source (groundwater) has shown an upward trend. Tube well irrigation particularly, has shown phenomenal rise over the years. Irrigation from tank sources has been declining since the inception of green revolution. Before nineteen seventies the share of tank irrigation was greater than that of tubewells. During the early 1980s, central and state governments initiated programs for subsidizing the expansion of groundwater irrigation, which led to a spurt in growth of tube well irrigation in the country. Rehabilitation of tanks, revival of irrigation infrastructure, and resuscitation of water harvesting systems with local indigenous knowledge would be the key for augmenting irrigation water. Rain water harvesting can be promoted as a core strategy for achieving sustainability of water resources and security (Rajput and Patel, 2012). It is important to harvest water from any water sources in ponds and reservoirs for various purposes including agriculture to stretch its usage to the maximum (Baipheti *et al.*, 2009). If conjunctive use of water is to be encouraged, then far more attention needs to be given for rehabilitation of tanks and enhance the irrigation potential created by the tanks.

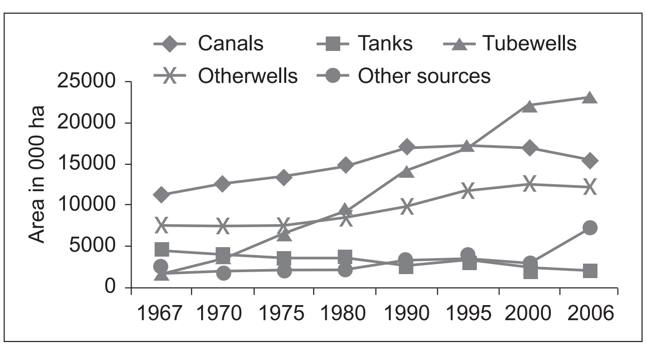

Figure 3. Trends in Sources of Irrigation in India

On the whole, tubewell irrigation emerged as an important source of irrigation not only at all India level, but also in the IGP which is the heart belt of Green Revolution. Over the last 40 years in IGP, the trend has been with surface water irrigation decline and ground water irrigation increase. Besides investment efforts and favorable policy atmosphere towards groundwater development, existence of an active groundwater market has also been an important characteristic of groundwater utilization in the IGP and more particularly in rice grown areas. Ground water market has helped small, marginal and resource poor farmers who are unable to make investments in pumps. The groundwater market flourished in a great deal though the kind of transaction is informal. The subsidized energy policy put forth by the state governments also helped the farmers in a way to go in for energized tube wells. As a result, number of energized tube wells swelled up across states in India. The relative reduction in risk due to the buffer provision of supplemental irrigation water has then encouraged intensification of other complementary inputs like fertilizer and other modern inputs. However, large scale application of chemical inputs may lead to environmental problems and health hazards.

Status of Groundwater Development in Irrigated Agriculture

Groundwater irrigation has been a preferred source of irrigation for the farmers as compared to surface systems by virtue of fairly assured supply of water. Groundwater is also generally more productive compared to surface irrigation. Some evidence in India suggests that crop yield / cubic meter on groundwater irrigated farms tends to be 1.2-3 times higher than on surface water irrigated farms (Dhawan, 1989). A study conducted by IWMI indicates that farmers with wells obtain 50 to100 % higher value of output per unit area compared to canal irrigators (Shah et al. 2003). As a result, the rapid expansion and increasingly greater reliance on the use of groundwater for irrigation has contributed significantly to agricultural and overall economic development of India. It was estimated that about two-fifths of India's agricultural output comes from areas irrigated with groundwater (World Bank 1998). Farmers have become increasingly dependent on groundwater because of limitations in surface water sources. This move towards groundwater sources has been further facilitated by the government policies on credit, subsidy policy on energy etc. Since agriculture is a state subject, making electricity available at highly subsidized rates with liberal tariff charging policies comes within the purview of state governments. This is one of the reasons for proliferation of tubewells across the country. Growth of tubewells has been tremendous both in Peninsular India and the Indo Gangetic Plain of India. Ground water exploitation is more in north western region where ground water development is designated as over exploited and critical zones.

Increase in well density, well failure, deepening of wells, rapidly falling water table, negative externalities emanating from deep groundwater extraction in many parts of India are raising serious concerns and posing major challenges, which require to be addressed both to sustain the benefits of groundwater irrigation and to ensure the sustainability of gains in agricultural production. The electricity consumption for irrigation pumping over the years has been increasing as a consequence of increase in the number of tubewells as well as increase in electricity consumption per tubewell. The latter has partly been on account of the larger amount of electricity required to pump groundwater from greater water depths due to decline in the water table. Ground water status presented in the table 2 reveals that over exploitation of groundwater is more in states like Punjab, Haryana, Rajasthan, Delhi, Tamil Nadu and Karnataka. In these states, many blocks/talukas are designated as critical. Therefore, priority needs to be accorded to these states for investment for groundwater recharge as well as efforts on demand management of ground water including adequate regulatory mechanism.

An analysis of growth of tube well irrigation in the Indo Gangetic Plain of India revealed that there has been higher growth of wells during 1970-80 and the growth in net area irrigated by tubewells was around 8.76 per cent and it declined to 5 per cent afterwards until it came down to 1.27 per cent recently in the past decade. Increase in number of tubewells and declining growth in area irrigated by tubewells implies the need for sustainable use of water. Declining growth in area irrigated by tubewells could be due to reduced supply of water as well as increasing awareness of farmers on judicious use of irrigation water. While the latter is good from sustainability point of view, over

Table 2. Ground water status in India

State	Total No. of blocks/talukas	Safe		Semi-Critical		Critical		Over-exploited	
		No.	%	No.	%	No.	%	No.	%
Andhra Pradesh	1231	760	62	175	14	77	6	219	18
Delhi	9	2	22	0	0	0	0	7	78
Gujarat	223	97	43	69	31	12	5	31	14
Haryana	113	42	37	5	4	11	10	55	49
Karnataka	175	93	53	14	8	3	2	65	37
Punjab	137	25	18	4	3	5	4	103	75
Rajasthan	237	32	14	14	6	50	21	140	59
Tamil Nadu	385	145	38	57	15	33	9	142	37
Uttar Pradesh	803	665	83	88	11	13	2	37	5
India	5723	4078	71	550	10	226	4	839	15

Source: Ministry of Water Resources, GOI (2010) exploitation of water needs to be curtailed, which could be partly done by encouraging conjunctive use of water. With increasing need of water for competing sectors, groundwater use has become indispensable over the years. An excessive extraction and mining of groundwater leads to depletion and degradation in quality of this precious resource in many parts of India, which deprives the future generation accessible to fresh water resources.

Apart from availability of water under threat, degradation of water is reported in eastern parts of India particularly in West Bengal, where arsenic and nitrate contamination is observed to be exceeding the limit. It is reported in the trans-Gangetic Plain, more so in Haryana, where water quality is poor, which may have profound impacts on health and environment in years to come. Lack of comprehensive policies to guide ground water development and regulate ground water use resulted in over exploitation of this precious resource to a greater extent. In the trans-Gangetic Plain, irrigation intensity increased from 148 to 180 per cent over the last four decades. Similarly in the lower Gangetic Plain, irrigation intensity has increased from nearly 100 per cent in 1960 to 178 per cent in 2008. Increasing irrigation intensity is a factor which shifts production frontier up however increasing level of environmental degradation and health hazards cannot be neglected too long. Such increase in irrigation intensity could be possible with the use of ground water which is apparently evident from the increase of number of tube wells installation in last three decades. For example, in Punjab state, the percentage share of tube well irrigation in net irrigated area is 72 per cent, which showed the skewed proportion of irrigation source towards tubewells. Nearly 75 per cent of the blocks are already designated as over-exploited.

Tubewell irrigation and energy demand

Tubewell irrigation has emerged as the backbone of Indian agriculture and accounts for 70–80% of the value of irrigated farm output (Sharma and Mehta, 2002). Despite its significance, sustainable use of groundwater resources is a concern as the groundwater extraction rate is more than that of recharge rate in several places. Such water extraction is primarily driven by irrigation demand and policy support of government in energy front. This is happening in spite of dismal energy situation in the country; therefore it is important to relook at the subsidy support of electricity to the farmers. The rising demand of energy and the soaring prices of diesel and inflated tariff rates for electricity prompt a reorientation of energy policy in agriculture sector.

Electricity is a major input to the agricultural activity in India and the agricultural sector accounts for 22% of all final electricity consumed in India in 2004 (CEA, 2006). In rural areas, electric operated pump sets are on the rise to provide irrigation facilities and as per the CEA (2008) estimates, nearly 15.4 million pump set had been installed. In another study, Purohit and and Michaelowa (2006) reported that more than 15 million electric and 6 million diesel irrigation pump sets are in operation. Pumps operated with electricity are generally preferred, due to convenience of use and the low subsidized price of electricity. Power pricing and subsidy to agriculture continues to hold differing views. In states like Tamil Nadu, power supply to farmers is free; and many other states, the flat electricity tariff – based on horsepower rating of the pump rather than actual metered consumption – charged to farmers is heavily subsidised. Annual losses to electricity boards on account of power subsidies to agriculture are estimated at Rs 260 billion in India; and these are growing at a compound annual growth rate of 26% (Gulati, 2002).

Badiani and Jessoe (2011) found that a 10 percent decrease in subsidies would reduce groundwater extraction by 4.3 percent, costing farmers 13 percent in agricultural revenues. It will not be a profitable proposition for the farmers to undertake farming activity any more unless farmers are offered with subsidized energy. But at the same time, if government decides to continue with status quo, then the entire cost should be borne by the government. It will be huge particularly in the context of exorbitant price rise of energy and will erode the government exchequer. This amount has to be met largely from the capital account and hence there is a likelihood of downgrading of capital asset creation in agriculture. This should be dealt in a holistic approach of considering both supply and demand of energy and water for irrigation. All possible efforts should be taken on demand side for judicious use of irrigation water and thereof energy and at the same time efforts are required on supply side to augment water and increase the supply of energy. These are to be viewed in a proper policy perspective without harming small and marginal farmers of the country and at the same time solving energy-irrigation crisis in future.

Farm Size and Use of Irrigation by Source

Farm size-wise and irrigation source-wise analysis revealed that area irrigated by tubewells has been predominant irrespective of farm size category (Table 3). On the whole, nearly 33 million hectare is irrigated by groundwater source and 17 million hectare is irrigated by canal. More particularly, tubewell is the major source of irrigation for marginal farmers followed by canals. Tanks contribution in net irrigated area is very less and the share can be increased while efforts are made on rehabilitation of tanks. While doing so, conjunctive use of water could be indirectly improved; this will pave the way for sustainable use of water. The last two irrigation census data pertaining to 2001 and 2006 revealed that canal and tank irrigation declined in all categories of farmers except marginal and small farmers. But, tubewell irrigation increased irrespective farm size category over these time periods. Overall, total irrigated area increased from 51.6 million hectare to 54.2 million hectare and the percentage share of irrigated area over the net area sown also increased from 38.9 per cent to 46.8 per cent. While aiming at sustainable use of water, policy benefiting marginal and small farmers to reduce the gap between area irrigated by tubewells and canals will help in encouraging conjunctive use of water. Therefore the disadvantaged sections of the farming community ie marginal and small farmers are to be given far more attention for achieving the inclusive growth in agriculture. It is important to see if those categories of farmers are benefited more from surface sources than groundwater. As discussed earlier, proliferation of tubewells, exceedingly faster rate of ground water exploitation, and decline in ground water table would result in more external costs, which may be irreversible. Therefore, policies on improving surface water sources through development, rehabilitation and efficient management, which benefits marginal and small farmers at large should be the future thrust.

Impact of irrigation on foodgrain production in India

In this section, the relationship between production of foodgrains and major factors like irrigation, fertilizer, seed, and pesticides was established using regression analysis. The hypothesis tested in the model was the marginal effect of irrigation on foodgrain production is higher than that of other factors. A regression model was

Table 3. Source-wise Distribution of Irrigated Area by Farm Size wise in India ('000 ha)

Size Class	Year	Canals	Tanks	Wells	Tubewells	Others	Total Irrigated	Net Sown Area (NSA)	% of Irrigated Area to NSA
Marginal	2000-1	3405	855	1296	5419	1409	12384	24266	51.03
	2005-6	3741	881	1266	6298	1365	13552	23557	57.53
Small	2000-1	2929	587	1971	4335	1069	10891	27854	39.10
	2005-6	2984	518	1909	4955	1036	11403	24314	46.90
Semi-medium	2000-1	3219	463	2500	4740	1010	11932	32608	36.59
	2005-6	3181	394	2485	5345	991	12396	27682	44.78
Medium	2000-1	3447	276	2511	4502	811	11547	32019	36.06
	2005-6	3384	228	2550	5013	807	11982	26838	44.65
Large	2000-1	1578	77	952	1715	550	4872	15929	30.59
	2005-6	1552	76	929	2031	349	4937	13464	36.67
All Classes	2000-1	14578	2258	9231	20711	4849	51627	132677	38.91
	2005-6	14842	2097	9139	23643	4548	54270	115855	46.84

Source: Based on data from Department of Agriculture and Cooperation (2000-1) and Agriculture Census (2005-6 fitted with irrigation, seeds, fertilizer and pesticides as explanatory variables and foodgrain production as dependent variable and the model is of the form: $PRODGrain = \beta_0 + \beta_1(Irr) + \beta_2(Fert) + \beta_3(Pes) + \beta_4(Seed)$

Whereas *PRODGrain* = production of foodgrain; *Irr* = net irrigated area; *Fert* = usage of fertilizer ;

Pes= pesticide usage; *Seed*= usage of seeds. Marginal impact of each predictor was derived from the estimated results. The explanatory variables explained the variations in the dependent variable, foodgrain production are reflected in high R square (0.89). The results suggest that irrigation variable is highly significant in explaining the variations in production of foodgrains. Marginal effect of irrigation variable was quite high in relation to other variables considered in the analysis. One unit increase in irrigated area will raise 1.87 unit of production of foodgrain, which evidently suggests the importance of irrigation in foodgrain production in India. Keeping in view the food security of the country in the face of soaring population and food demand, irrigation sector and investment in the sector needs to be given top priority in order to expand the irrigation frontier in the total net sown area of the country. The contribution of each of the explanatory variables and its extent of influence on foodgrain production and the significance level are presented in table 4.

Table 4. Regression estimation results

Variable (1)	Coefficients (β) (2)	Elasticity (3)	t statistic (4)	Sig. (5)
Irrigation	1.869	0.48	4.877	.000
Fertilizer	-1.446	0.12	-2.427	.030
Pesticides	.028	7.07E-06	.179	.860
Seeds	.551	0.003	1.664	.120
Constant	147.527	-	-2.154	.051

Note: $R2= 0.89$* significant at 1 per cent level.

Computation of the elasticity with respect to production of foodgrains reveals the marginal impact of irrigation and its importance on production with an elasticity value of 0.48, which is higher than that of fertilizer with an elasticity value of 0.12. The marginal effect of contribution of other factors on production of foodgrains is still less than irrigation and fertilizer. This cause and effect relationship further bolsters the fact that irrigation has a critical role in the production of foodgrains in India.

CONCLUSIONS

The influence of irrigation on production growth of foodgrains in the country has been noteworthy, which was partly due to the conscious efforts of Central and State governments in irrigation sector. Irrigation potential created and utilized has increased over a period of time although there is a gap in potential created and utilized. Of late, with the increase in population, per capita water availability is less and annual irrigation water demand is increasing. The trends in different sources of irrigation both surface and groundwater sources have shown diametrically opposite directions. High growth of tubewells, increase in share of tubewell irrigation over other surface sources, subsidized tariff for electricity for agriculture purposes thereby injudicious use of water, decline in water table, over exploitation of groundwater are some of the grey areas which need attention in future. It is important to promote conjunctive use of water, which could be made possible only through enhancing the irrigation potential of surface water sources. More water augmentation could be done through installation of farm ponds, revitalization of defunct tanks, and resuscitation of community based water management in canal and tank command areas. Marginal and small farmers form the central foci of farming community and irrigation policies benefiting small and marginal farmers will pave the way for achieving inclusive agricultural growth. In sum, to achieve the sustainable and inclusive growth, it is important to pay more emphasis on both supply and demand fronts in irrigation sector. Efforts on water augmentation, distribution, and creation of awareness on optimal use of water will be the key to bring in water supply and demand match and also to achieve the set target of agricultural production.

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Spatial and temporal variations in rainfall and rainwater harvesting potential for Kutch district, Gujarat

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ABSTRACT

The Kutch district of Gujarat receives highly variable and erratic rainfall leading to protracted droughts. The daily rainfall data of 1975-2011 for nine talukas of Kutch district have been statistically analyzed to study their spatial and temporal variation. The mean date of onset of effective monsoon in the district varied from July 12 (Mandvi) to July 25 (Rapar) with earliest onset of effective monsoon (p=0.68) during June 20 (Mundra) to June 27 (Bhuj). In general, for the entire district, the average onset of effective monsoon may occur from June 16 to July 10 with standard deviation of 24 days and it may cease around August 29. Mean date of withdrawal of monsoon ranged from August 20 (Lakhpat) to Sept 8 (Anjar). On an average each taluka experiences at least two critical dry spells from the monsoon period. The entire district may experience critical dry spells of 77 days duration comprising 29, 28 and 20 days starting on Jul 13, Aug 5 and Aug 20, respectively. It indicates acute necessity of storing runoff water for the region to tackle the imminent water shortage problems for crop production. On an average rainfall during the three to four wet spells ranged in the district from 418 mm at Bhuj to 550 mm at Mundra. The first wet spell of the order of 209 mm at Bharuch to 314 mm at Mundra may be harvested and stored in rainwater harvesting structures. In general, for the entire district, about 548 mm of rainwater can be harnessed and stored in water harvesting structures.

Key words: rainwater, harvesting, dry spells, wet spells, effective monsoon, Gujarat

INTRODUCTION

The Kutch district (45,652 km^2) is located between 22°41’11" to 24° 41’ 47" north latitude and 68°09’46" to 71°54’47" east longitude in north-western region of the Gujarat state. This district shares its north and north-west border with Sind (Pakistan) whereas the Arabian sea lies in the west and south-west. Administratively the district is divided into nine talukas: Naliya, Anjar, Bhachau, Bhuj, Lakhpat, Mandvi, Mundra, Nakhtrana and Rapar (Fig 1). Kutch falls in the arid tracts and has a tropical monsoon climate. It receives much of its rainfall from the south-west monsoon. The average annual rainfall (1961-2011) is 395 mm, which varies from 330 mm (Lakhpat) to 469 mm (Mundra) and so is classified as an arid district. The distribution of the meager rainfall 395 is highly skewed and erratic, leading to protracted droughts. Six severe, three moderate and five mild meteorological droughts were recorded within a span of 23 years (1972-94). The Indian arid zone accounts for approximately 12% of the country’s geographical area and Gujarat occupies second largest arid and semi-arid area in the country. Drought and long dry spells are common features and a large number of villages in the Kutch district are affected by the water scarcity problem. The surface and groundwater resources have been receding all over the state due to over exploitation and increasingly deficient recharge. About 4,77,200 ha of cultivated area is affected by soil salinity. Maximum salt affected cultivated area lies in Anjar taluka (86%), followed by Bhachau (59%), Lakhpat (48%), Mandvi (40%), Naliya (23%), Mundra (23%), Bhuj (12%), and Rapar (11%). There

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are 20 medium irrigation schemes with a total live storage capacity of about 281 MCM and 162 minor irrigation schemes with a total live storage of about 252 MCM. However, only 28% of the potential created (533 MCM) was utilized annually by these schemes (1984-85 to 1994-95) to irrigate 14,068 ha (minor 7857 ha and medium 6211 ha) (Anonymous, 1996).

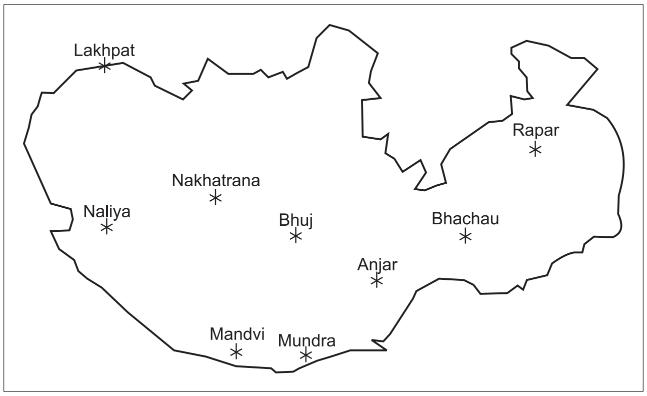

Fig. 1. Location of various talukas in Kutch district, Gujarat

Human and Livestock Population: The district has population of about 12.625 lakhs (1991 census) with an average density of 65 persons km^{-2} as against 4 persons km^{-2} in most arid regions of the world. The population increase for the period between 1901 and 1991 was only 159 per cent as compared to 354 per cent for the Gujarat 252 per cent for the whole of India. In the first five decades of 20th century the population growth was a meager 16.3 per cent. However a rapid increase (122 per cent) has occurred during the last four decades, the rural and urban population has increased by 56 per cent and 187 per cent respectively with a decadal growth rate of 16 per cent and 43 per cent, respectively. Livestock population also increased from 9.40 lakhs (48 animals km^{-2}) in 1962 to 14.13 lakhs (73 animals km^{-2}) in 1992 showing an increase of 50 per cent within a span of 30 years.

Soils: Main geological formations contributing to the soil formation in the Kutch district include sedimentary rocks of marine and non-marine origin, basaltic trap, laterites, limestone and alluvium formed under different geological situations. Soils of Kutch can be broadly classified into sandy soils which cover a vast area of the district, coastal alluvial soils that are located along the coast of Mundra and Mandvi talukas, black soils in the central part of district, shallow and skeletal soils developed on the slopes of the hilly areas in Anjar, Rapar, Mandvi, Mundra, Bhuj and Nakhtrana talukas and the mud soils located in the coastal belt formed under the influence of sea water. The soils in the Kutch district are generally low Nitrogen and medium in phosphorus and potassium 96 per cent of the soils have low iron and high lime contents.

Surface Waters: In Kutch district, the availability of surface water depends on the intensity, duration and amount of rainfall. The reservoirs are not filled up to the capacity for several years at a stretch because of arid climate and low rainfall. It is difficult to establish rainfall runoff relationship due to non-availability of proper stream gauging data. The runoff coefficients worked out on the basis of the designed inflow data of medium dams in different talukas are Anjar-0.2082, Bhachau-0.2164, Bhuj-0.2299, Lakhpat-0.2092, Mandvi-0.2370, Mundra-0.2294, Nakhtrana-0.2193, Naliya -0.1854 and Rapar-0.1952 (Singh and Kar, 1996). Out of the total 1482.71 MCM of runoff, an estimated 847.38 MCM water is being stored in different storage reservoirs and village tanks. Thus, nearly 57.15% of runoff is surplus which goes into the sea and the Ranns.

Groundwater: Fresh groundwater resources are limited in Kutch district, mainly due to scanty rainfall and also because the district has nearly 60 per cent saline area. Among the 166 wells examined, about 9 per cent wells tapped water at less than 30 m depth, 43.4 per cent tapped water at 10-20 m depth and 27.1 per cent had it at less than 10 m depth (Singh and Kar, 1996). Excessive withdrawal of groundwater has led GWRDC to categorise Anjar and Bhachau under over–exploited talukas, Mandvi under dark category and Naliya, Nakhtrana, Mundra and Rapar under gray category (GWRDC, 1991). Only two talukas viz. Bhuj and Lakhpat were considered as safe areas with regard to ground water availability. Rate of depletion of 1.2 m per year in Bhuj and Nakhtrana and 0.8m per year in Mandvi and Mundra talukas resulted in considerable decline (10-15 m) in water table during 1980-91 (GWRDC, 1995).

Agriculture: The total cultivated area in Kutch district increased by 15 per cent from during 1961-62 to 1992-93. At taluka level, the increase was recorded in all except Naliya and Anjar, where the cultivated land decreased by 17 per cent and 29 per cent, respectively. Major crops like jowar, bajra, pulses, groundnut and cotton accounted for 78 per cent of the total cultivated area during 1961-62 which decreased to 72 per cent during 1992-93. Groundnut, a salinity sensitive crop was cultivated mainly in Nakhtrana and Mandvi (56 per cent and 20 per cent of total groundnut cultivation respectively) during 1961-62. Groundnut cultivation showed a significant decrease of 33 per cent in Nakhtrana taluka during 1992-93. Cotton was mainly cultivated in saline tracts of Anjar, Bhachau, Rapar, Mandvi and Mundra talukas in 1,06,684 ha in 1961-62 which decreased to 55,288 ha in 1992-93.

MATERIALS AND METHODS

Daily rainfall data of 1975-2011 for all nine taluka were collected from Kutch district panchayat pffice, Bhuj (Gujarat). Details on agricultural statistics were collected from the office of the Joint Director (Agriculture), Ahmedabad (Gujarat). Information on other aspects was collected from published literatures. Computer programme by Ashokraj (1977) has been used to study various aspects related to onset of effective monsoon, critical dry spells and rainfall during wet spells. The harnessable runoff based on USDA-SCS Curve Number method for the region was also estimated.

RESULTS AND DISCUSSION

Rainfall depth duration relationship

Average rainfall during different storm periods (Table 1) shows that average 1-day annual maximum

Table 1.Average of 1-7 days continuous moving maximum rainfall for various talukas in Kutch district (1975-2011)

Code and Name of Raingauge station	Average rainfall (mm) during different storm periods (day)						
Taluka	1	2	3	4	5	6	7
ANJ (Anjar)	106	148	161	168	174	178	185
BHA (Bhachau)	103	135	148	161	169	171	181
BHU (Bhuj)	105	141	159	169	174	184	188
LAK (Lakhpat)	111	151	173	189	192	195	197
MAN (Mandvi)	120	158	177	179	189	197	203
MUN (Mundra)	129	172	190	202	212	219	228
NAK (Nakhtrana)	123	158	176	187	194	197	203
NAL (Naliya)	142	183	201	204	214	217	226
RAP (Rapar)	110	150	166	170	174	181	194
Whole district	84	123	144	156	166	172	178

rainfall ranged from 103 mm (Bhachau) to 142 mm (Naliya) with district average of 84 mm (Fig 2). On the other hand maximum one-day annual rainfall ranged from 375 mm (Bhachau, Mandvi) to 683 mm (Naliya). Maximum one day annual rainfall in order of 265.2 mm (Nakhtrana) to 467.9 mm (Bhuj) was reported by Singh and Kar (1996) that falls within the above limit. Analysis of longest possible duration rainfall data will help in establishing statistical parameters. Analysis of 1-7 day continuous moving maximum annual rainfall showed that average 1-day annual maximum rainfall ranged from 176 mm to 243 mm for the same talukas with district average at 183 mm.

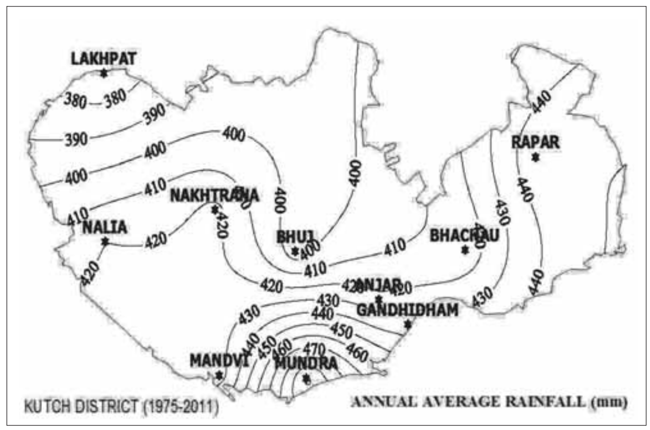

Fig. 2. Average annual rainfall pattern (1975-2011) in various talukas of Kutch district

Distribution of Monsoon Rains

Annual rainfall of 1975-2011 (except 1987, extremely dry year) showed that on an average the district experienced drought and below normal rains in 11 out of 51 years (43%) (Table 2). It received normal rain only in 12 out of 51 years (23.5%). Likewise, above normal and surplus rains were experienced in 7 years (13.7%) and 10 years (19.6%) respectively out of 51 years (Fig 3). Pooled data of 1901-99 from different sources (Singh et al., 1990; Khandelwal et al., 2002) showed that the district experienced drought, below normal, normal, above normal and surplus rains in 17, 24, 28, 14 and 15 out of 98 years, respectively. These two separate inferences establish that the district experienced drought and below normal rainfall to the extent of 41-42 per cent. Hence, there is need to study critically on onset of effective monsoon and related aspects for better agricultural water management

Table 2. Monthly and rainy season average rainfall (mm) with coefficient of variation in Kutch district (1975-2011)

Taluka station	JUNE		JULY		AUGUST		SEPTEMBER		SEASON		ANNUAL	
	AVG	CV	AVG	CV	AVG	CV	AVG	CV	AVG	CV	AVG	CV
ANJ	63	127	161	91	129	113	53	136	406	59	426	57
BHA	50	120	160	77	142	102	57	151	408	62	425	60
BHU	53	114	151	77	138	101	60	161	402	61	419	59
LAK	34	152	146	133	115	142	49	260	407	82	407	75
MAN	74	144	177	112	133	100	58	174	441	70	456	68
MUN	68	154	204	96	152	81	56	126	481	53	504	52
NAK	47	151	151	114	137	122	63	163	398	65	429	59
NAL	44	173	167	118	134	115	47	180	392	63	423	55
RAP	63	153	141	80	168	115	75	152	446	64	469	63
DISTRICT	54	122	156	90	134	104	57	143	440	57	422	53

AVG=average; CV=coefficient of variation (%)

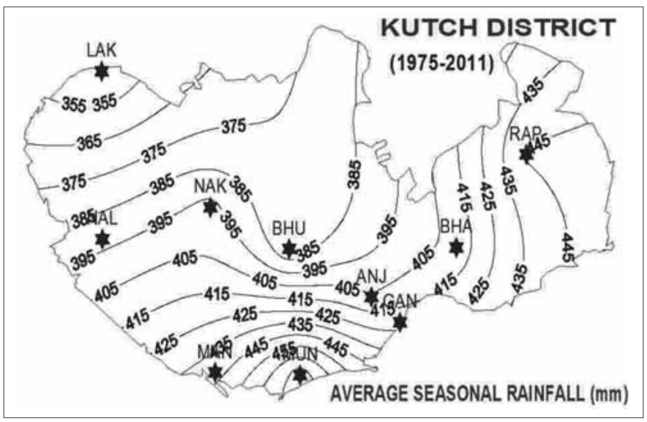

Fig. 3. Average seasonal rainfall pattern (1975-2011) in various talukas of Kutch district (Gujarat)

in the district. Minimum annual rainfall, except 1987 (extremely dry) ranged from 19 mm (Lakhpat, 1991) to 115 mm (Bhachau, 1986) with minimum of district average of 91 mm (1991). Similarly, annual maximum rainfall ranged from 965 mm (Bhuj, 1994) to 1594 mm (Rapar, 1975) with maximum of district average at 984 mm (1994). The coefficient of variation of annual rainfall ranged from 57% (Naliya) to 80% (Lakhpat). Singh and Kar (1996) also reported that coefficient of variation ranged from 56.1% (Anjar) to 80.7% (Naliya).

Onset of Effective Monsoon

The results of analysis of onset of effective monsoon (Ashokraj, 1977) presented in Table 3 shows that earliest onset of effective monsoon in the district varied from June 20 (Mundra) to June 27 (Anjar, Bhuj) with district average estimated as July 12. Similarly, average date for onset of effective monsoon varied from July 12 (Mandvi) to July 25 (Rapar) with district average estimated as July 10 (Fig 3). Standard deviation of onset of effective monsoon varied from 16 days at Bhachau to 28 days at Rapar. However, withdrawal of monsoon rains from August 20 (earliest) in case of Lakhpat to Sept 8 (latest) in case of Anjar, Nakhtrana and Naliya. Such dates of onset of effective monsoon and withdrawal of monsoon rains are useful for sowing/ irrigating crops and other on-farm practices.

Table 3. Dates of onset and withdrawal of effective monsoon in various talukas of Kutch district

Taluka Station	Onset of effective monsoon (p=0.68)			Devi-ation (days)	Withdrawal of effective monsoon
	Earliest	Mean	Latest		
ANJ	Jun 26	Jul 14	Aug 02	18	Sep 08
BHA	Jun 30	Jul 16	Aug 02	17	Sep 06
BHU	Jun 27	Jul 16	Aug 06	20	Sep 02
LAK	Jun 24	Jul 17	Aug 09	23	Aug 22
MAN	Jun 26	Jul 14	Aug 03	19	Sep 05
MUN	Jun 19	Jul 12	Aug 05	24	Sep 05
NAK	Jun 26	Jul 19	Aug 11	23	Sep 07
NAL	Jun 28	Jul 23	Aug 18	26	Aug 26
RAP	Jun 29	Jul 25	Aug 20	26	Sep 02
DISTRICT	Jun 15	Jul 09	Aug 02	24	Aug 31

Table 4. Distribution of critical dry spells (CDS) in Kutch district

Taluka	First CDS		Second CDS		Third CDS		Total
Station	Date	Length	Date	Length	Date	Length	Length
ANJ	Jul 22	32	Jul 31	26	Aug 16	18	76
BHA	Jul 25	26	Aug 08	26	Sep 2	16	68
BHU	Jul 22	33	Aug 18	21	-	-	54
LAK	Jul 18	25	Jul 31	28	-	-	53
MAN	Jul 23	25	Aug 19	27	Sep 06	23	75
MUN	Jul 19	29	Aug 09	23	Aug 16	15	68
NAK	Jul 22	26	Aug 07	38	Aug 30	23	85
NAL	Jul 23	24	Aug 10	20	Aug 19	10	52
RAP	Aug 01	23	Aug 21	21	-	-	45
DISTRICT	Jul 13	27	Aug 06	27	Aug 27	20	77

Critical Dry Spells

On an average, the entire district experiences at least one critical dry spell (Table 4) in each year. Duration of the critical dry spells varied from 45 (Rapar) to 85 (Nakhtrana) days with a district average of 77 days. The first critical dry spell commenced mostly in July and with duration ranging from 24 days (Nakhtrana, Naliya and Rapar) to 34 days (Bhuj). Similarly, the second critical dry spell occurred mostly in August with duration ranging from 18 days (Naliya) to 38 days (Nakhtrana).

Rainfall during Wet Spells

On an average, total rainfall during the wet spells (Table 5) ranged from 418.3 mm (Bhuj) to 550 mm (Mundra). It is estimated that a total of nearly of 524 mm could be retained during the four wet spells occurring in the district and it can be suitably harvested and harnessed for use for agricultural production. It is estimated that rainfall in order of 210 mm (Rapar) to 314 mm (Mundra), 55.8 mm (Nakhtana) to 169.8 mm (Rapar) and 14.5 mm (Naliya) to 96 mm (Nakhtrana) during the first, second and third wet spells in months of July,

Table 5. Rainfall during wet spells at different talukas in Kutch district

Taluka	Rainfall (mm) during Wet Spells				
	First	Second	Third	Fourth	Total
ANJ	241.6(Jul 14-30)	66.0(Aug 25-28)	87.9(Aug 27-29)	32.0(Sep 04-05)	427.5
BHA	209.7(Jul 16 - Jul 29)	117.7(Aug22-27)	93.0(Sep 4-10)	55.0(Sep 19)	475.4
BHU	219.2(Jul 16-26)	108.8(Aug25-Aug30)	90.3(Sep 9-15)	-	418.3
LAK	290.7(Jul 17-30)	116.8(Aug 13-18)	50.7(Aug 29-Sep2)	38.0(Aug 17)	496.2
MAN	283.0(Jul 14-Aug3)	120.8(Aug 19-24)	26.2(Sep 17)	17.0(Oct 1)	447.0
MUN	314.3(Jul 12-26)	100.6(Aug 19-24)	90.1(Sep 03-07)	45.0(Sep 02-04)	550.0
NAK	282.7(Jul 19-Aug 05)	55.8(Aug 18-20)	96.1(Sep 15-17)	-	434.6
NAL	249.2(Jul 23-Aug 02)	132.5(Aug 18-22)	14.5(Aug 31)	45.0(Aug30-31)	441.2
RAP	210.1(Jul 25-Aug 06)	169.8(Aug 26-31)	54.9(Sep 12-15)	-	434.8
DISTRICT	202.1(Jul09-23)	164.3(Aug10-20)	80.3(Sep 04-10)	102.0(Sep 17-22)	548.7

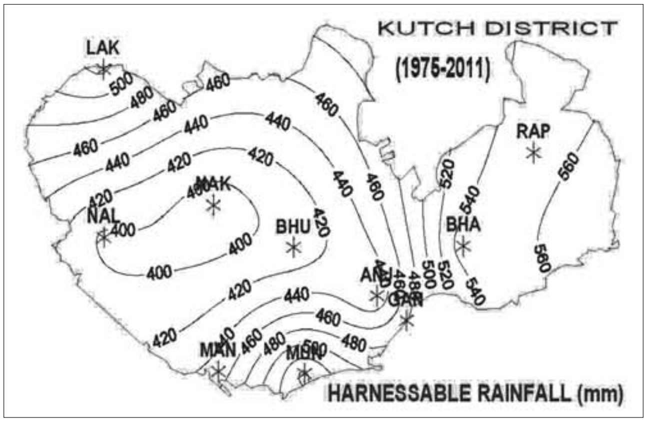

Fig. 4. Harnessable rainfall in various talukas of Kutch district

August and September can be harvested and utilized for crop production (Fig 4).

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Moisture distribution and fertilizer mobility under drip fertigation in Mulberry

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ABSTRACT

A study was conducted to find the moisture distribution and fertilizer mobility as affected by irrigation and fertigation on mulberry in clay loam soil at Tamil Nadu Agricultural University Farm, Tamil Nadu. The irrigation treatment consist of single row drip, paired row drip and paired row Micro-tube irrigation at 80%, 60% and 40% of surface irrigation level were given once in 2 days. Surface irrigation with 5 cm depth of water was applied once in a week. Two fertigation levels of 100 and 75 % of recommended dose of N and K fertilizers were applied through fertigation for drip treatments. For surface irrigation fertilizers were applied as band placement method. Soil moisture content at surface layers in surface irrigation treatment was lower compared to subsurface layers. In drip irrigation treatments, the moisture content decreased as depth and distance increased from the emitting point. The fertilizer distribution in the soil layers was more or less similar for all the fertigation treatments. Due to difference in the quantum of water applied through different drip treatments, the concentration differed in different layers due to variations of leaching.

Key words: drip irrigation; fertigation; fertilizer mobility; soil moisture distribution

INTRODUCTION

Drip irrigation is a technique in which drop by drop application of water is done in the crop root zone in order to meet the crop water requirement and maintain the optimum soil water status around the vicinity of plant roots. It generates a restricted but concentrated root system requiring frequent nutrient supply that may be satisfied by applying fertilizers in irrigation water i.e. by fertigation. Many scientists revealed the superiority of fertigation and balanced fertilization in different crops and orchards (Vaezi *et al.*, 2003, Malakouti *et al.*, *2003* and Asadi *et al.*, 2005). Fertigation not only economizes the water use, but also improves the nutrient use efficiency, as the fertilizer applied remains confined to the rootzone of the crop. Studies revealed significant fertilizer savings of 20–60% and 8–41% increase in yields of horticulture and vegetable crops due to fertigation. Fertilizer use efficiency up to 95% can be achieved through drip fertigation (Singh *et al.*, 2010). Maximization of crop yield and quality and minimization of leaching below the rooting zone may be achieved by managing fertilizer concentrations in measured quantities of irrigation water, according to crop requirements. Fertigation saves fertilizer as it permits applying fertilizer in small quantities at a time matching with the plants nutrient need. Besides it is considered eco-friendly as it avoids leaching of fertilizers (Sharma *et al.*, 2012).

Information on the nutrient movement and distribution under fertigation is rather scanty. Very little work has been done on spatial distribution of the fertilizer nutrients supplied through fertigation. Hence, an attempt was made to investigate the nitrogen and potassium dynamics in soil under drip irrigation and fertigation system in mulberry. The objective of this paper is to study the movement and distribution of moisture and fertilizer under drip fertigation and compare it with conventional irrigation method.

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MATERIALS AND METHODS

The field experiment was carried out during 2003-2005 in Tamil Nadu Agricultural University Farm located at 11°N latitude and 77°E longitude at an altitude of 427 m above MSL. The soil of the experimental field is clay loam. The mulberry is a widely spaced crop with the spacing of 90 cm ´ 90 cm. The experiment was laid out in FRBD with 2 replications. 10 irrigation levels and 2 fertigation levels thus there were 20 treatment combinations. The treatments detail is given in Table 1.

Table 1. Treatments detail

Irrigation levels	
T_1	Surface irrigation with 5 cm depth of water (control) was applied once in a week
T_2	Single row drip irrigation at 80% of surface irrigation level
T_3	Single row drip irrigation at 60% of surface irrigation level
T_4	Single row drip irrigation at 40% of surface irrigation level
T_5	Paired row drip irrigation at 80% of surface irrigation level
T_6	Paired row drip irrigation at 60% of surface irrigation level
T_7	Paired row drip irrigation at 40% of surface irrigation level
T_8	Micro-tube irrigation at 80% of surface irrigation level
T_9	Micro-tube irrigation at 60% of surface irrigation level
T_{10}	Micro-tube irrigation at 40% of surface irrigation level
Fertigation levels	
F_1	100% of recommended fertilizer dose through fertigation (for T_2 to T_{10})
F_2	75% of recommended fertilizer dose through fertigation (for T_2 to T_{10})

For all drip irrigation treatments (T_2 to T_{10}) irrigation were given on alternate days. Two fertigation levels of 100 % (F_1) and 75 % (F_2) of recommended N and K fertilizers were applied through fertigation for drip treatments (T_2 to T_{10}). For surface irrigation (T_1) fertilizers were applied as band placement method. Urea and muriate of potash were applied through fertigation in all the drip irrigated plots. Phosphorus was applied as basal dose for all the plots for each season.

Soil moisture distribution is one of the most important factors involved in successful design and management of a drip system. The soil samples were taken with a screw auger at 0-15, 15 – 30 and 30-45 cm depths after 1st, 2nd, 3rd, 4th, 5th, 6th and 7th day of irrigation in control plot. In drip irrigated plots (4, 8 and 20 lit/hr) soil samples were taken at 0-15, 15-30 and 30-45 cm soil depth at a distance of 0, 15, 30 and 45 cm away from the emitting device. Then the moisture content was determined by oven dry method. To assess the fertilizer mobility, soil samples were collected one week after fertigation in each treatment. Sampling was done near the emitting point, 15, 30 and 45 cm horizontally away from the emitting point at 0-15, 15-30 and 30-45 cm depths. The soil samples were analysed for NH_4-N, NO_3-N and K content using Kjel plus apparatus (Kjeldahl, 1983) and flame photometer (Jackson, 1973).

Table 2. Soil moisture distribution pattern in surface irrigation

Sampling depth (cm)	Moisture content at various time interval (%)						
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day
0-15	27.1	25.4	22.3	20.4	18.8	17.7	16.3
15-30	27.4	26.8	23.4	21.7	18.6	17.8	16.7
30-45	26.7	25.2	23.1	21.6	19.8	18.0	17.6

Table 3. Soil moisture distribution pattern 24 hours after irrigation at different drip layouts

Distance from emitter	Depth (cm)	Soil moisture distribution at different drip layouts (%)		
		Single row drip irrigation (4 lit/hr)	Paired row drip irrigation (8 lit/hr)	Micro-tube irrigation (20 lit/hr)
0	0-15	26.4	27.5	27.0
	15-30	25.8	27.2	28.1
	30-45	19.6	26.0	26.3
15	0-15	25.2	26.3	25.4
	15-30	25.9	26.7	27.2
	30-45	18.2	22.4	24.5
30	0-15	23.7	24.2	25.7
	15-30	24.3	24.8	26.2
	30-45	17.3	22.0	23.7
45	0-15	21.5	23.2	23.7
	15-30	20.7	23.2	24.6
	30-45	17.0	19.4	21.2

RESULTS AND DISCUSSION

Soil moisture distribution

Moisture contents recorded in surface and drip irrigation treatments are presented in Tables 2 and 3 respectively. The soil moisture content was gradually decreasing as the days increased. The moisture content of soil after 1 day of irrigation varies in the range of 26 to 27.4 % in various soil depths. After 7 days of irrigation the moisture content was reduced gradually in the range of 16.3 to 17.6 %. The soil moisture content at surface layer in surface irrigation treatment was lower compared to subsurface layers as the days after irrigation increased and there was more depletion of moisture in 0-15 cm layer due to evaporation.

Moisture content estimated 24 hours after irrigation at various horizontal distances from the emitter point indicated that the moisture content decreased in deeper soil layers as the distance from emitters increased. In single row drip irrigation system (with emitter capacity 4 lit/hr) the higher moisture content (25.9 %) was found at 15-30 cm depth at 15 cm away from the emitting point, whereas the lowest moisture content was found at 30-45 cm depth at 45 cm away from the emitting point. In paired row drip irrigation (with emitter capacity 8 lit/hr) and paired row micro tube irrigation (emitter capacity 20 lit/hr) the higher moisture content was found in the upper layer of soil depth near the emitting point. Overall in 8 and 20 lit/hr emission devices, the estimated moisture content was more or less equal and the field capacity level was maintained in all the layers since the dripper capacity is more. The moisture content decreased as the distance and depth increased from the emitting point in all the drip layouts. The moisture content decreased as the distance increased from the emitting point. Soil moisture distribution mainly depended on the rate of application, amount of water and initial moisture content of the soil (Khepar *et al.*, 1983). The moisture content in the lower layers was high compared to the surface layer. Further, soil moisture decreased with decreased level of irrigation. This was also indicated by Chakraborty *et al.* (1998) that the soil water content was relatively higher by volume near the emitter throughout the experiment. The soil water content decreased as the distance from the emitting point increased.

Fertilizer distribution in soil

Observations were taken on potassium, ammonium and nitrate concentrations in the soil samples taken at 0-15, 15-30 and 30-45 cm depths of the profile at the emitting points and 15, 30 and 45 cm horizontally away from the emitting points one week after fertigation.

Nitrate-nitrogen movement and distribution

During crop growth period, in the fertigation treatments the maximum concentrations of NO_3-N were found at some depth in the profile. The distribution pattern was more or less similar for all the fertigation treatments, although there was difference in the level of concentration.

Surface irrigation with 100 % recommended fertilizer dose (T_1F_1)

In surface irrigation with 100 % recommended fertilizer dose treatment the maximum concentration (35 mg g^{-1}) was found in depth of 15-30 cm compared to 0-15 cm and 30-45 cm layers.

Comparison of surface irrigation with drip at 80 % of surface irrigation and 100 % of recommended fertilizer dose (T_2F_1 and T_5F_1)

In treatments T_2 and T_5 (80 % of surface irrigation), maximum NO_3-N concentration occurred at 45 cm depth below the emitting point but it was more at 0-15 cm depth at a distance of 15 cm away from the emitter. At a distance of 30 cm away from emitter, concentration was more at 15-30 cm depth for T_2 and it was more at 45 cm depth for T_5. At a distance of 45 cm away from emitter, similar distribution and concentration were found. In T_2, the maximum concentration was 49 mg g^{-1} at 30-45 cm depth and in T_5, the maximum concentration was 42 mg g^{-1} at 0-15 cm depth 15 cm away from the emitting point (Fig. 1). In T_5, the concentration at 30-45 cm depth below the emitting point was 35 mg g^{-1}. This may be due to higher emitter discharge (8 lit/hr), which leached NO_3-N to lower layers i.e. beyond 45 cm depth.

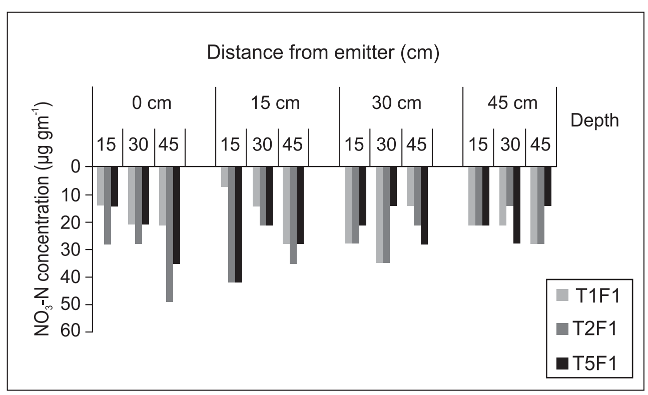

Fig. 1. NO_3-N distribution for surface irrigation vs. drip irrigation at 80% of surface irrigation

Comparison of surface irrigation with drip and Micro-tube system at 60% of surface irrigation and 75% of recommended fertilizer dose (T_6F_2 and T_9F_2)

In the treatments T_6 and T_9 (60% of surface irrigation with 75 % of recommended fertilizer dose), maximum NO_3-N concentrations of 42 and 35 mg g^{-1} were obtained at 30-45 cm depth below the emitting point and 15-30 cm depth at 15 cm away from emitting point respectively (Fig. 2). In T_9, the concentration at 30-45 cm depth below the emitting point was 35 mg g^{-1}. Due to higher emitter discharge (20 lit / hr), the NO_3-N might be leached to lower layers, i.e. beyond 45 cm depth.

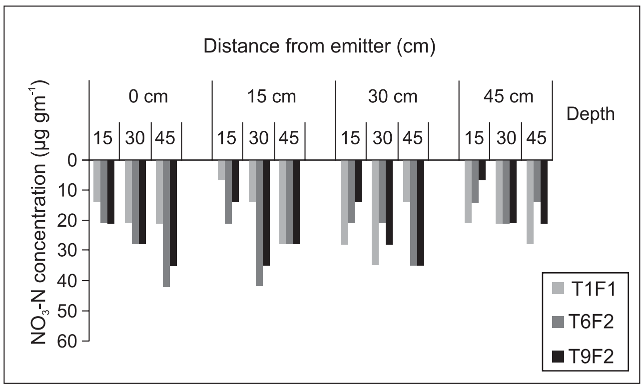

Fig. 2. NO_3-N distribution for surface irrigation Vs drip irrigation at 60% of surface irrigation

Comparison of surface irrigation with drip and Micro-tube system at 40 % of surface irrigation and 75 % of recommended fertilizer dose (T_4F_2 and $T_{10}F_2$)

Maximum NO_3-N concentration (35 mg g^{-1}) was recorded at 15-30 cm depth below the emitting point and 15 cm away from the emitting point in T_4 (Fig. 3). In T_{10}, the concentration of NO_3-N was

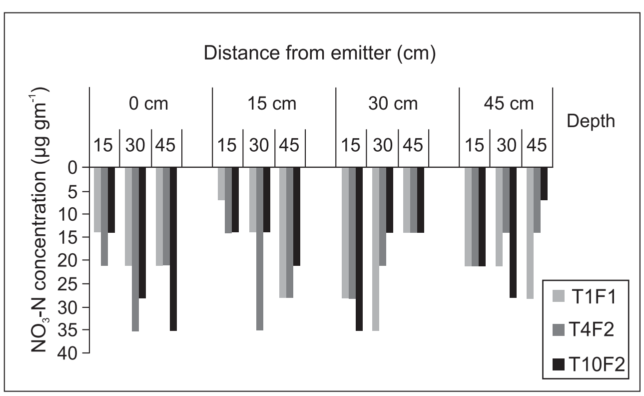

Fig. 3. NO_3-N distribution for surface irrigation Vs drip irrigation at 40% of surface irrigation

maximum at 30-45 cm depth below the emitting point and at 0-15 cm depth at 30 cm away from the emitting point. In both the treatments, at 45 cm away from the emitting point, the concentration was less, which may be due to application of water at 40 % of surface irrigation, wherein water movement beyond 30 cm is less. Under micro irrigation treatments (T_2 to T_{10}) urea was applied through drip and Micro-tubes, whereas in T_1, the flood irrigation system was employed with band placement of fertilizers. Due to difference in the quantum of water applied through different drip treatments, the concentration was different in different layers. Due to leaching effect in T_1, the concentration was less up to 30-45 cm depth, but maximum concentration in drip treatments was confined to within 30-45 cm depth since Nitrate ion being mobile had a tendency to move away from the emitter to the periphery of the water front. Gerstle *et al.* (1981) reported the bromacil distribution for the weekly irrigation treatment exhibited a highly leached zone around and under the emitter and a small zone of concentration on the soil surface near the wetting front due to alternate wetting and evaporation cycles. Karlen *et al.* (1985) studied the effect of N fertilizer application to tomato and found that NO_3-N concentration was higher in upper 30 cm soil layer due to fertigation than broadcasting of fertilizer. Subbarayappa *et al.* (1994) stated that mulberry absorbed nitrogen either as ammonium (NH_4^+) or as nitrate ion (NO_3^-). The ammonium ions could be held in a exchangeable and available form on the surfaces of clay and humus. Chakraborty *et al.* (1999) stated that NO_3-N neither accumulated at the periphery of the wetting front nor was leached from the root zone under drip systems.

NH_4-N movement and distribution

NH_4-N movement and distribution did not show any marked difference among the treatments.

Surface irrigation with 100 % recommended fertilizer dose (T_1F_1)

In T_1, maximum NH_4-N concentration of 56 mg g^{-1} was registered at 30-45 cm depth followed by 49 mg g^{-1} at 15-30 cm depth. It was unevenly distributed at different distances from plant. Uniform distribution of fertilizers through fertigation was found in drip treatments rather than in band placement in surface irrigation method.

Comparison of surface irrigation with drip at 80 % of surface irrigation and 100 % of recommended fertilizer dose (T_2F_1 and T_5F_1)

In T_2 and T_5 (drip at 80 % of surface irrigation), maximum NH_4-N concentration (70 mg g^{-1}) was recorded at 15-30 cm depth below the emitting point. The concentration was confined within 15-30 cm depth at 30 cm away from the emitting point. Beyond 30 cm distance and 15-30 cm depth, the concentration was less (Fig. 4).

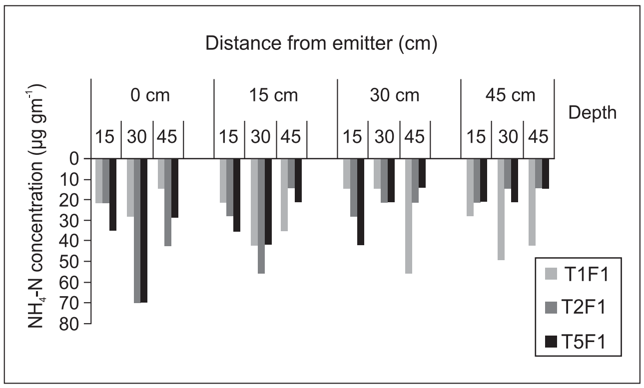

Fig. 4. NH_4-N distribution for surface irrigation Vs drip irrigation at 80% of surface irrigation.

Comparison of surface irrigation with drip and Micro-tube system at 60 % of surface irrigation and 75 % of recommended fertilizer dose (T_6F_2 and T_9F_2)

In T_6, NH_4-N concentration (56 mg g^{-1}) was maximum in 15-30 cm depth, at 15 cm away from the emitting point. In T_9, maximum concentration of 49 µg g^{-1} was found at 15-30 cm depth below and 30 cm away from the emitting point (Fig. 5). This might be due to higher discharge rate (20 lit / hr) of Micro-tubes even though quantum of water applied was equal to drip system with 8 lit / hr drippers.

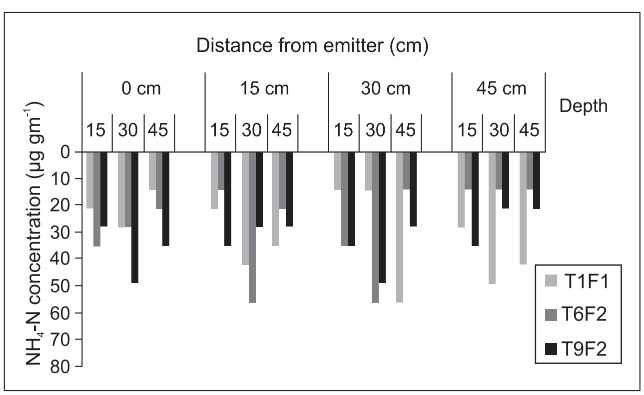

Fig. 5. NH_4-N distribution for surface irrigation Vs drip irrigation at 60% of surface irrigation.

Comparison of surface irrigation with drip and Micro-tube irrigation at 40 % of surface irrigation and 75 % of recommended fertilizer dose (T_4F_2 and $T_{10}F_2$)

NH_4-N concentration was maximum (42 mg g^{-1}) at 0-15 cm depth below the emitting point in T_4. In T_{10}, maximum concentration (56 mg g^{-1}) was found at 15-30 cm depth at 15 cm away from the emitting point (Fig. 6). The increase in NH_4-N concentration immediately in the vicinity of the emitter was a consequence of the hydrolysis of urea (Haynes, 1990).

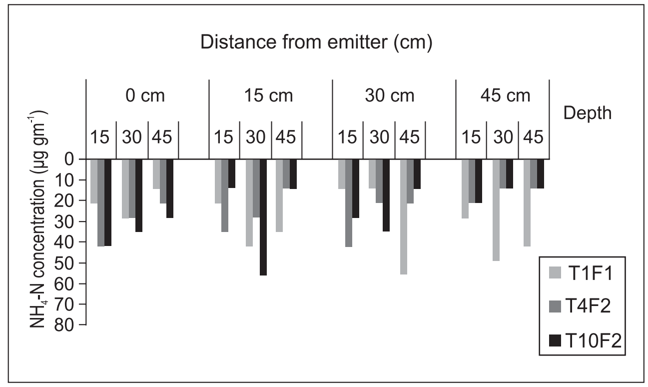

Fig. 6. NH_4-N distribution for surface irrigation Vs drip irrigation at 40% of surface irrigation.

This consistently wet condition around the emitter also ensured that the conversion of NH_4-N to NO_3-N occurred at some distance away from the emitter in a relatively drier zone, where more oxygen was available (Laher and Avnimelech, 1980). Shivakumar (1998) reported that the NO_3-N, P and K were higher in the root zone of ferti-drip soil (3.82 to 50.1, 3.32 to 20.2 and 222.3 to 643.5 mg kg^{-1} soil respectively) than in fertilizer applied soil with furrow irrigation (2.89 to 32.0, 2.7 to 8.2 and 229 to 584 mg kg^{-1} soil respectively). Chakraborty *et al.* (1998) reported that ammonium concentration was maximum below the emitter and it decreased as the wetting zone moved away from the emitter. The zone of maximum nitrate ion concentration was always below the surface layer in drip irrigation treatments.

Potassium movement and distribution

Surface irrigation with 100 % recommended fertilizer dose (T_1F_1)

In surface irrigation treatment, uneven distribution of K content was found. Maximum K content (63 ppm) was found at 30-45 cm depth and it was less in upper layers.

Comparison of surface irrigation with drip at 80 % of surface irrigation and 100 % of recommended fertilizer dose (T_2F_1 and T_5F_1)

Maximum K content (64 ppm) was recorded at 15-30 cm below the emitting point in T_2. Up to 45 cm depth and 45 cm away from the emitting point the distribution was similar. In T_5, maximum K content (67 ppm) was recorded at 45 cm below the emitting point (Fig. 7).

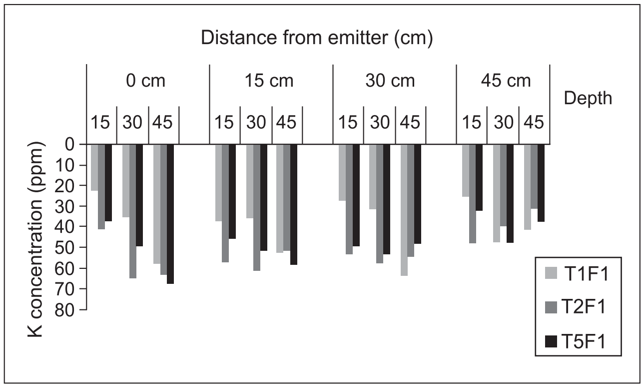

Fig. 7. Potassium distribution for surface irrigation Vs drip irrigation at 80% of surface irrigation.

Comparison of surface irrigation with drip and Micro-tube system at 60 % of surface irrigation and 75 % of recommended fertilizer dose (T_6F_2 and T_9F_2)

In T_6, maximum K content (62 ppm) was estimated at 15-30 cm depth at 15 cm away from the emitting point. In T_9, maximum K content (64 ppm) was found at 30-45 cm below the emitting point (Fig. 8).

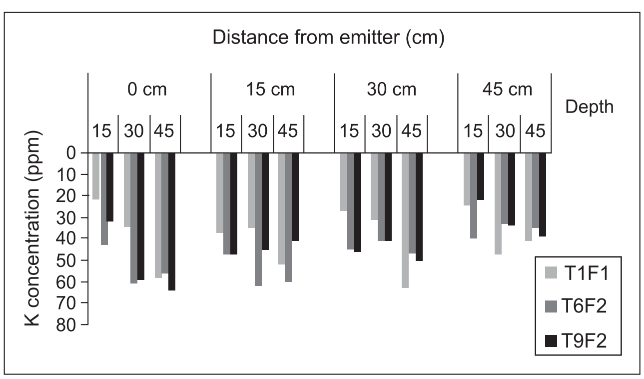

Fig. 8. Potassium distribution for surface irrigation Vs drip irrigation at 60% of surface irrigation.

Comparison of surface irrigation with drip and Micro-tube system at 40 % of surface irrigation and 75 % of recommended fertilizer dose (T_4F_2 and $T_{10}F_2$)

In T_4, maximum K content (59 ppm) was recorded at 0-15 cm depth below the emitting point. In T_{10}, maximum K content of 62 ppm was estimated at 0-15 cm depth at 15 cm away from the emitting point (Fig. 9). The concentration decreased as the distance increased from the emitting point due to less quantum of water supplied in this treatment.

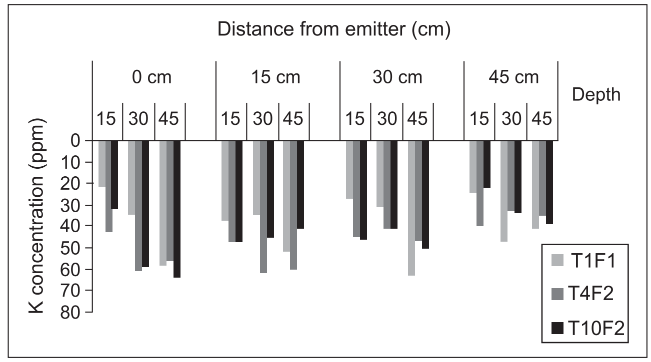

Fig. 9. Potassium distribution for surface irrigation Vs drip irrigation at 40% of surface irrigation.

CONCLUSIONS

Soil moisture content at surface layers in surface irrigation treatment was lower compared to subsurface layers because of higher density of roots and more depletion of moisture in the 0-15 cm layer due to evaporation. In drip irrigation treatments, the moisture content decreased as depth and distance increased from the emitting point. The fertilizer distribution in the soil layers was more or less similar for all the fertigation treatments, although there was difference in the level of concentration in different depths of the soil. Since, venturi device was used for fertigation, there was a high pressure loss in the system which might results in uneven fertilizer distribution in the soil. A drip irrigation system producing a uniform water application does not necessarily mean a uniform fertilizer distribution when it is used for fertigation. The fertigation devices performances should be considered in detail for uniform fertilizer distribution, hence the relationship between water application uniformity and fertigation uniformity for a drip irrigation system was highly associated with injection method.

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Determination of drainage coefficient for surface drainage design in rainfed low land rice areas of Mahanadi Delta

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ABSTRACT

The concept of drainage coefficient is used in the design of drainage systems for agricultural lands. The design of an economic and hydrological efficient surface drainage system depends largely on the selection of a proper drainage coefficient. In this paper, an attempt was made to compute the drainage coefficient from rainfall data in the lowland water logged areas of Daya-Bhargavi doab of Mahanadi delta, Odisha, for paddy crop. The computation procedure involved the probability analysis of 21 yrs daily rainfall data and use of Simplified Hydrologic Procedure, Curve Number method, Cypress-Creek formula and Rational method. The values of drainage coefficient computed by Curve Number method and Cypress-Creak formula were found to be closer and the Simplified Hydrologic Procedure gave a slightly higher value. The values of drainage coefficient computed by Curve Number method and Cypress-Creak formula are found to be 26.86 mm/day and 31.69 mm/day, respectively and the Simplified Hydrologic Procedure and Rational formula give higher values of 45 mm/day and 360.56 mm/day, respectively. The drainage coefficient of 26.86 mm/day as computed by Curve Number method is found to be the best fit value for the study area that is to be adopted for design of surface drainage system with 7 days storm and 8 years return period. Accordingly the value of design method of discharge as obtained by the curve number method for design of surface drainage system is computed as 0.59 m^3/s. A value of 0.59 m^3/s as design discharge from CN method and 6.74 m^3/s as peak discharge from Rational method are found suitable for the design of the channel and the outfall structure, respectively.

Key words: Drainage coefficient, lowland rice, Mahanadi delta, Surface drainage system, Water logged area

INTRODUCTION

Mahanadi river basin is the biggest drainage basin among all the drainage basins of Odisha which spreads over an area of 65,581 sq.km. having a channel length of 494 km in the state. Mahanadi delta is the oldest irrigation system of Odisha occupying an area of 9 lakh sq. km. out of which, irrigation is provided to a gross command area of 5.2 lakh ha and culturable command area of 3.03 lakh ha. The general slope of the area is 0.20%to 0.03%. The delta area is divided into two distinct stages viz. stage-I and stage-II. The total command area of Mahanadi Delta is divided into eight numbers of sub areas bonded by river branching and the sea. Each sub area becomes the command area between two rivers and is called a 'doab' which is an independent drainage unit. Each stage comprises of 4 numbers of doabs. In stage-I delta command area, the flood embankments are continuous. There is no possibility of water from other drainage basins entering into the command area except in case of breaches. But in stage- II area, escapes have been provided in the river embankments to give them relief by allowing certain quantities of flood water into the command area after the river discharge exceeds a fixed limit. These

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escapes are located near the head of the doabs and the water gets entry into the drainage channels increasing their congestion problem (Annonymous, 1989). Hence the stage-II delta has more acute water logging problems than stage-I delta. The flat topography, non uniform and heavy rainfall during south-west monsoon season i.e. June to September and congestion of drainage channels aggravate the problems of water logging. Once the flood water is allowed to enter the doab area, it is not easily drained and water logging remains there for a long period. Most of the irrigated areas under paddy crop are subjected to submergence for periods more than 4 to 10 days. The rising water table restricts soil aeration and root development of the crops, affects soil temperature, hinders with tillage operations and brings up harmful substances to the crop root zone depth. It is a recurring phenomenon every year leading to considerable crop damage and economic loss at many places of coastal belt of Orissa. However, existing drainage systems in the Mahanadi delta of Odisha are poor due to improper design of surface drainage system. Further, various reasons for water logging condition of these areas are seepage from unlined canals, damaged portions of lined canal beds, blockage of natural drainage due to the net work of canal and roads, poor working of existing surface drainage systems, under utilization of groundwater for irrigation, internal flow of subsurface water and injudicious water management (Chitale, 1991).

During monsoon, the heavy and concentrated rainfall causes severe water logging and damage to the rice crop at some growth stage or the other. It is a recurring phenomenon every year leading to considerable crop damage. Efforts are therefore needed to develop the surface drainage system of these areas to reduce the severity of water logging. The design of an economic and efficient surface drainage system depends to a very great extent on the selection of a proper drainage coefficient (Rao and Dhruvanarayana, 1979). In this paper, the various methods of determining drainage coefficient are discussed and compared so as to test their suitability for adoption as per the present field conditions.

Study Area

The study area comes within Mahanadi Command Area Stage-II under Daya- Bhargavi doab, the third largest doab of Mahanadi delta system. The GCA and CCA of the doab are 0.089 Mha and 0.047 Mha respectively out of which 0.0203 Mha area is affected by poor drainage (Panda and Rajput, 2003). The study area belongs to villages Kakudi Kusanga and Parinjhar and is getting its runoff from a catchment area of 190 ha covering village Kakudi Kusanga and surrounding villages namely Parinjhar and Jhintisasan. The ayacut of the study area is bounded by Tarakaj trunk drain in the south, Sakhigopal branch canal in the east and Binayakpur minor in the west. The water logging problems of the area become aggravated by its flat topography and paddy - paddy cropping pattern. The topography is nearly flat with average land slope of 0.05% and the soil texture is generally sandy loam to clay loam. The average annual rainfall of the region is found to be 1419 mm. During crop growth period, the average standing water depth in the rice fields vary from 15 cm to 75 cm.

MATERIALS AND METHODS

Drainage coefficient is the key parameter for design of surface drainage system. An increase in drainage coefficient value helps in reduction of maximum ponding depth and duration of pondage, but it involves larger channel dimensions, more loss of agricultural land and more cost of construction. On the other hand, an underestimation of this value may result in crop loss due to yield reduction. Hence there is a need for balance between the drainage coefficient and the depth / duration of submergence based on the crop tolerance limit. The materials used and various methods and procedures adopted for determination of drainage coefficient are summarized into the following steps-

The daily rainfall data covering a period of 21 years (1990-2010) was collected for the study area from the District Emergency (Flood) Cell, Puri. For the rice area under study, crop tolerance period and the depth of submergence allowed were assumed as 7 days and 150 mm, respectively. A return period of 8 years was adopted for rainfall analysis by considering one crop failure in 4 years due to irrigation i.e. 75 % dependable irrigation as well as one failure in 8 years due to drainage congestion (Anonymous, 1989). The moving total method was adopted using Microsoft-Excel to make the moving totals of daily rainfall data for 7 consecutive days and their maximum values were obtained for a particular year. The process was repeated for computation of 7 consecutive days rainfall for whole 21 years of data. Probabilities of occurrence of 7 days maximum consecutive rainfall at various return periods were computed by Weibull's plotting position formula. The 7-day maximum rainfall corresponding to return period of 8 years were computed. Deducting a storage depth of 150 mm, the resulting rainfall magnitude was used for the hydrologic design i.e. computation of the drainage coefficient and design runoff. The following approaches were considered for estimation of drainage coefficient.

1) Methods for direct depth measurement-
   a) Simplified hydrologic procedure or DDF curve method, b) Curve number method
2) Methods for Volumetric measurement-
   a) Cypress-Creek formula, b) Rational formula

Simplified Hydrologic Procedure

This procedure was established by Raadsma and Schulze (1974) and also suggested by Ritzema (1994). This is a graphical method to determine drainage coefficient with the help of rainfall depth-duration-frequency curve. The losses due to interception, infiltration and evapotranspiration are neglected in this procedure due to maximum saturated conditions of atmosphere and soil surface. The drainage coefficient computed by this method is independent of the size of the watershed. A minimum allowance is made for surface ponding for the said crop and any water excess than this limit is to be removed by the drainage system within that particular period. The low land rice areas like Mahanadi delta command area usually satisfy the above assumptions and the drainage coefficient is computed accordingly.

To compute drainage coefficient, the maximum consecutive daily rainfall are determined for the study area for different return periods. The duration and depth of rainfall are plotted along *X* and *Y* axis, respectively. For each return period, the depth–duration curve is drawn which is called DDF curve of rainfall. For paddy crop and for the study area, as discussed earlier, a storage depth of 150 mm and a return period of 8 years has been adopted. A tangent from 150 mm point on depth Y axis is drawn to the depth duration frequency (DDF) curve. The slope of this tangent line gives the drainage coefficient or design discharge rate in mm / day. To make the slope calculation easy, the tangent line is simply shifted to pass through the origin of graph to get a line parallel to the original tangent line. Here the area bounded by this drainage coefficient line and the X axis represents the water to be drained out from crop field. Similarly the area between this line and the rainfall curve indicates the storage depth of excess water within that period.

Curve Number (CN) Method

It is known as Hydrologic Soil Cover Complex method or simply CN method. The term Hydrologic Soil Cover Complex is adopted as it considers the effect of soil type or group, soil wetness or antecedent moisture condition (AMC), land coverage by vegetation and nature of cultivation practices etc and the combined effect of all these parameters is expressed by the term 'Curve Number'. By CN method, the 'design rainfall' is converted to the 'design runoff' and the drainage coefficient is computed as follows:

Direct runoff or surface runoff,

$$Q = \frac{(P - I_a)^2}{P - I_a + S}$$

Where, I_a = Initial abstraction from rain=0.3 S taken for the present project,

P = Rainfall depth and S = Maximum or potential abstraction

So, $Q = \frac{(P - 0.3S)^2}{P + 0.7S}$ where, $S = \frac{25400}{CN - 254}$

This depth of runoff is to be removed within a period of 7 days.

Cypress-Creek Formula

The formula estimates the design discharge rate of runoff as,

$Q = CA^p$

where, Q = Design discharge in cumec,

A = Watershed area in Sq.km = 1.9 sq.km.

p = Index of A, usually equal to 5 / 6 or 0.833.

C =Coefficient which takes care of characteristics of soil / vegetation, land slope, rainfall condition etc. and is calculated by Stephens & Mills formula as,

C = 0.2089 + 0.0074 Re

Where, Re = Rainfall excess in mm as estimated by CN method.

Rational Formula

Rational formula is the most widely used procedure to estimate the peak rate of runoff at the outlet of watershed.

The peak discharge is given by,

$$Q = CIA / 36$$

where, Q = peak runoff rate in m^3/sec; A= watershed area in ha; I = rainfall intensity in cm / hr for a duration equal to time of concentration (T_c) and for a particular return period; C = runoff co-efficient = 0.3 assumed for the study area.

The time of concentration 'T_c' is the most important factor to decide the rainfall intensity 'I' in the formula which is given by Kirpitch formula as:

$$T_c = 0.0195 \ L^{0.77} S^{-0.385}$$

where, T_c= time of concentration in minute; L = maximum length of water flow *i.e* from most remote point to the outlet in metre (calculated 1800 m for the study area); S = average slope of watershed land in m / m (calculated 0.0005 for the study area).

To find the rainfall intensity for the estimated T_c value, the 1 hour rainfall maps of India for 10yr & 25yr return periods and the intensity conversion graph have been obtained from Murty and Jha (2009). Now corresponding to the available value of 1hr rainfall intensities (along Y-axis), the intensity for duration equal to T_c(in min.) can be found out from X-axis. This value will be the 'I' value in the Rational equation.

RESULTS AND DISCUSSION

Simplified Hydrologic Procedure

The maximum consecutive daily rainfall values from 1 to 7 days are determined for different return periods as shown in table 1 and the DDF curves were drawn and is presented in Fig. 1. For the present study, 8 yrs return period was considered. So a tangent was drawn to the 8 yr return period curve from the point of 150mm rainfall as shown in fig. no.4. The slope of the line was coming out as 45. Thus the drainage coefficient was found to be 45 mm / day. Here, as indicated in the graph, the excess ponding water within these 7 consecutive days period, reaches to a height ranging from 30 mm (end of 7 day) to 170.6 mm (end of 2 days).

Table 1. Maximum consecutive day rainfall (mm) at different return periods

Return Period	1 day	2 days	3 days	4 days	5 days	6 days	7 days
5 years	172.7	252.2	288.8	300.7	301.2	309.1	323.3
8 years	177.5	260.6	299.1	313.4	313.4	319.1	345.1
10 years	181.8	265.5	311.4	323.6	323.6	325.5	387.7
20 years	192.2	279.5	347.4	424.7	497.5	572.7	662.6

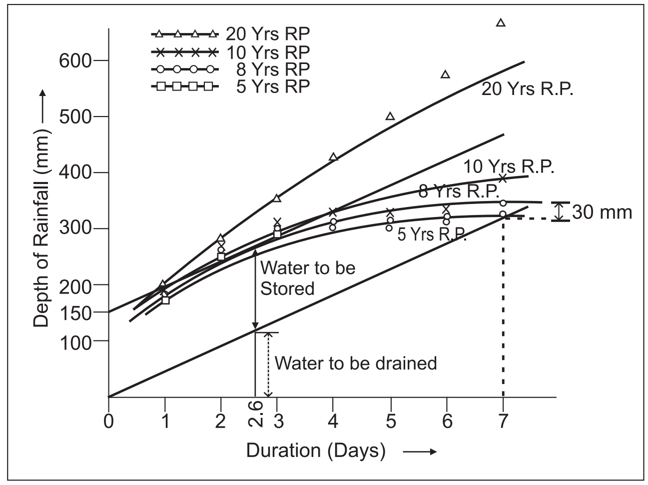

Fig 1. Rainfall DDF Curve at different return periods

SCS-Curve Number Method

The project area falls into AMC–III category and soil group–B. Under such conditions the value of the curve number using the conversion factor for AMC–III came out to be 98. Now, potential maximum retention,

$$S = \frac{25400}{98} - 254 = 5.18 \text{ mm}$$

The 7 days consecutive rainfall for 8 yrs return period from the probability analysis =345 mm

Deducting the storage depth of 150mm, rainfall depth (P) =195mm

Direct runoff depth, $Q = (P-0.3S)^2 / (P+0.7S) = (195-0.3\times5.18)^2 / (195+0.7\times5.18)$ =188mm

Hence, Drainage coefficient or rainfall excess = $\frac{188}{7}$ = 26.86 mm / day

Cypress – Creek Formula

Rainfall excess , Re = 26.86 mm / day, as found out by CN method

Runoff coefficient, C = 0.2089 + 0.0074 (Re) = 0.4086

Design Discharge, $Q = CA^p = 0.4086(1.9)^{0.833} = 0.697$ cumec

So, Drainage coefficient = Discharge / Area = 0.697 cumec / 190 ha = 31.69 mm / day

Rational Formula

The time of concentration (T_c) = $0.0195 (1800)^{0.77} (0.0005)^{-0.385}$ =116.8 mins.

a) For channel design, the 10 year return period map indicates that the 1 hour rainfall for the given location= 80mm / hr or, 8cm / hr. Using conversion graph, the desired rainfall intensity for a duration equal to time of concentration of 116.8mins = 5.0cm / hr

Hence, Peak discharge, Q_p = CIA / 36 = (0.3x5.0x190) / 36 = 7.92 cumec

So, the Discharge rate or the Drainage Coefficient for the area = Q_p / Area = 7.92cumec / 190ha = 0.36 m / day i.e. 360 mm / day

b) For Structural design, usually a return period of 25 yrs is considered and the map shows that, the 1 hour rainfall for the given location= 100 mm / hr or 10cm / hr. From conversion graph, the desired rainfall intensity for duration equal time of concentration of 116.8 min = 7.1 cm / hr.

Hence, peak discharge will be Q_p = CIA / 36 = (0.3x7.1x190) / 36 = 11.24 cumec

Now the drainage coefficient and design / peak discharge as calculated by different approaches are summarized below:

Methods adopted	Drainage coefficient (mm / day)	Design discharge (cumec)	Peak discharge (cumec)
SHP / DDF curve method	45.00	0.989	-
SCS-CN method	26.86	0.59	-
Cypress-Creek formula	31.69	0.697	-
Rational formula	360.56	-	7.92 (channel) 11.24 (Structure)

The result obtained by SHP / DDF is higher than those coming out from SCS-CN method or Cypress-Creek formula. This may be due to the fact that a return period of 8 yrs is taken for plotting the depth-duration-frequency curve. This is on a higher and safer side as it is a general practice to provide protection to farm crops against storms of 2 to 5 year return periods (Rao and Dhrubanarayan, 1979). A higher drainage coefficient indicates higher cost and larger dimensions that consume more agricultural land which may not accommodate to the available field conditions. Higher drainage coefficient values are required for vegetables for their survival as they can withstand only 24hrs of submergence (Murthy and Jha, 2009). But in case of paddy, higher drainage coefficient is not required for surface drainage design as the crop can withstand relatively higher depth of standing water for some days. On the contrary, lower values of drainage coefficient are permissible although it creates the temporary inundation of the neighbouring agricultural lands (Bhattacharya and Michael, 2003). The SCS-CN method or Cypress-Creek formula give similar and acceptable results for drainage rates to be taken for drainage channel design. But preference should be given to Curve Number method because it takes in to account many parameters like soil characteristics, rainfall, field moisture conditions, physical condition of watershed etc, where as Cypress-Creek formula is only an empirical formula which is developed based on observations at a particular place and may not exactly fit to the other areas. Hence the value obtained by CN method may be taken for design of surface drainage channels.

The Rational method gives a very high value of drainage coefficient for drainage design. This is because this formula assumes a uniform distribution of rainfall intensity over the whole catchment area which does not occurs in real situation. Rather, rainfall occurs with high intensities and short durations over small areas and never becomes uniform. Moreover a relatively higher return period (10 yrs) in the climatological map has been considered for drainage channel design, which gives higher results. Also the discharge calculated by this formula is the peak discharge which is much more than the design discharge value to be considered from drainage channel design. Hence for channel design, this value is not advisable to accept. However this peak discharge value may be considered for structural design purpose as failure of structures may cause serious problem to the crop and involve more economic loss.

CONCLUSION

Selection of proper drainage coefficient is very much essential in the design of an efficient surface drainage system as higher values mean larger and costly channels whereas lower values may not give the desired protection causing damage to crops. The design of surface drainage network is a function of drainage coefficient selected for the area and the drainage coefficient is a function of the drainage area and the run off created from rainfall. The values of drainage coefficient computed by Curve Number method and Cypress-Creak formula were found to be 26.86 mm / day and 31.69 mm / day respectively and the Simplified Hydrologic Procedure and Rational formula gave higher values of 45 mm / day and 360.56 mm / day respectively. The drainage coefficient of 26.86 mm / day as computed by Curve Number method was found to be the best fit value for the study area to be adopted for design of surface drainage system with 7 days storm and 8 year return period. Accordingly the value of design method of discharge as obtained by the curve number method for design of surface drainage system was computed as 0.59 m^3/s. A value of 0.59 m^3/s as design discharge from CN method and 6.74 m^3/s as peak discharge from Rational method were found suitable for the design of the channel and the outfall structure respectively.

The low land rice cultivation requires surface ponding throughout the crop growing season. Thus the drainage coefficient in lowland rice fields should be based on the quantity of rainfall which may cause excess flooding lasting for several days and occurring at a particular frequency. Hence, the drainage coefficient for the study area was determined basing on the analysis of rainfall data. The curve number method resulted in the minimum value among all the approaches followed. The simplified hydrologic procedure in which the aerial distribution of rainfall and losses like interception, infiltration, etc are neglected, gave drainage coefficient little higher than the value obtained by Curve Number method. The use of empirical formulae should be avoided and if it is inevitable to use due to want of other data, then Cypress-Creek formula should be followed for the delta area which also gives closure value of drainage coefficient.

In the field it always becomes very difficult to maintain a stable section of drain which can carry the design discharge. Design discharge flows occasionally in the drain. As found from field observations, drains of bigger size than design section tend to deteriorate fast as they have to carry in general a smaller discharge, than the design value and heavy weed growth as well as siltation take place inside the drain. On the other hand, the drains of smaller size than the design section remain in better condition and can carry occasionally higher discharge with marginal scouring of the channel and overtopping of side lands. Hence the value obtained by the Curve Number approach is suggested as the suitable value of drainage coefficient for design of surface drainage channel for the study area.

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Wind drift and evaporation losses under various operating conditions of sprinkler irrigation system

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ABSTRACT

Sprinkler irrigation is an advanced method of irrigation through which water can be used effectively. However in the field, sprinkler irrigation is also associated with problems like water losses due to wind drift and evaporation, distortion of application pattern by wind and modification of infiltration characteristics of the soil by impact of drops on the soil surface. These problems are associated with the movement and physical condition of individual droplets sprinkled through the system. Sprinkler drop size influences important aspect of irrigation such as sprinkler pattern distortion by wind, evaporation and wind drift losses, wind drift when irrigating with effluent water. As a step to explore proper solution to some of the above problems, a field investigation was conducted to determine the wind drift and evaporation losses from rotary sprinkler and to study the effect of nozzle size, operating pressure and nozzle elevation on it. Wind drift and evaporation losses were determined by catch can method at three operating pressures i.e. 2.5, 2.0 and 1.5 kg cm^{-2} with three nozzles elevations 150, 110 and 75 cm for 5.6, 4.7 & 3.1 mm nozzle sizes. As per the results of the field study, it was found that wind drift and evaporation losses were increased with an increase in pressure and nozzle elevation but decreased with an increase in nozzle size. It was also found that rates of increase of wind drift and evaporation losses were more at lower pressure (1.5 kg cm^{-2}) and less at higher pressure (2.5 kg cm^{-2}).

Key words: rotary sprinkler, wind drift & evaporation losses, nozzle size,operating pressure, nozzle elevation

INTRODUCTION

In the sprinkler method of irrigation, water is sprayed into the air and allowed to fall on the ground surface somewhat resembling rainfall. The flexibility of sprinkler equipment and its efficient control of water application make this method adaptable to most topographical conditions without extensive land preparation. It is specially suitable for steep slopes or irregular topography. The development of a variety of sprinkler devices has increased dramatically in recent years. The same are available from the conventional single or double nozzle impact sprinkler with many types of nozzle to various type of deflection plate sprinklers. The basic objective of sprinkler irrigation is to simulate the rainfall and to apply uniformly a calculated depth of water at a predetermined application rate. The irrigation efficiency of the sprinkler irrigation system depends upon the degree of uniformity of water application. Water spray distribution characteristics and spacing regulate the uniformity of water application. The spray distribution characteristics of sprinkler heads are typical and change with nozzle size, operating pressure and nozzle elevation. But wind drift and evaporation losses affect the water distribution pattern of sprinklers. Spray evaporation was negligible relative to drift loss (Seginer and Kostrinsky, 1975). Some authors found losses of 5-10 % under moderate evaporative demand (Keller and Bliesner,

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1990), losses of 30 % (Yazar, 1984) and losses up to 50 % (Frost and Schwalen, 1955). It is a general belief that *WDEL* are not fully consumptive, since they partly contribute to decrease crop water requirements (Tarjuelo *et al.*, 2000). So, knowledge about wind drift and evaporation losses for sprinkler is important to achieve proper distribution of spray water and the maximum efficiency from the system. Hence, a sprinkler operating on particular soil, slope, crop and climatic conditions, the knowledge of wind drift and evaporation losses becomes an essential requirement. Numerous studies (Dechmi *et al.*, 2003; Fukui *et al.*, 1980; Kincaid *et al.*, 1996; Kohl, 1974; Lorenzini, 2002; Lorenzini and DeWrachien, 2005; Tarjuelo *et al.*, 1999; Zapata *et al.*, 2007) have surveyed the factors influencing sprinkler irrigation performance. Nozzle size, operating pressure and nozzle elevation are some factors which play an important role to influence sprinkler irrigation performance with respect to droplet size falling at different radial distances from the nozzle due to wind drift. Therefore, a study was under taken with the objective to understand the effect of nozzle size, operating pressure & nozzle elevation on wind drift and evaporation losses from rotary sprinklers.

MATERIAL AND METHODS

The study was conducted in the agricultural field of the instruction farm of College of Technology and Engineering, Udaipur. The variables taken under the study were nozzle size, operating pressure and nozzle elevation. Three-nozzle sizes of 5.6, 4.7 & 3.1 mm with three nozzle elevations of 150, 110 and 75 cm were tested at three operating pressures i.e. 2.5, 2.0 and 1.5 kg cm^{-2}.

The wind drift and evaporation losses were computed using catch can method. The catch cans of cylindrical metal, 100 mm diameter and 115 mm height were placed in a square grid network of 2×2 meter within the sprinkler area. The pressure at the sprinkler nozzle was measured with the help of pitot tube and pressure gauge attachment. The test was run for 1 hour and at the termination of duration; the amount of water collected in catch can was measured in terms of depth with the help of a measuring cylinder.

Wind drift and evaporation losses represent the percentage of the water emitted by the sprinklers which never reached the soil surface and therefore was either drifted to other locations or evaporated. In each experiment, the wind drift and evaporation losses was determined using following relationship:

$$WDEL\,(\%) = \frac{V_d - V_c}{V_d} \times 100$$

where,

WDEL = wind drift and evaporation losses, per cent

V_d = discharged volume, m^3

V_c = catch can volume, m^3

RESULTS AND DISCUSSION

The wind drift and evaporation losses were estimated using amount of water caught in catch cans and discharge obtained from nozzles under different operating conditions. The values of wind drift and evaporation losses (WDEL) for each experiment are shown in Table 1 and Fig. 1, 2 and 3. During the experiment, wind speed ranged from 1.9 to 6.6 km/hr and wind drift and evaporation losses ranged from 1.04 to 2.48 per cent. Wind speed during the experiment with 5.6 mm nozzle size ranged from 2.3 to 6.6 km/hr and the wind drift and evaporation losses ranged from 1.04 to 2.48 per cent (Table 1). For 4.7 mm nozzle size (wind speed 1.9 to 3.6 km hr^{-}1.) and for 3.1 mm nozzle size (wind speed 2.1 to 4.1 km hr^{-}1) wind drift and evaporation losses ranged from 0.96 to 1.72 per cent and 1.47 to 2.46 per cent respectively.

Table 1 indicates that WDEL decreased from 2.24 to 2.41 per cent when nozzle diameter reduced from 5.6 m to 3.1 mm at 1.5 kg cm^{-2} operating pressure and 75 cm nozzle elevation. Same trend also observed for another operating pressure and nozzle elevation. Hence, it is concluded that WDEL increased with decrease in nozzle size (Fig.1) However, this trend was not observed for 4.7 mm nozzle size. This may be due to the low wind velocity. From these results we can conclude that wind drift and evaporation losses decreased with in an increase in nozzle size corresponding to wind speed at specific operating pressure and nozzle elevation. These outcomes may be due to the fact that, greater diameter of nozzle produces larger diameter of water drops and that can resist the effect of wind strongly. Larger size drops remain in air for shorter duration resulting in low wind drift and evaporation losses. It was also observed that wind drift and evaporation losses increased with decrease in nozzle size. This may

Table 1. Wind drift and evaporation losses (WEDL) from different nozzle sizes at different operating pressures and nozzle elevations

Nozzle size, (mm)	Pressure, (kg cm^{-2})	Nozzle elevation, (cm)	Wind velocity, (km hr^{-1})	Temp. (°C)	Humidity (%)	Discharged volume, (lph)	Catch cans volume, (lph)	WDEL (%)
5.6	1.5	75	5.2	29.4	58.0	1787.69	1747.65	2.24
		110	6.6	26.8	64.5	1766.90	1723.09	2.48
		150	5.0	27.2	44.0	1745.55	1705.76	2.28
5.6	2.0	75	2.3	26.9	43.5	2045.59	2021.95	1.16
		110	2.5	30.2	43.5	2025.41	2002.73	1.12
		150	1.9	21.1	59.5	2006.55	1985.69	1.04
5.6	2.5	75	3.5	34.2	45.5	2283.15	2248.45	1.52
		110	4.5	31.6	54.5	2269.23	2225.12	1.94
		150	5.4	29.9	52.	2248.65	2195.77	2.35
4.7	1.5	75	3.5	29.8	42.5	994.96	978.49	1.65
		110	3.6	21.0	50.5	983.62	966.49	1.72
		150	3.2	31.6	49.0	970.83	954.84	1.64
4.7	2.0	75	1.9	12.3	43.7	1140.93	1129.49	0.96
		110	2.0	13.8	36.0	1129.68	1118.28	1.01
		150	2.6	14.0	37.0	1116.17	1103.67	1.12
3.1	2.5	75	2.0	15.0	43.0	1291.19	1278.08	1.16
		110	2.4	16.8	46.0	1277.43	1263.38	1.10
		150	3.6	16.0	42.0	1262.24	1240.03	1.76
3.1	1.5	75	4.0	21.4	31.0	591.14	577.16	2.41
		110	4.1	19.0	27.5	582.29	567.16	2.46
		150	3.0	20.1	34.0	575.10	563.95	1.94
3.1	2.0	75	2.4	18.2	41.0	673.39	662.39	1.58
		110	2.1	19.8	43.5	664.50	654.72	1.472
		150	2.8	29.0	26.5	652.80	640.38	1.90
3.1	2.5	75	3.4	29.4	38.0	746.50	729.07	2.33
		110	3.4	26.8	40.5	737.50	720.07	2.36
		150	3.5	27.2	33.0	725.57	707.99	2.42

be due to the fact that small nozzle size produced lesser water drop diameter which can sustain in air for longer duration and provide more chance and time to affect the drops for wind to drift and for evaporation losses also. Same results of wind drift and evaporation losses for different nozzle sizes were observed by Playan *et al.* (2006) from rotating spray plate sprinkler.

Further, it is observed from Table 1 and Fig. 2 that wind drift and evaporation losses increased with an increase in operating pressure. This may be due to the fact that with higher pressures, the water from the nozzle breaks into very fine drops and fell very near to sprinkler. These fine drops remain air borne for more time that provides more chance to be affected by wind and also provide more time for evaporation of water drops resulting in more wind drift and evaporation losses. However, this trend was not observed for 1.5 kg cm^{-2} operating pressure and 2.0 kg cm^{-2} operating

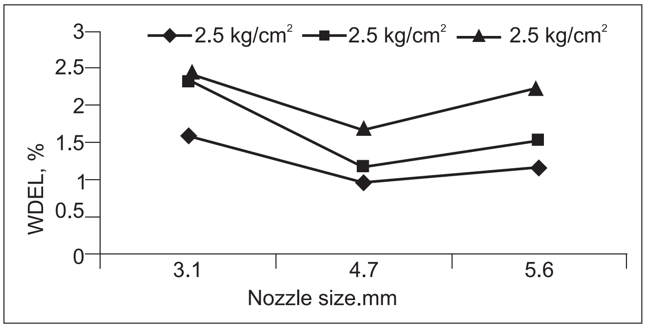

Fig. 1. Effect of nozzle size on wind drift and evaporation losses with 75 cm elevation at different pressures

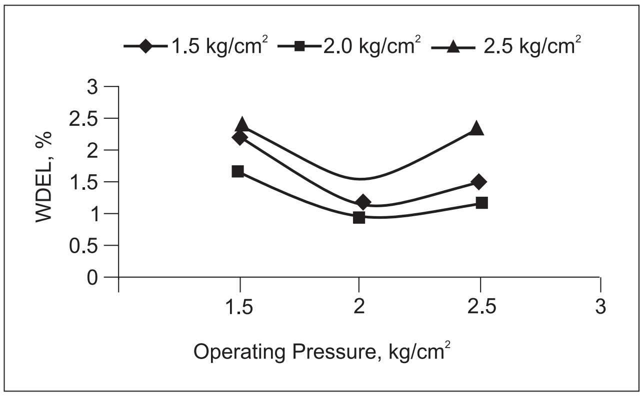

Fig.2. Effect of operating pressure on wind drift and evaporation losses with 75 cm nozzle elevation at different pressures

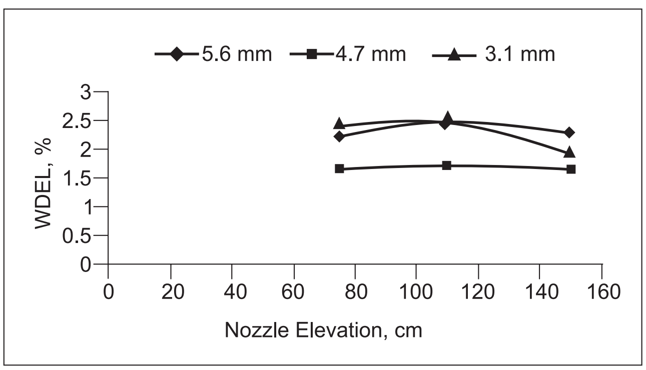

Fig. 3. Effect of nozzle elevation on wind drift and evaporation losses with 75 cm nozzle elevation for different nozzle sizes

pressure which attained minimum WDEL that may be due to climatology data variation. Here it can not be said that how much percentage of wind drift and evaporation losses increased or decreased because different operating pressures attained different wind speeds which produce variation in wind drift and evaporation losses shown in Fig. 2. This may be due to the fact that as we increased the operating pressure the breakup of water stream increases and also broke the water into fine drops and these fine drops are more sensitive to be affected by wind resulting in high wind drift and evaporation losses.

Also, Table 1 and Fig. 3 showed the effect of nozzle elevation on wind drift and evaporation losses from which it is observed that wind drift and evaporation losses increased with an increase in nozzle elevation and vice versa. This is because as the nozzle elevation increases, the water stream breaks in fine drops that easily get affected by wind which may drift significantly. Besides, time of sustaining of drops in air or flying of drop in air gets increased which provides time and chances for effect of wind on water drops and also provides more time for evaporation of water drops. Here it cannot give the percent of decreased or increase in wind drift and evaporation losses by virtue of nozzle elevation because different nozzle elevations attain the different velocity which significantly increase or decrease the wind drift and evaporation losses of respective nozzle elevation. It can be concluded that wind drift and evaporation losses will be increased with an increase nozzle elevation, if the wind velocity keeps constant. Same was also observed by Salvador *et al*. (2005), when he studied the characteristics of WDEL for solid set type sprinkler in the semi – arid metrological condition of Zaragoza (Spain).

Hence, with all these observations it can be concluded that the wind drift and evaporation losses increased with decrease in nozzle diameter, lower nozzle elevation and increased pressure with the respective wind speeds during data collection if wind speed remained constant. Besides, wind speed is a factor which significantly affects the wind drift and evaporation losses as compare to nozzle diameter, operating pressure and nozzle elevation. The rate of wind drift and evaporation losses was less at greater nozzle size and lower nozzle elevation than smaller nozzle size and higher nozzle elevation. The rate of increase of wind drift and evaporation loss was more at operating pressure of 1.5 kg cm^{-2} (lower pressure). The rate of increase of wind drift and evaporation losses was less at 2.0 to 2.5 kg cm^{-2} (higher pressure). This may be due to the fact that drops produced at high pressure can resist and reduce the effect of wind velocity resulting into low wind drift and evaporation losses. Here we can not say how much percentage of WDEL increased or decreased, because we did not obtain a fix trend of WDEL due to climatological data variation

CONCLUSION

Wind drift and evaporation losses increase with an increase in pressure & nozzle elevation but decrease with an increase in nozzle size, if wind blows uniformly during the operating time of sprinkler.

The rate of increase of wind drift and evaporation losses are more at lower operating pressure (1.5 kg cm^{-2}) while the rate of increase of wind drift and evaporation losses was less at higher operating pressure (2.5 kg cm^{-2}). However, no fixed trend was observed due to climatological data variation. WDEL are dependent upon climatic parameters, operating conditions and sprinkler configuration.

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Innovative design and layout of Staggered Contour Trenches (SCTs) leads to higher survival of plantation and reclamation of wastelands

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ABSTRACT

Considering the soil depth, soil type, slope of land, maximum possible 6-hr rainfall and consequent runoff (for 5 year return period), Staggered Contour Trenches (SCTs) were identified as suitable treatment for reclamation of highly degraded upper reaches across different watersheds under Indo-German Watershed Development Programme- Andhra Pradesh (IGWDP-AP). The design of SCTs involved in fixing the horizontal interval and vertical interval between the successive contour lines and spacing between the successive trenches in a row, after selecting the suitable length, width and depth as per site conditions. Contour lines were marked using A-frame. In the new design of SCT, the trench length was either set equal to base width of A-frame or fixed two times of base width of frame. The dug out soil from the trenches is placed in the half moon fashion around the trench. Usually berm of 0.3-0.5 m is maintained between the trench and half moon embankment in the conventional design and layout. However, with a view to improve survival of plants, planting on the berm of excavated trench and bund placed in the half moon fashion around the trench has been incorporated in the layout. Accordingly, berm of 1.5 m was followed between the trench and half moon shaped bund. This innovative SCT design and layout was successfully field tested across 15 watersheds under IGWDP-AP. The length of SCTs varied from 2-4 m. The width of trenches was 0.5- 0.6 m and the depth varied from 0.3-0.6 m. Custard apple, Pongamia, Glyrecidia, Amla, Cashew, etc. were planted on the berm. In case of trenches with 2 m length, single plant on the berm and those with 4 m length 2 plants on the berm were planted. It was observed that simple modification (of restricting the length of SCT to either base width of A-frame or two times of it, increasing the berm space to 1.5 m, placing the dugout soil around the trench in half moon fashion and planting on the berm of excavated trench) in the design and layout of SCTs improved the survival of plants. The data collected from 15 different watersheds revealed that the average survival percentage of plantation was more than 90 per cent. Thus, the modified and innovative design and layout of SCTs helped in situ rain water harvesting and availability of soil moisture for longer period leading to better survival of plantation and reclamation of wastelands.

Key words: Staggered Contour Trench (SCT), rain water, plantation, wasteland and survival of plantation

INTRODUCTION

As per the latest estimates of National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), India, about 45 per cent of total geographical area i.e. 146 m. ha in India is affected by various degradation processes with water erosion being the chief contributor. Large-scale land degradation has long-term environmental and socio-economic implications. The negative environmental implications include loss of biodiversity and ecological stability, frequent occurrence of floods and droughts, silting up of reservoirs and changes in

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hydrological regimes. Sustainable agricultural production can be achieved by preventing land degradation, reclaiming the already affected areas, maintaining soil's productive potential and reducing environmental pollution, while emphasizing reduction in chemical and energy – intensive inputs (Sharda, 2007). In this context, participatory integrated watershed development is now widely recognized as a potential approach for vitalizing rural economy by regenerating the degraded ecosystems. Watershed development aims to bring about the best possible balance in the environment between natural resources on one side and man and grazing animals on the other.

The Indo-German Watershed Development Programme (IGWDP), a bilateral programme of Government of Germany and Government of India is a novel initiative for regeneration of natural resources through participatory approaches that emphasizes on self help, environmental protection and poverty alleviation. The programme is implemented by Village Watershed Development Committee (VWDC- a body nominated by villagers) in association with local Non-Governmental Organization (NGO), known as Project Facilitating Agency (PFA) in each watershed. The Indo German Watershed Development Programme- Andhra Pradesh (IGWDP-AP) was initiated to address the issues concerning the rehabilitation of degraded watersheds in the districts of Karimnagar, Medak, Warangal and Adilabad in Telangana region of Andhra Pradesh. KfW, a German Development Bank is the funding agency on behalf of Government of Germany and NABARD is the legal holder of the projects in India.

The upper reaches of watersheds usually have an undulating topography and are foci for soil erosion. The uncontrolled runoff from these areas causes extensive damage to the adjoining agricultural land. Contour trenching is useful for soil and moisture conservation and afforestation purposes both on hill slopes as well as degraded and bare wastelands (Murty, 1998; Ravi Babu and Mishra, 2005 and Mishra *et al.*, 2006). Contour trenching helps in *insitu* conservation of soil moisture and thus facilitates quick establishment of vegetation and rehabilitation of sloping wastelands. However, the field supervisors/engineers in India often adopt thumb rules in layout and design of contour trenches, which leads to either under or over design resulting in their failure or excessive cost (Mishra and Ravi Babu, 2010).

Contour trenching is of two types (1) Continuous Contour Trenching (CCT) and (2) Staggered Contour Trenching (SCT). Considering the field level problems associated with layout and alignment of contours for longer lengths, SCTs are preferred to CCTs. The design of SCT involves fixing the Horizontal Interval (HI) and Vertical Interval (VI) between the successive contour lines and inters spacing between the successive trenches in a row, after selecting the suitable length, width and depth as per site conditions (Ravi Babu, 2009). The step by step procedure described by Ravi Babu, (2009) was used in design of SCTs with the modification that the trench length was either set equal to or fixed two times that of base width of A-frame. Furher, with a view to improve survival of plants, planting on the berm of excavated trench and bund placed in the half moon fashion around the trench has been thought of. Accordingly, berm of 1.5 m was considered between the trench and half moon shaped bund.

This modified SCT design and layout was successfully field tested across 15 watersheds (Shivarvenkatpur, Kasireddipalli, Tigulnarsapur and Mylaram in Medak district; Ayyagaripalli and Chintapalli in Warangal district; Battulapalli in Karimagar district and Settihadapnoor, Sakeda, Kohinoor B, Dhurvaguda, Dharmasagar, Rampur, Yammaikunta and Indervelli in Adilabad district) under IGWDP-AP. The modifications in the design and layout of SCTs and its impact on survival of plantation is presented and discussed in this paper.

MATERIALS AND METHODS

Considering the soil depth, soil type, slope of land, maximum possible 6-hr rainfall and consequent runoff (for 5 year return period), Staggered Contour Trenches (SCTs) were designed for reclamation of highly degraded upper reaches across different watersheds under IGWDP-AP.

The design of SCT involved in fixing the HI and VI between the successive contour lines and spacing between the successive trenches in a row, after selecting the suitable length, width and depth as per site conditions. First, the design depth of rainfall for 5-year return period and for 6-hrs. duration of storm was found. The runoff coefficient duly considering the land use, soil texture and land slope was estimated. Subsequently, the expected runoff depth was calculated using runoff coefficient ad design depth of rainfall. The step by step procedure described by Ravi Babu, (2009) as below was used in the design of SCTs.

Assuming rectangular cross-section, the following relationship is used in case of SCTs:

W x D = (Q x HI) (1+ X / L) …(1)

Where, Q= Runoff depth, m

HI = Horizontal Interval, m

W = Width of trench, m

D = Depth of trench, m

X = Inter space between trenches, m

L = Length of trench, m

In the improved design of SCT, the length of trench was set equal to base width of A-frame. In case, the base width of A-frame is less than 2 m, the length of trench was set equal to two times that of base width of trench. The spacing between successive trenches (X) in each row is set equal to length of trench (L) for simplicity of calculations. Therefore, the above relationship becomes the following:

W x D = (Q x HI)x (2) …(2)

Depending on the site conditions and available soil depth, the depth of trench was fixed. As rectangular cross-section was assumed, the width of the trench was set as 1.5 – 2 times that of depth of trench. Then, HI was worked out as

HI = (W x D) / (2 x Q) …(3)

Total length of trenches per ha =(1 / 2) x [10000 / ((HI)] …(4)

(Since Length of each trench = inter space between successive trenches)

Number of trenches per ha = Total length / length of each SCT …(5)

Volume of earth work per trench = length x cross-section …(6)

Total volume of earth work per ha = No. of trenches per ha x volume of earth work per trench …(7)

Contour lines were marked using A-frame. In the modified design of SCT, the trench length was either set equal to base width of A-frame or fixed two times of base width of frame. The dug out soil from the trenches is placed in the half moon fashion around the trench. Usually berm of 0.3-0.5 m is maintained between the trench and embankment in the conventional design and layout. However, with a view to improve survival of plants, planting on the berm of excavated trench and soil / bund placed in the half moon fashion around the trench. Accordingly, berm of 1.5 m was followed between the trench and half moon shaped bund has been attempted. The point wise comparison of modified design and layout of SCTs with conventional SCTs has been given in Table 1.

Table 1. Modified vs. conventional design and layout of SCTs

S.No.	Parameter / Activity	Modified design and layout	Conventional design and layout
1.	Design procedure followed	(a) Considering the soil depth, soil texture, slope of land, maximum possible 6-hr rainfall and consequent runoff (for 5 year return period), SCTs are designed. (b) The design of SCT involved in fixing the horizontal interval / vertical interval between the successive contour lines and spacing between the successive trenches in a row, after selecting the suitable length, width and depth as per site	(a)Thumb rules are generally followed. (b) The length, width and depth of trench and horizontal / vertical interval are fixed without considering land use, soil slope, soil conditions. texture and expected runoff, etc.
2.	Cross-section (width x depth) of trench	Depending on the site conditions and available soil depth, the depth of trench is fixed. As rectangular cross-section was assumed, the width of the trench was set as 1.5 – 2 times that of depth of trench.	The usual cross section of SCT (in terms of width x depth) is 0.6 m x 0.3 m or 0.5 x 0.5 m
3.	Length of trench	(a) In the improved design of SCT, the length of trench was set equal to base width of A-frame. In case, the based width of A-frame is less than 2 m, the length of trench is set equal to two times that of base width of trench. (b) The length of trench varied between 2-4 m depending on the base width of A-frame.	(a) Staggered trenches are constructed across the slope with lengths varying from 5 to 15 m (Katyal *et al.*, 1995). (b) Under MGNREGA in AP, SCTs of length varying between 7-15 m are found to be made.

S.No.	Parameter / Activity	Modified design and layout	Conventional design and layout
4.	Inter spacing between the trenches in a given row	The spacing between successive trenches in each row is set equal to length of trench facilitating easy layout by even unskilled labour.	As longer trench length is adopted the spacing between trenches in each row is also found to be relatively high.
5.	Horizontal Interval between successive trench lines	Proper Horizontal Interval of 2-10 m is maintained between successive SCTs depending on the soil texture, slope, location, selected cross-section of the trench and design depth of runoff, etc.	Thumb rules are generally followed.
6.	Marking of contour lines and layout of trenches	(a) Contour lines are marked using A-frame / hydromarker (b) Layout of SCTs is very easy as the length of SCTs is limited to base width of A-frame (c) As the length of SCT is linked to base width of A-frame, the errors in layout of contours and SCTs is avoided and trenches are laid exactly on the contours thus facilitating better harvesting of rainwater.	(a) Marking of SCTs is done across the slope (b) As the length of SCT has no relation to base width of A-frame, the layout of contours and SCTs is always prone to errors. (c) Poor alignment of contours s over long length would result in breaches due to concentration of runoff. A breach in one SCT would lead to chain reaction and formation of gullies.
7.	Berm	Minimum berm of 1.5 m was followed between the trench and half moon shaped bund.	Usually berm of 0.3-0.5 m is maintained between the trench and embankment
8.	Placement of soil	The soil excavated (i.e. spoil) is placed in half moon shape at the downstream side of the trench. Thus the trench and half moon shaped bund act as catch pit for the plant.	Excavated soil is placed at the downstream side of the trench.
9.	Bund sectioning	Clod breaking and proper sectioning (as per the design specification) of the soil is carried out.	Required attention is not paid towards clod breaking and proper sectioning of the bund.
10.	Revetment	In highly sloping land, the bund on the downstream side is supported with local stone revetment	This is not attended to in the conventional method
11.	Plantation	(a) Planting is done on the berm of excavated trench and bund placed in the half moon fashion around the trench. (b) It is easy for the plant roots to extract soil moisture from the trenches as it is available within 0.3- 0.5 m radius. Planting on the berm enables shallow root system of plants to absorb trapped rain water, which seeps through the soil from the trenches.	(a) Trench layout is not taken into account while taking up plantation. The plantation is carried out as per the spacing norms. (b) It is difficult for the plants to extract soil moisture (seepage) from the trenches because of shallow root system of plants (in the establishment stage) and relatively possible higher distance of trench and plant.
12.	Availability of catch pit	Separate catch pit for each plant is available facilitating better establishment and survival of plantation and reclamation of wastelands.	Separate catchment pit (trench) may not be available for each plant.

The modified SCT design and layout was successfully field tested across 15 watersheds (Shivarvenkatpur, Kasireddipalli, Tigulnarsapur and Mylaram in Medak district; Ayyagaripalli and Chintapalli in Warangal district; Battulapalli in Karimagar district and Settihadapnoor, Sakeda, Kohinoor B, Dhurvaguda, Dharmasagar, Rampur, Yammaikunta and Indervelli in Adilabad district).

Planting was carried out in the year 2010 on the berm of trench and half moon shaped bund across 15 watersheds. The data related to watershed wise number plants planted and the number of surviving plants as on 30 May 2012 in the SCT treated area was collected and the survival percentage was worked out. Thus the impact of innovative design and layout of SCTs on survival percentage of plantation was assessed and interpretations were drawn.

RESULTS AND DISCUSSION

This innovative SCT design and layout was successfully field tested across 15 watersheds under IGWDP-AP. The design details of SCTs for two selected watersheds (one for red sandy loam soils and the other with black cotton soils) are furnished as sample in Table 2. Based on the width of fabricated A-frame at the base, the length of SCT is fixed s 2 m in Ayyagaripalli watershed and the same in the case of Kohinoor B watershed is 3 m. The spacing of trenches in a line was set equal to length of SCT and the HI between the consecutive lines was 7 and 4 m in Ayyagaripalli and Kohinoor B watersheds, respectively (Table 2).

Table 2. Design details of SCTs for two selected watersheds (Ayyagaripalli, Warangal and Kohinoor B, Adilanad)

S. No.	Item	Ayyagaripalli, Warangal	Kohinoor, Adilabad
1.	Area in ha	2.5	4
2.	Slope of land in %	12	16
3.	Type of soil	Sandy loam	Heavy clay
4.	Estimated depth of runoff (mm)	20	42.6
5.	Cross-section of trench (sq.m)	0.27	0.3
6.	Length of trench in m	2	3
7.	Spacing of trenches in a line in m	2	3
8.	Horizontal Interval in m	7	4
9.	Vertical Interval in m	0.8	0.6

Across 15 watersheds in which SCTs were executed, the length of SCTs varied from 2 - 4 m. The width of trenches was 0.5- 0.6 m and the depth varied from 0.3-0.4 m. The excavated soil is placed around the trench in half moon fashion leaving berm of 1.5 m. Custard apple, Pongamia, Glyrecidia, Casia siamia, Teak, Bamboo, Amla, Cashew, etc. were planted on the berm. In case of trenches with 2 m length, single plant on the berm and those with 4 m length 2 plants on the berm were planted. The data collected from different watersheds is presented in Table 3. It can be observed from Table 3 that the survival percentage of plantation varied from 61 to 97 % across 15 watersheds in which this activity was taken up. The average percentage of survival of plantation was found to be 91 per cent (Table 3). The views of (treated) area and plantation during pre and post development were depicted in plates 1 to 6. The excavated trench, plantation on the berm and half moon shaped bund around the trench can be seen from the plates. The impact of the SCTs in trapping rainwater, improvement of soil moisture and consequent facilitation of establishment of green grass and plantation in wastelands could be visualized from the plates.

For most of the plants, concentration of moisture absorbing roots is greatest in upper part of the root zone and near the base of plants. Extraction of soil moisture is very rapid in the zone of greatest root concentration and under favorable environmental conditions. Further, the shorter length of SCTs has very less chance of deviating from contours and they are found to be very effective in trapping runoff and as a result increased the soil moisture availability. Thus, better moisture conservation in the soil profile has been observed in the case of modified SCTs. As the planting is done on the berm of excavated trench and bund placed in the half moon fashion around the trench, it is easy for the plant roots to extract soil moisture from the trenches as it is available within 0.3- 0.5 m radius. Planting on the berm thus enabled shallow root system of plants to absorb trapped rain water, which seeps through the soil from the trenches and resulted in facilitating plants to establish and survive in the severely degraded uplands in watersheds.

Table 3. Watershed wise survival percentage of plantation

S. No. (1)	Name of the watershed (2)	Name of the farmer / owner (3)	Area treated with SCTs (ha) (4)	Average slope(%) (5)	Total No. of plants planted (6)	Species of plants (7)	Total no. of surviving plants as on 30.05.2012 (8)	Percentage of survival (9)
1.	Mylaram	Chakali Mallaiah	0.5	8	256	Custard apple, Pongamia	234	91
2.	Mylaram	Chutta Kanakaiah	2	8	321	Custard apple, Pongamia	287	89
3.	Settihad-punoor	Kanaka Jugadhirao	2.83	14	1833	Fruit plants	1685	92
4.	Settihad-punoor	Pendhur Thulasi Ram	1	12	180	Fruit plants	171	95
5.	Kohinoor-B	Common land	4.04	16	758	Pongamia, Glyrecidia, Custard apple, Bamboo, etc.	714	94
6.	Sakeda	Marapa Jyothibai	1	8	220	Fruit plants	188	85
7.	Sakeda	Kotrenga nagu	1	8	385	Fruit plants	369	96
8.	Dhurvaguda	Common land	20	15	7500	Pongamia, Custard apple, Teak, Amla	7125	95
9.	Dharmasagar	A.Bheemrao and others	12	6	5100	Pongamia, 4590 Custard apple, Teak	90	
10.	Rampur	Common land, K.Dharmu and others	6	4	4500	Pongamia, Custard apple, Teak	4050	90
11.	Shivarven-katapur	Gout Land	34	8	12500	Custard apple	11890	95
12.	Kasireddypally	Gout Land	8	5	6000	Custard apple	5824	97
13.	Thigulnarsapur	Gout Land	12	6	6000	Custard apple	4842	81
14.	Ayyagaripally	Govt Land	2.5	12	2040	Custard apple, Pongamia and Casia siamia	1800	88
15.	Chintapally	Govt Land	3	12	1547	Pongamia and Casia siamia	950	61
	Total				49140		44719	91


Fig. 1& 2: Close view of Cashew and Custard apple plants surviving only on account of SCTs in Settihadapnoor (Adilabad) and Shivarvenkatpur (Medak) watersheds


Fig. 3 &4: Pre-development (Dhurvaguda, Adilabad) Post-development (Dhurvaguda, Adilabad)


Fig. 4 & 5: Pre-development (Yammaikunta, Adilabad) Post-development (Yammaikunta, Adilabad)

It was observed that simple modification (of restricting the length of SCT to either base width of A- frame or two times of it, increasing the berm space to 1.5 m, placing the dugout soil around the trench in half moon fashion and planting on the berm of excavated trench) in the design and layout of SCTs improved the survival of plants.

CONCLUSION

The modified and innovative design and layout of SCTs helped *insitu* rain water harvesting and availability of soil moisture for longer period leading to better survival of plantation and reclamation of wastelands. This design and layout may be adopted in other degraded upper reaches of watersheds for better establishment and survival of plantation and reclamation of wastelands.

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Study of the shifting cultivation scenario in Aizwal district, Mizoram using remote sensing techniques

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ABSTRACT

Shifting cultivation is an age old practice in north eastern states. Mizoram is one of the seven states of the region where 70% of the total population is engaged in agriculture. Aizwal, the capital of Mizoram also thrives on the primitive practice of shifting cultivation *(jhuming)* as a source of livelihood. The introduction of watershed approach in the shifting cultivation area during 1994-95 was an innovation from Government of India for central assistance to the region for eco-development through conserving soil and water. The impact of central effort has been studied with the aid of digital IRS remote sensing data at a periodicity of 5 years. Supervised classification of land use/ land cover of digital remote sensing data for 2000, 2005 and 2010 have been employed to abstract the extent of current *jhum* land and abandoned *jhum* land of Aizwal district. Over-all biomass changes during the period have also been derived using Normalized Difference Vegetation Index (NDVI) analysis. Increasing trend of both current *jhuming* (1.45 to 4.18%) and abandoned *jhum* (27.82 to 50.01%) land have been observed during the span of 10 years (2000- 2010). The forest area of Aizwal district has been reduced from 69% to 44% during the period. The over-all biomass has also been reduced from 91% to 64% from 2000 to 2010. All these points indicate negative impact of the central assistance programme to contain shifting cultivation. However, introduction of new land use policy by the Mizoram government is a positive step to discourage shifting cultivation practice in the state.

Key words: Shifting cultivation, current *jhum* land, abandoned *jhum* land, land use/ land cover changes, NDVI

INTRODUCTION

Shifting cultivation is a form of agriculture in which the cultivated or cropped area is shifted regularly to allow soil fertility to recover under conditions of natural regetation re-growth. The economic survey indicated that 32 per cent of the cultivated area was under *jhum* and only 20 per cent of the demand for rice could be met from within the state. More than 70% of the total population of Mizoram is engaged in some form of agriculture (Anon 2012).

In India shifting cultivation is very common in north eastern states of which it is very extensive in Nagaland. In Mizoram, Aizwal is one of the progressive districts practicing shifting or jhum cultivation over decades. The usual practice is cleaning forest area by slashing and burning followed by agriculture and horticulture cropping. Such kind of age old agriculture practice is now being discouraged by the Government of Mizoram in the new land use policy adopted in 2009 (Anonymous 2012).

Land use/ land cover changes play an important role in the environmental processes, and also act as a sensitive indicator for environmental and global changes (Van Wijngaarden, 1991). The monitoring of vegetation cover can provide useful clues concerning our changing environment and help natural resource management. Traditional method to monitor the vegetation is by field investigation. It is less efficient and high labor demanding, especially for large areas, and impossible to conduct continuous investigations and that too for inaccessible areas (Li *et al.* 2010).

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The Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India also made an initiative to conserve the natural resources through Watershed Development Programme in the Shifting Cultivation Area (WDPSCA) as per the directives of National Development Council during 1994-95 (Anonymous 2012).

Satellite remote sensing by virtue of tremendous capability in terms of synoptic view, multi-spectral sensing, multi-temporal data acquisition, real time data acquisition and computer compatibility serve as a potent tool to study the land resources of inaccessible terrain, mountains, hills and remote villages in the country from laboratory using image analysis system. Remote Sensing (RS) is nowadays, an advanced powerful monitoring tool for its convenience and high efficiency. Thereby, it has been widely employed to monitor the vegetation changes (Sabins and Floyd 1977; Justice and Hiernaux 1986; Townshend and Justice 1986; Al-Bakri and Taylor 2003). The impact assessment of this scheme on the land use / land cover pattern has been studied using remote sensing and geographic information system.

The paper deals with the study of dynamics of shifting cultivation using digital image analysis of IRS LISS III and IRS P6 data of five years periodicity since 2000 to 2010 of Aizwal district, Mizoram.

Methodology

The study has been carried out using ERDAS Imagine software with following steps:

- Scanning of SOI toposheets on 1:50000 scale to .tiff format
- Geometric correction of each Survey of India toposheet using 16 GCPs and GCS- Everest 1956, India (India,Nepal)
- Image to image rectification of un-projected 2000 digital IRS 1C data using rectified SOI toposheet as reference image
- Image to image rectification of re-projected 2005 and 2010 digital IRS 1D and IRS P6 data using rectified Survey of India toposheet as reference base
- Mosaic of geo-rectified image of adjacent path and row
- Preparation of district shape file polygon vector layer of appropriate projection system
- Creation of image file for Aizwal district
- Generation of Un-supervised classified images from district subset images for necessary ground truth collection

Supervised classification of image for land use/ land cover changes and over-all biomass analysis have been carried out by adopting following approach:

- Ground truth collection
- Supervised classification of summer images based on ground information
- Extraction of aerial extent of shifting cultivation area
- Generation of statistics on different land use / land cover classes
- Generation of NDVI for evaluation of biomass content
- Change detection analysis (2000 & 2010) using NDVI to evaluate the overall impact of shifting cultivation over a time span of 10 years

RESULTS AND DISCUSSION

It is observed out of supervised classification of land use/ land cover analysis that spatial extent of shifting cultivation area (Fig.1 and Table 1) in Aizwal district, Mizoram is increasing over the time. The area under abandoned jhum land increased from 27.82 to 50.01% during 2000 to 2010. The extent of current jhum land is also increased to 4.18% in 2010 from 1.45% in 2000 and 1.72% in 2005 respectively. However, it reflects the influence of Local Village Council in controlling the jhum cultivation in the district. The new land use policy of Mizoram Government is aimed to discourage the shifting cultivation through shifting to stable farming with a provision of financial support to 120000 shifting cultivators within five years.

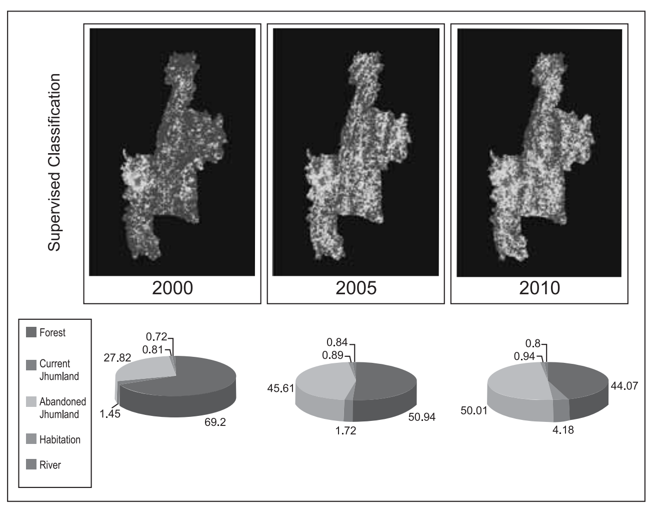

Fig 1. Land Use/ Land Cover changes in Aizwal district during 2000 - 2010

Table 1. Statistics on land use / land cover changes in Aizwal during 2000-2010

Land use	2000		2005		2010	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest	218255	69.20	160647	50.94	138998	44.07
Current jhum land	4585	1.45	5428	1.72	13185	4.18
Abandoned jhum land	87754	27.82	143860	45.61	157728	50.01
Habitation	2539	0.81	2799	0.89	2954	0.94
River	2266	0.72	2664	0.84	2533	0.80
Total	315398	100	315398	100	315398	100

It is also observed that an inverse relationship exists between forest vegetation and shifting cultivation area (i.e., current and abandoned jhum land) in the district (Fig.2).

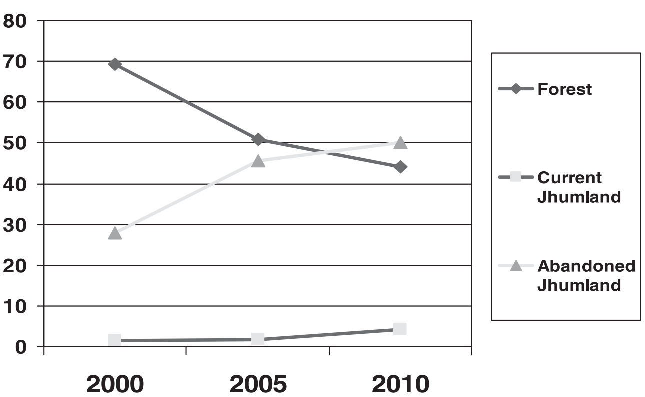

Fig. 2. Scenario of Shifting Cultivation in Aizwal District during 2000 - 2010

The impact of watershed development is reflected in terms of overall change in biomass from Normalized Differential Vegetative Index (NDVI) (Fig. 3). The higher value of NDVI (-1 to +1) indicates higher biomass content. NDVI values are classified in five different categories which are presented in Table 2. The study reveals that the biomass content has been reduced to 63.69% in 2010 from 91.46 % in 2005 and 91.78% in 2000 which reflects the negative impact of watershed development in containing shifting cultivation in Aizwal district. Higher biomass content in 2000 and 2005 are indicative of lesser area under shifting cultivation (Fig. 4).

It is seen from the study that the shifting cultivation practices was in check till 2005 which has been increased more than two folds in 2010 resulting depletion of forest cover in from 69 to 44% in a span of 10 years. Such depletion of green cover will

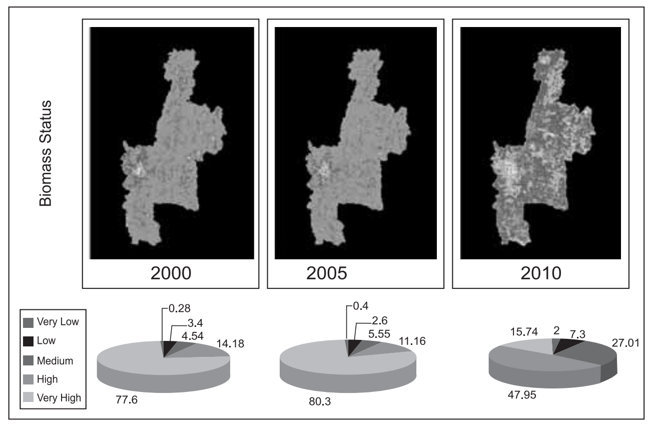

Fig. 3. NDVI analysis for Biomass Change Detection during 2000- 2010

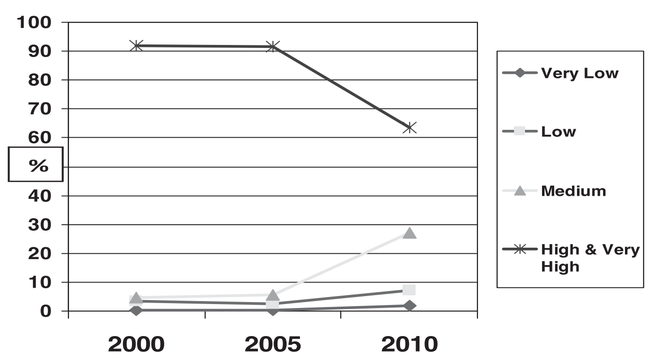

Table 2. Statistics on Overall changes of biomass during 2000 – 2010 in Aizwal

NDVI class	Area (ha)		
	2000	2005	2010
Very Low	873	1259	6294
Low	10718	8185	23031
Medium	14326	17516	85202
High	44723	35185	151228
Very High	244758	253252	49642
Total	315398	315398	315398

impact carbon sequestration and induce ecological imbalance in the district. There is a need to control the shifting cultivation practice as per the new land use policy of Government of Mizoram to stem ecological disaster in the region.

CONCLUSION

It may be inferred from the supervised classification of land use/ land cover that both current and abandoned jhum area have increased from 2000 to 2010 that point towards insignificant impact of watershed development to arrest shifting cultivation practice in Aizwal district, Mizoram. Similar observation has also been made from NDVI analysis. It is hoped that the new land use policy would be effective in controlling the shifting cultivation of Aizwal and the Mizoram state as well.

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Challenges in managing agricultural knowledge

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ABSTRACT

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

Key words: Portal, documentation, Geographical Information System, agro-climatic, knowledge explosion, Integrated technology

INTRODUCTION

Knowledge management in agriculture is crucial factor concerned with ways of exchanging knowledge among those who can develop it and those who can use it. Knowledge management programmes, based on this approach, attempt to manage the process of information exchange between groups of specialists, companies, and research and development (R&D) organizations.

Information technology (IT) has become the buzzword in India these days. It is making tremendous impact on the rural economy due to its wide application and reach. The National agricultural research and extension systems of India have developed content in English, Hindi and regional languages in support of extension and education over the time. Presently, the availability of information in the digital format or media is scarcely available. Thus, the need for content digitization and creation of new content in the digital mode has become indispensable. The vast

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quantum of knowledge is being shared in interactions among experts and with farmers. However, this rich information is most of the time not capitalized for synthesis, analysis and codification for re-use. The agricultural extension system requires timely, adequate and quality update and accurate content for providing the effective information delivery to the farmers. The prospective of ICT lies in bringing about an overall qualitative development in life by providing timely and quality information inputs for decision making.

Usefulness of ICT

Planning tools and systems for the agriculture sector are the areas where ICTs can add significant value. The Geographic Information Systems (GIS) offer agriculture and natural resource management planners an increasingly way to plan for land use, track or estimate environmental impacts, visualize important social data, and compare different agricultural development scenarios. Agricultural and land use planners have used maps as a standard tool for years, but the ability of GIS to remake maps rapidly in response to new data or analysis allows planners new degrees of freedom in foreseeing and preventing disaster, or planning development scenarios (Eastman et al., 1996).

Accurate and timely information regarding areas of food surplus and shortages driven by the vagaries of climate can be facilitated through ICT. Such use can contribute to improved food management and food security. Effective and responsible GIS use demands extensive data sets including detailed data gathered from multiple locations, each geo-referenced (i.e. with location information) so that it can be mapped correctly by the GIS.

Large data sets present a human and management challenge, but ICT systems can be deployed to aggregate such data from multiple sources, permitting distributed teams of surveyors to gather data and use the telephone, Internet to record and synchronize survey information to a central database. ICT enables a better understanding of issues such as can be changed and linked to the management and conservation of biodiversity. The power of ICT as an information and networking medium enables citizens to act as environmental enforcement agents, alerting decision makers to compliance infringements while leveraging on their power to reach and influence public opinion. Any programme that provides connectivity has the potential to increase sustainability, given appropriate content and training. Two application areas key to natural resource management are GIS mapping and land registration. ICT can contribute to environmental sustainability by providing public access to information and a means of participation by the public in decision making, information dissemination, public awareness, promotion of best practice techniques and technologies; source of alternative livelihoods; and environmental monitoring, mapping and management (Nnadi, et al, 2010).

Effective environmental databases can be used to track the status of various environmental indicators and impacts for sustainable environmental management and protection.

Impact of ICT on Research and Extension

The impact of ICT in agricultural research is quite significant. This is taking place through three means. The first is the changing nature of agricultural information systems, which is having a profound impact on how research results are communicated and disseminated.

With the development of web-based information systems the possibility of accessing databases and information on-line has increased dramatically, with the incidental problems that is generating from the point of view of the confidentiality of the information and of the economics of information management.

The rapid expansion of web publishing is dramatically changing the way people access information, and is leading to the development of metadatabases. Based on virtual libraries that provide direct access to the publication, wherever it is located, as long as the publication is accessible through the web. Secondly, the significant advances that are being made in software applications related to agricultural research techniques, coupled with advances in other areas of science.

ICT Role in Agricultural Knowledge Management

Knowledge sharing, exchanging and dissemination are elements in a broader theme which is knowledge management. The central purpose of knowledge management is to transform our intellectual assets into enduring value (Metcalfe, 2005). The basic idea is to strengthen, improve and propel the organization by using the wealth of information and knowledge that the organization and its members collectively possess (Milton, 2003). Large part of knowledge is a tacit knowledge not explicit.This is true for knowledge in agriculture where a lot of good practices are transferred without being well documented in books, papers or extension documents. To manage the knowledge properly, ICT is needed. In effect, there are many information technologies that can be used for knowledge management. Content management system in its wider sense including data bases and multimedia, is the core technology of information and knowledge management. This technology can be used in different applications.

- Building a national agriculture research information system needs to include research outcomes, projects, institutions and researchers in every country, and a regional research information system that works as a portal for all the national agriculture research information system for:
- Developing an information system of indigenous agricultural practices can enable researchers to examine this knowledge and decide on its usefulness for sustainable development. Such a system will also keep this knowledge for future generation before it disappear as a result of advanced technologies.
- Developing an information system recording matured technologies that on a trial basis have proven successful and success stories that have achieved economic growth will strengthen the interaction between inventors and innovators. This will lead to an innovation-driven economic growth paradigm
- Storing and retrieving images, videotapes and audiotapes related to different agricultural activities.
- Geographic Information System (GIS) are needed to store databases about natural resources with a graphical user interface that enables users to access these data easily using geographical maps. Decision support system techniques are needed in many applications:
- Simulating and modeling methods can be used to build computer systems that can model and simulate the effect of different agricultural production policies on the economy and the environment to help top management make decisions.

Agricultural Knowledge Generation, Refinement and Dissemination

Technology assessment, refinement and dissemination are important for agricultural transformation. The foremost requirement for developing appropriate technologies for its acceptance by the farmers may be increased involvement of farmers in the process of technology generation, refinement and dissemination. Farmer participatory research (FPR) encourages farmers to engage in experiments in their own fields so that they can learn, adopt new technologies share with other farmers. New information, technologies and concepts get communicated to farmers through the FPR approach.The rise of FPR was a deliberate effort among agricultural professionals to combine farmers' indigenous traditional knowledge (ITK) with the more widely recognized expertise of the agricultural research community. The technology innovation process includes research followed by technology development, testing and adaptation, technology diffusion. The Technology Integration refers to the process or a set of activities that must happen if new information can be put to use in the farm production system.

It is to be reemphasized that technology and research information has been used as synonym without considering their basic structural differences. A more holistic approach through the process of technology integration can provide a base for reconciling the need for higher productivity with productive employment and income generation without displacing labour. While the need for a technological base for extension might seem a truism, it is frequently poorly handled in the design and operation of extension systems.

The current emphasis on transfer of technology is on high potential areas with the main issue on adaptation of available technology. The real challenge is on transfer of technology in the marginal areas to small-scale production systems. In resource-poor areas, it is required to optimize returns from the minimum use of external inputs and to quantify the level of inputs required to ensure that the system is truly sustainable. The strategy followed in designing and implementing transfer of technology projects has been based more on the supply of technological information than on the prior consideration of limitations at the farm level. The usual approach has been that any technology which produces the best results at the experimental level is superior, and that is what should be offered to the farmers.What is needed is a technology generation and transfer mechanism and a methodology that will make it possible to recognize and classify the different types of small farmers. Then and only then, the organizational design can generate and make available to farmers an appropriate technology which they will be able to adapt.

More participatory and demand driven research is the need of the hour. The social scientists have to be involved as member of the Inter-disciplinary team at the time of formulation of projects and its implementation. Research in extension education has to be based on appropriate sampling, quasi experimental designs and statistical tools. The extension research findings have to be utilized for agricultural research and development.

In order to have appropriate convergence and integration of research, education and extension, the ICAR may specifically play more role to Agricultural universities and Deemed universities. There is need to tap the large reservoir of farmers' tacit knowledge to consider their perspective and for blending with the scientific findings to develop applicable knowledge and appropriate technologies.

The impact assessment of the technological interventions need to be researched with appropriate use of new tools focusing on profitability and livelihood security indicators rather than collecting data only on yield. There should be institutional arrangements with adequate funding support for validation and effective application of the innovations developed by farmer-innovators.

It is essential to do process documentation of various multi extension multi extension models prevailing across India so as to encourage greater adoption of technologies to suit regional agro-climate and location specific needs. It is essential to do process documentation of various multi extension multi extension models prevailing across India so as to encourage greater adoption of technologies to suit regional agro-climate and location specific needs.Enabling policies are required for effective application of emerging technologies having good production potential like Bt Brinjal and other technologies developed in India.

Knowledge Generation and Dissemination

Krishi Vigyan Kendras to play the role of knowledge resource centre for effective knowledge management. There is a need to mobilize small and marginal farmers for diversified Agriculture to meet the increasing demand for horticultural products.

Institutionalization of linkage among farmers, researchers, extension workers and other stakeholders need to be made to promote mutual trust. Generation and dissemination of market oriented information is very essential for making agriculture profitable and sustainable.

Institution based training has its own importance. For effective communication and dissemination of technologies, the community based training programmes in villages need to be encouraged. Integrated technology dissemination system combining all the available technologies from research institutes, extension organizations, input dealers, corporate R&D companies and marketing agencies need to be promoted for effective adoption of agriculture technologies and development of agri- business models.

There are large number of indigenous technologies innovated by the farmers most appropriate to their agro- climatic situation. Such technologies should be meticulously identified, validated on scientific principlesand shared among farmers. It is essential to do process documentation of various multi extension multi extension models prevailing across India so as to encourage greater adoption of technologies to suit regional agro-climate and location specific needs. Frontline demonstrations conducted by KVKs in India have been found to be proven and effective mechanism to demonstrate the production potential of technologies to farmers and extension personnel.

Use of ICT for Agricultural Knowledge Management

Knowledge and information have become the major drivers of social and economic transformation in the world. They are of even higher significance in agriculture, which sustains the food and livelihood security as well as economic growth. Presently, the agriculture across the globe is facing challenges in the wake of increasing climatic variability, biotic stresses, and competitive global market; declining base of production resources; growing essentiality of application of hi-tech and precision farming for adaptation and increasing need for matching the pace of technological advancements and knowledge explosion. Therefore, access to real time information and validated as well as processed technological knowledge have to be ensured to the farming community and other related stakeholders for informed, quality and prompt decisions. The concern is how to strengthen the collation, integration and customization of knowledge and information as well as their speedy flow and utilization among the community at large. Information and Communications Technologies (ICT), such as the World Wide Web, e-mail, telephones, fibre optics and satellites have revolutionized the way not only of interaction and networking pattern in the societies but also the very design and functioning of knowledge management models and information sharing mechanisms. ICT can enable individuals, communities and institutions to generate, access, share, adapt and apply larger volume of information at an enhanced rate and at reduced costs. They are also the potential means for community empowerment as well as solutions to the dwindling strength of extension functionaries.

ICT can facilitate larger awareness and extent of people's participation in development processes. The existing gaps between the haves and haves not with respect to knowledge and information could be bridged effectively across societies, cultures, communities and gender. Realizing their immense potential as engine of growth and development, several countries made initiatives of ICT application in agricultural knowledge and information management. The use of ICT to improve information flow and to connect people within the rural areas has proved that illiteracy of farming communities may no longer be an excuse to be denied of some form of extension system. Mobile telephony, innovative community radio and television programs, mobile phones in combination with radio, video shows, information kiosks, web portals, rural tele-centers, farmer call centers, video-conference, offline multimedia CDs, open distance learning, etc are the major forms of ICTs applied in various countries.

Major Issues

Opportunities and challenges of using ICT as well as various forms and cases of ICT applications is a major concern. The other important issues is location specific and vernacular based content development, user friendliness, cost-effectiveness, capacity building, development and deployment of usable ICT products, enhanced investments in ICT application and impact assessment, etc.

A range of challenges which ICT-based initiative experience include technological dependence; lack of accessible telecommunication and internet infrastructure in rural and remote areas; capital cost of ICTs, high cost of on-going access and support; inherent need for capacity building; difficulty in integrating with existing media, local communication methods and traditions; and, lack of involvement of all stakeholders, especially women and youth were highlighted.

For effective application of ICTs for agricultural knowledge management, there is a need to:

- Build capacity of farmers and extension workers in optimum use of mobile networks.
- Promotion of mobile networks along with community radios will enhance the knowledge management at grassroots level.
- Voice-based mobile advisory in local language is to be emphasized for easy understanding of farmers.
- Low cost teleconferencing may be encouraged to enhance the knowledge sharing and problem solving capabilities of extension personnel.
- Commodity based Knowledge Portals may be developed with vernacular language content using combination of knowledge management tools and based on local needs.
- To enhance the uses of ICT in agriculture, there is a need for capacity building and training of users, KVK staff and farmers for the strength of ICT for extension purposes.
- Farmers' success stories should be disseminated through print media and ICT tools.

CONCLUSION

Information and communication technology for development is a phenomenon as well as a medium that' has radically improved interaction throughout the world. Thus, there is the need to develop a strong linkage complimented by flawless information flow enhanced through the effective use of information and communication technologies by the extension service to significantly boost agricultural production and improve rural livelihoods. This will enhance the quality of interaction between extension agents and their clientele instead of moving messages through a long chain of hierarchical system. The web-based system would not only strive to generate high-yielding agricultural technologies that are sufficiently adapted and relevant to specific local environments, but also provide useful services needed to raise the quality of life by accelerating the diffusion and mass adoption of new technologies on farms. An effective information technology does not only create demand for but also supply information package that are desired to undertake necessary modifications of given technologies or help to plan new agricultural research agenda. There is need to tap the large reservoir of farmers' tacit knowledge to consider their perspective and for blending with the scientific findings to develop applicable knowledge and appropriate technologies. Promotion of mobile networks along with community radios may enhance the knowledge management at grassroots level.

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Development of Computer Aided Design procedure for bench terraces

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ABSTRACT

Bench terracing in which step like fields are developed by cutting and filling of the soil across general slope is the only way to practice agriculture on steep slopes. The design of a bench terracing system involves a large number of parameters pertaining to climate, topography, soil characteristics, cropping systems, farming operations and availability of construction material. Based on the nature of bench and riser these terraces are classified into a number of types like table top, inclined inward or inclined outward with inclined or vertical riser. Each type of bench terrace system has its own peculiarity which makes them suitable to a particular set of conditions. Thus before taking up the design, the selection of an appropriate type of bench terracing system required to be designed in an area becomes necessary in order to make the system effective under existing conditions at the place. The functional utility, limitation and requirement of each design parameter in isolation and in combinations are to be understood adequately to arrive at a logical solution. To examine efficacy of different design alternatives, one has to work out a number of design solutions based on different possible combinations of input variables which becomes time consuming and tedious task particularly when attempted through use of a number of mathematical relationships. In this paper a computer aided design solution for bench terracing system for easy and accurate determination of design parameters for various combinations of input variables at a place has been developed. This computer aided design procedure is likely to prove immensely helpful to field level workers and organizations to arrive at an optimal design of bench terraces for all possible combinations of input variables.

Key words: Bench terrace, computer algorithm, flow chart

INTRODUCTION

Adoption of bench terracing is the only way to put steep sloping lands in hilly areas to agricultural use. In Bench terraces the soil is cut from the upper area and filled in the lower area. By cutting and filling of the soil a series of steps like fields are constructed across the general slope of the land which also helps in reducing soil erosion and conserving runoff water. On the basis of the nature of riser inclination and the nature of the bench, these terraces are classified into different categories as terraces with vertical risers and level bench terraces with inclined risers and level bench, terraces with vertical risers and outward sloping bench, terraces with inclined risers and outward sloping bench, terraces with vertical risers and inward sloping bench and terraces with inclined risers and inward sloping bench (Fig. 1). The design and adoptability of each type of these terraces is referred to a particular set of site conditions and requirements. This limitation thus makes it essential to select an appropriate type of bench terracing system at a place before attempting design and construction. For example, in low rainfall areas where the soil depth is shallow the outward sloping benches are found to be more relevant as compared to inward sloping bench terraces. Similarly, in high rainfall areas where the soil depth is sufficient, inward sloping bench terraces will prove to be more effective in comparison to others. Also, depending

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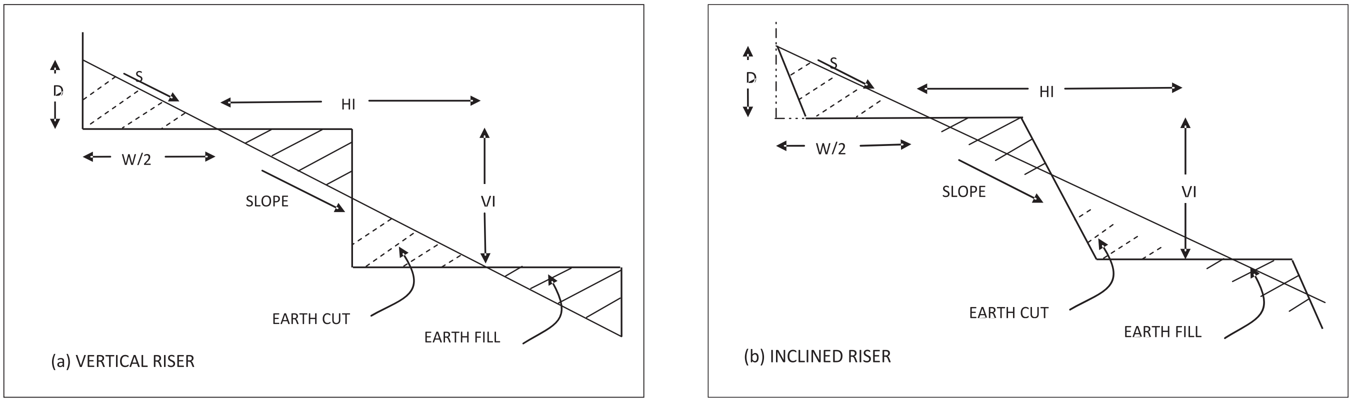
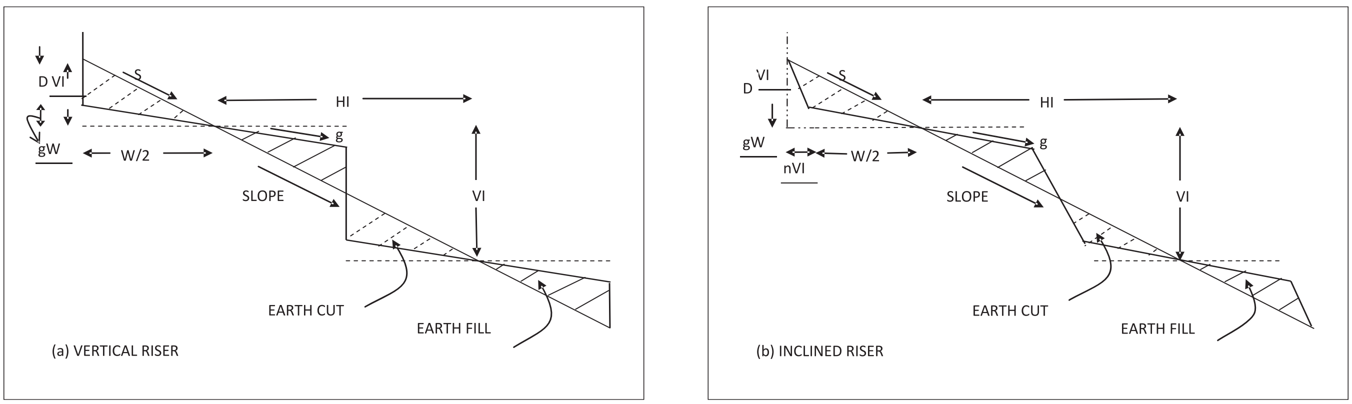
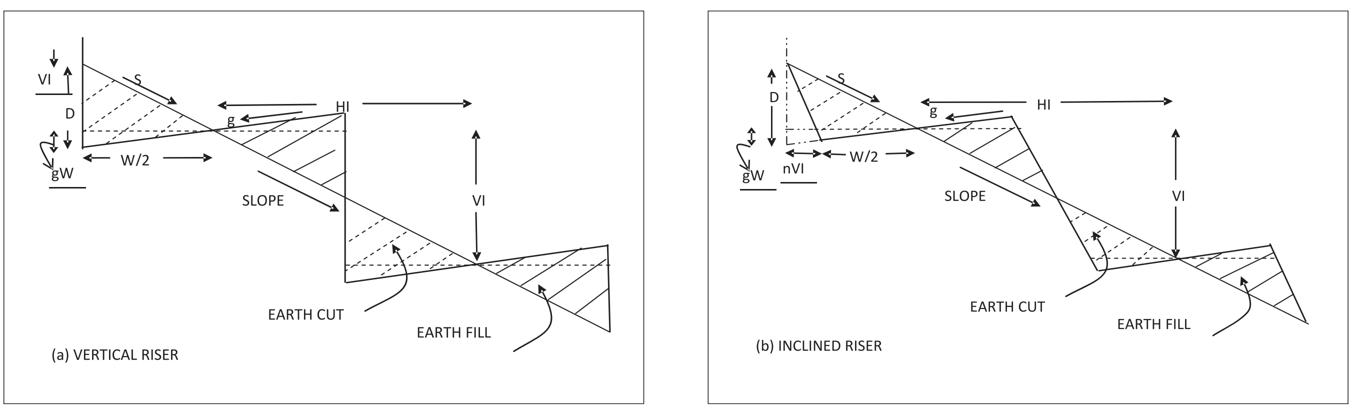


A. Level bench terraces



B. Outward sloping bench terraces



C. Inward sloping bench

Fig. 1. Line diagram of different bench terraces with vertical and inclined risers

upon the height and stability of the soil material, the riser may be kept as vertical or inclined.

The design of a bench terracing system is cumbersome and tedious job as it involves large number of parameters pertaining to climate, topography, soil characteristics, cropping system, farming operations and availability of construction material. The construction of bench terraces in an area not only requires a sound technical know how but also huge monetary provisions as it involves tremendous amount of earth work. To make the design of bench terraces cost effective and efficient, not only selection of an appropriate type of bench terracing system as per the existing conditions but also accurate determination of design parameters considering various design variables at a place becomes essential. Field level organizations involved in this area of work may find it difficult to arrive at an optimal design using conventional mathematical design procedures as it will require lot of efforts and time. As an alternative approach, a design solution based on computer aided design will prove to be immensely helpful to easily and quickly determine design parameters for various combinations of input variables at a place. Based on above considerations a computer aided design solution for bench terracing system for easy and accurate determination of design parameters for various combinations of input variables at a place has been developed. This design procedure is very simple and user friendly as it provides various design parameters of bench terracing system by just entering the values of input design variables for any conditions.

MATERIALS AND METHODS

Land slope, soil depth, rainfall conditions, soil type, type of crops grown and type of machinery being used are basic information required in the selection and design of a bench terracing system in an area. Considering these input information and their combinations, the design parameters like width of the bench (W), vertical interval (VI), horizontal interval (HI), required depth of cut (D_c), riser inclination (n), slope across the bench (g), slope along the bench (s), earthwork volume (E_w) and percent area loss (AL) are to be determined.

The permissible available depth of cut of soil proves to be a limiting factor and in no case the soil should be dug more than the permissible depth. Further, in developing the computer program the depth of cut has been considered upto a maximum of 1m only as digging more than 1m depth will increase the cost of construction. Similarly, the width of bench has been considered in the range of 3m minimum to a maximum of 6m depending upon available land slope. This is because less than 3m wide bench will make agricultural operations difficult while keeping bench width more than 6m will increase the depth of cut. Similarly, the maximum height of riser has been considered as 2m, as risers greater than 2 m height will become unstable. The values of inclination of the risers (n) have been fixed as n = 0 for vertical risers and n = 6 (6 vertical to 1 horizontal) for stone boulder inclined risers, the slope across the bench (g) has been fixed at 5% and the slope along the length of bench is fixed at 0.1%. The nature of the riser is decided according to the extent of its size and the nature of the soil. With above consideration, the design parameters of bench terrace were determined as below.

Width of bench

The actual width of the bench depends upon the slope of the land. The bench width decreases with increasing land slope and is decided based on the following recommendations (Das, 2002).

Slope of land (S), %	Width of bench (W), m
10-15	6.0-4.5
15-25	4.5
> 25	3.0

Vertical and horizontal interval

The vertical interval (VI) is the elevation difference and the horizontal interval (HI) is the horizontal spacing between two consecutive benches. Both are related with land slope as expressed in the following relationship,

$$\frac{VI}{HI}\times 100 = S \qquad \ldots (1)$$

The horizontal interval is related with bench width as,

$$HI = W + n\,(VI) \qquad \ldots (2)$$

where, n is inclination of the riser and is kept as 1:6 (H:V) for stone boulder risers. For vertical riser the value of n is zero.

Required depth of cut

The required depth of cut (D_c) depends on vertical interval and the width of bench and is expressed as,

$$D_c = \frac{VI}{2} \pm \frac{gW}{2} \qquad \ldots (3)$$

where, g is the slope across the bench in m/m. Positive and negative signs are used in inward and outward sloping bench terraces respectively. In case of level bench, the value of g is zero and the depth of cut is just half of the vertical interval. Generally the value of inward slope ranges between 2 to 10% depending upon the drainage requirement (Suresh, 2009). However for application purpose an inward and outward slope of 5% has been selected in the present study. The bench is provided with a longitudinal slope of 0.1% along its length to facilitate drainage lengthwise. Care should be taken that the required depth of cut does not exceed the available permissible depth of cut at a site.

Earthwork volume

The construction of a bench terrace system involves a huge soil mass movement as the soil cut from the upper half is filled in the lower half to give it a shape of bench. The earthwork volume (E_w) depends on depth of cut, width of bench and length of bench terrace and can be expressed as,

$$E_w = \frac{1}{4} DWL = \frac{D \times W \times AP}{4 \times HI} \qquad \text{... (4)}$$

where L is the length of the bench in m in an area AP is the area of plot in sq-m. The cost of earth work can be obtained by multiplying the volume of earth work with unit cost of earth work.

Percent area loss

Due to inclined nature of riser the cultivable area is lost in the construction of terraces. To minimize the loss of useful land the riser should be made as vertical as possible while ensuring its stability. The area loss, AL (m^2), is given as,

$$AL = n \times VI \times L = n \times \frac{S}{100} \times HI \times \frac{AP}{HI}$$

Therefore area loss (%AL) as percent of the total area (AP) can be given as,

or, $$\%AL = \frac{n \times S \times AP}{100 \times AP} \times 100 \qquad \text{... (5)}$$

To minimize the area lost in the construction of bench terracing system the riser should be made as steep as possible. For this consideration stone boulder risers have only been considered in this study. If the height of the riser is upto1.5 m, they may be kept vertical but if the height of risers exceeds 1.5 m then these are to be inclined with an inclination of 1:6 (H:V) so that the area lost in the construction of bench terraces is minimized.

Flowchart and computer program for bench terrace design

The flow chart depicting the procedure employed during the development of the computer program based on various input variables is illustrated in Fig. 2. A computer program was developed in C++ which enables the user to get the values of the design parameters for various bench terracing systems involving various combinations of input variables.

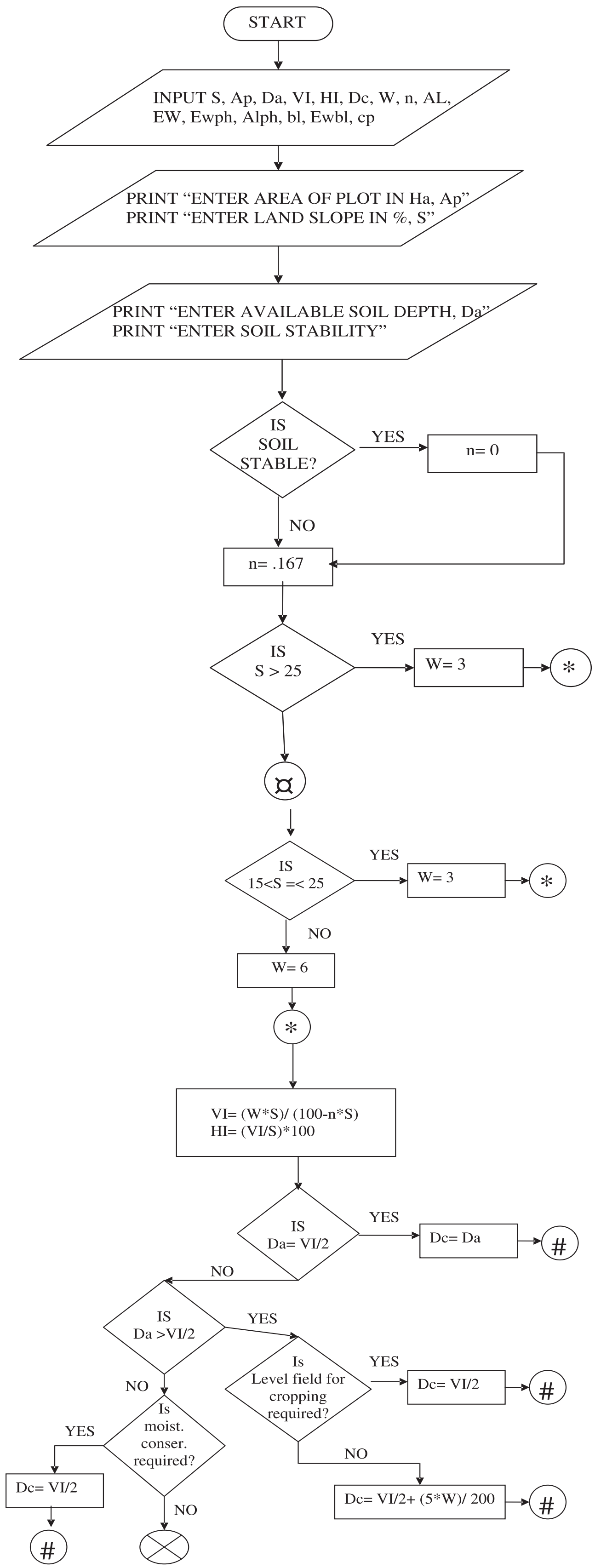
Working principle of developed program

Using the known values of area of the land to be terraced, land slope and the available permissible soil depth for the land to be terraced at a particular site, the detailed working mechanism of the developed program is as follows,

i. After entering these variables the program enquires about the soil stability.

Table 1. Relations developed between different parameters for various types of bench terraces

Type of bench terrace	Vertical interval	Horizontal interval	Earthwork volume per ha, (m^3)	Percent area lost, % AL
Terraces with vertical risers and level bench	2D	W	2500 D	zero
Terraces with inclined risers and level bench	2D	W + VI		
Terraces with vertical risers and outward sloping bench	2D + gW	W	2500 D	zero
Terraces with inclined risers and outward sloping bench	2D + gW	W + VI		
Terraces with vertical risers and inward sloping bench	2D - gW	W	2500 D	zero
Terraces with inclined risers and inward sloping bench	2D - gW	W + VI		



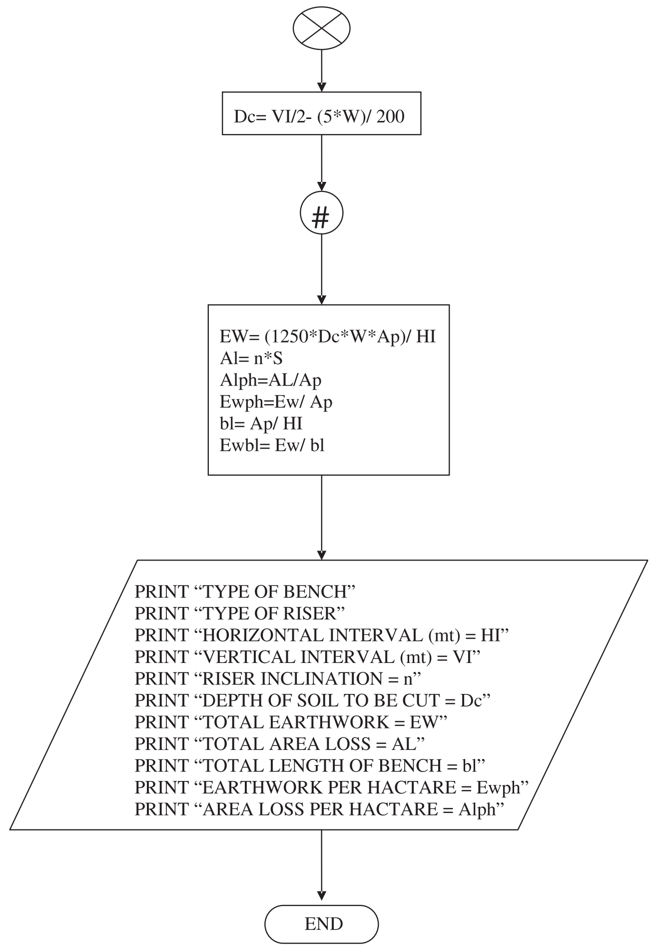


Fig. 2 Flow chart for developed computer program

ii. Enter ‘0’ for stable soil and ‘1’ for unstable soil at the prompt.

iii. If the soil is stable, the program sets the slope of the riser as zero (n = 0) for the case of unstable soil the riser inclination is taken as n = 0.167.

iv. According to the slope entered, the width of the bench is fixed as recommended.

v. The values of vertical interval (VI) and horizontal interval (HI) are determined.

vi. The available soil depth (D_a) is compared with VI/2; if

   a. D_a = VI/2 the depth of cut (D_c) is fixed to be equal to D_a

   b. D_a > VI/2 we can go either for an inward sloping bench or a flat bench according to the cropping pattern of the region and D_c is calculated.

   c. D_a < VI/2 we can go for flat or outward sloping bench; to be decided on the basis of moisture conservation required.

ix. Then the earthwork and percent area loss are determined.

x. The program calculated values of design parameters are displayed indicating the type of bench system best suited for the entered parameters/conditions

RESULTS AND DISCUSSION

The developed program is easy and accurate for determining design parameters of a bench terracing system as compared to the existing design procedure. The developed approach also enables the user to analyze various sets of input restrictions and the values of various design parameters can be determined without involving any mathematics. A semi skilled person with a basic knowledge of computer application can perform the design of bench terraces for any set of conditions. The design parameters obtained for a table top bench terrace system by using developed computer program are shown in Tables 2 to 7. To ensure the validity and applicability of the developed design procedure using a computer program, hypothetical problems

Table 2. Calculated values of design parameters for bench terraces with vertical riser (n=0) and level bench (g=0)

Land slope, (%)	Width of bench (m)	Available depth (Da), (m)	Slope (%)	Stability	Cropping pattern requires level field	Moisture conser-vation required	VI (m)	HI (m)	Calculated depth of cut (Dc), (m)	Earthwork (EW) (cu. m/ha.)	Area loss (%)
10 -15	6.0	0.3	10	“	—-	—-	0.60	6.0	0.300	375.00	0
	6.0	0.5	12	“	“	—-	0.72	6.0	0.360	450.00	0
	6.0	0.7	14	“	“	—-	0.84	6.0	0.420	525.00	0
	6.0	0.9	15	“	“	—-	0.90	6.0	0.450	562.50	0
15 - 25	4.5	0.3	16	“	—-	“	0.72	4.5	0.360	450.00	0
	4.5	0.5	18	“	“	—-	0.81	4.5	0.405	506.25	0
	4.5	0.7	20	“	“	—-	0.90	4.5	0.450	562.50	0
	4.5	0.9	24	“	“	—-	1.08	4.5	0.540	675.00	0
>25	3.0	0.3	30	“	—-	“	0.90	3.0	0.450	562.50	0
	3.0	0.5	35	“	—-	“	1.05	3.0	0.525	656.25	0
	3.0	0.7	40	“	“	—-	1.20	3.0	0.600	750.00	0
	3.0	0.9	45	“	“	—-	1.35	3.0	0.675	843.75	0

Table 3. Calculated design parameters for bench terraces with inclined riser (n=1/6) and level bench (g=0)

Land slope, (%)	Width of bench (m)	Available depth (Da), (m)	Slope (%)	Stability	Cropping pattern requires level field	Moisture conser-vation required	VI (m)	HI (m)	Calculated depth of cut (Dc), (m)	Earthwork (EW) (cu. m/ha.)	Area loss (%)
10 - 15	6.0	0.3	10	×	—-	“	0.610	6.102	0.305	375.00	1.670
	6.0	0.5	12	×	“	—-	0.735	6.123	0.367	450.00	2.004
	6.0	0.7	14	×	“	—-	0.860	6.144	0.430	520.00	2.338
	6.0	0.9	15	×	“	—-	0.923	6.154	0.462	562.50	2.505
15- 25	4.5	0.3	16	×	—-	“	0.740	4.624	0.370	450.00	2.672
	4.5	0.5	18	×	“	—-	0.835	4.639	0.418	506.25	3.006
	4.5	0.7	20	×	“	—-	0.931	4.655	0.466	562.49	3.340
	4.5	0.9	24	×	“	—-	1.125	4.688	0.563	675.00	4.000
>25	3.0	0.3	30	×	—-	“	0.947	3.158	0.474	562.50	5.010
	3.0	0.5	35	×	“	—-	1.115	3.186	0.558	656.25	5.845
	3.0	0.7	40	×	“	—-	1.286	3.215	0.643	750.00	6.680
	3.0	0.9	45	×	“	—-	1.460	3.244	0.730	843.75	7.515

Table 4. Calculated values of design parameters for bench terraces with vertical riser (n=0) and outward sloping (g=5%)

Land slope, (%)	Width of bench (m)	Available depth (Da), (m)	Slope (%)	Stability	Cropping pattern requires level field	Moisture conser-vation required	VI (m)	HI (m)	Calculated depth of cut (Dc), (m)	Earthwork (EW) (cu. m / ha.)	Area loss (%)
10-15	6.0	0.25	10	“	—-	—-	0.600	6.0	0.150	187.50	0
	6.0	0.35	12	“	—-	—-	0.720	6.0	0.210	262.50	0
	6.0	0.40	14	“	—-	—-	0.840	6.0	0.270	337.49	0
	6.0	0.42	15	“	—-	—-	0.900	6.0	0.300	374.99	0
15-25	4.5	0.3	16	“	—-	—-	0.720	4.5	0.248	309.37	0
	4.5	0.4	18	“	—-	—-	0.810	4.5	0.292	365.62	0
	4.5	0.44	20	“	—-	—-	0.900	4.5	0.337	421.87	0
	4.5	0.5	24	“	—-	—-	1.000	4.5	0.428	534.37	0
>25	3.0	0.3	30	“	—-	—-	0.900	3.0	0.375	468.75	0
	3.0	0.5	35	“	—-	—-	1.050	3.0	0.450	562.50	0
	3.0	0.7	50	“	—-	—-	1.500	3.0	0.675	843.75	0
	3.0	0.9	70	“	—-	—-	2.100	3.0	0.975	1218.75	0

Table 5. Calculated values of design parameters for bench terraces with inclined riser (n=1/6) and outward sloping (g= 5%)

Land slope, (%)	Width of bench (m)	Available depth (Da), (m)	Slope (%)	Stability	Cropping pattern requires level field	Moisture conser-vation required	VI (m)	HI (m)	Calculated depth of cut (Dc), (m)	Earthwork (EW) (cu. m / ha.)	Area loss (%)
10-15	6.0	0.25	10	×	—-	—-	0.610	6.102	0.155	190.63	1.670
	6.0	0.35	12	×	—-	—-	0.735	6.123	0.217	266.25	2.004
	6.0	0.40	14	×	—-	—-	0.860	6.144	0.280	341.88	2.338
	6.0	0.42	15	×	—-	—-	0.923	6.154	0.312	379.69	2.505
15-25	4.5	0.3	16	×	—-	—-	0.740	4.624	0.257	313.13	2.672
	4.5	0.4	18	×	—-	—-	0.835	4.639	0.305	369.85	3.006
	4.5	0.44	20	×	—-	—-	0.931	4.655	0.353	426.57	3.340
	4.5	0.5	24	×	—-	—-	1.125	4.688	0.450	540.01	4.000
>25	3.0	0.3	30	×	—-	—-	0.947	3.158	0.399	473.44	5.010
	3.0	0.5	35	×	—-	—-	1.115	3.186	0.483	567.97	5.845
	3.0	0.7	50	×	—-	—-	1.637	3.273	0.743	851.57	8.350
	3.0	0.9	70	×	—-	—-	2.378	3.397	1.114	1229.7	11.69

Table 6. Calculated values of design parameters for bench terraces with vertical riser (n=0) and inward sloping (g= 5%)

Land slope, (%)	Width of bench (m)	Available depth (Da), (m)	Slope (%)	Stability	Cropping pattern requires level field	Moisture conser-vation required	VI (m)	HI (m)	Calculated depth of cut (Dc), (m)	Earthwork (EW) (cu. m / ha.)	Area loss (%)
10-15	6.0	0.50	10	"	—-	—-	0.600	6.0	0.450	562.50	0
	6.0	0.70	12	"	—-	—-	0.720	6.0	0.510	637.50	0
	6.0	0.90	14	"	—-	—-	0.840	6.0	0.570	712.50	0
	6.0	1.00	15	"	—-	—-	0.900	6.0	0.600	749.00	0
15- 25	4.5	0.50	16	"	—-	—-	0.720	4.5	0.473	590.62	0
	4.5	0.70	18	"	—-	—-	0.810	4.5	0.517	646.87	0
	4.5	0.90	24	"	—-	—-	1.080	4.5	0.653	815.62	0
	4.5	1.00	25	"	—-	—-	1.125	4.5	0.675	843.75	0
>25	3.0	0.50	30	"	—-	—-	0.900	3.0	0.525	656.25	0
	3.0	0.70	35	"	—-	—-	1.050	3.0	0.600	750.00	0
	3.0	0.90	40	"	—-	—-	1.200	3.0	0.675	843.75	0
	3.0	1.00	45	"	—-	—-	1.350	3.0	0.750	937.50	0

Table 7. Calculated values of design parameters for bench terraces with inclined riser (n=1/6) and inward sloping (g=5%)

Land slope, (%)	Width of bench (m)	Available depth (Da), (m)	Slope (%)	Stability	Cropping pattern requires level field	Moisture conser-vation required	VI (m)	HI (m)	Calculated depth of cut (Dc), (m)	Earthwork (EW) (cu. m / ha.)	Area loss (%)
10-15	6.0	0.50	10	×	—-	—-	0.610	6.102	0.455	559.36	1.670
	6.0	0.70	12	×	—-	—-	0.735	6.123	0.517	633.74	2.004
	6.0	0.90	14	×	—-	—-	0.860	6.144	0.580	708.11	2.338
	6.0	1.00	15	×	—-	—-	0.923	6.154	0.612	745.30	2.505
15- 25	4.5	0.50	16	×	—-	—-	0.740	4.624	0.482	586.86	2.672
	4.5	0.70	18	×	—-	—-	0.835	4.639	0.530	642.64	3.006
	4.5	0.90	24	×	—-	—-	1.125	4.688	0.675	809.88	3.340
	4.5	1.00	25	×	—-	—-	1.174	4.696	0.700	837.87	4.000
>25	3.0	0.50	30	×	—-	—-	0.947	3.158	0.549	651.55	5.010
	3.0	0.70	35	×	—-	—-	1.115	3.186	0.633	744.52	5.845
	3.0	0.90	40	×	—-	—-	1.286	3.215	0.718	837.48	6.680
	3.0	1.00	45	×	—-	—-	1.460	3.244	0.805	930.45	7.715

were considered with various input information and the results obtained by the developed procedure were compared with the results obtained by using conventional method for the similar input variables. The values of design parameters obtained from both these methods were found exactly similar as tabulated in Table 8.

Table 8. Comparison of design parameters obtained by developed design procedure and by conventional method for terraces with vertical riser and level bench

Type of bench terrace	Para-meters	Existing method	Developed software	Remarks
Terraces with vertical riser and level bench	S, %	12	12	same
	W, m	6.0	6.0	same
	Dc, m	0.360	0.360	same
	VI, m	0.720	0.720	same
	HI, m	6.000	6.000	same
	EW, m^3/ha.	450.00	450.00	same
	% AL	0	0	same
Terraces with inclined riser and level bench	S, %	20	20	same
	W, m	4.5	4.5	same
	Dc, m	0.466	0.466	same
	VI, m	0.931	0.931	same
	HI, m	4.655	4.655	same
	EW, m^3/ha.	562.49	562.49	same
	% AL	3.34	3.34	same
Terraces with vertical riser and outward sloping bench	S, %	14	14	same
	W, m	6.0	6.0	same
	Dc, m	0.270	0.270	same
	VI, m	0.840	0.840	same
	HI, m	6.000	6.000	same
	EW, m^3/ha.	337.49	337.49	same
	% AL	0	0	same
Terraces with vertical riser and outward sloping bench	S, %	20	20	same
	W, m	4.5	4.5	same
	Dc, m	0.353	0.353	same
	VI, m	0.931	0.931	same
	HI, m	4.655	4.655	same
	EW, m^3/ha.	426.57	426.57	same
	% AL	3.340	3.340	same
Terraces with vertical riser and outward sloping bench	S, %	14	14	same
	W, m	6.0	6.0	same
	Dc, m	0.570	0.570	same
	VI, m	0.840	0.840	same
	HI, m	6.000	6.000	same
	EW, m^3/ha.	712.50	712.50	same
	% AL	0	0	same
Terraces with inclined riser and level bench	S, %	24	24	same
	W, m	4.5	4.5	same
	Dc, m	0.675	0.675	same
	VI, m	1.125	1.125	same
	HI, m	4.688	4.688	same
	EW, m^3/ha.	809.88	809.88	same
	% AL	3.340	3.340	same

CONCLUSION

Considering the hypothetical design problems, the developed design procedure has been compared and verified with existing design procedure for various types of terrace systems. Under various input design variables the solutions obtained by using these two procedures were observed to be same and thus the developed design procedure becomes applicable for all the conditions of bench terracing systems considered in the study. Moreover the developed procedure has an edge over the conventional procedure as it is simple to use, accurate, user friendly and enables analysis of variety and wide range of design alternatives very quickly. As an added advantage, any semi skilled person with only basic knowledge of computer application can perform the design very effectively.

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NREGA: Science based perspective plan preparation and ex-ante impact assessment – A case study for Sitapur district of Uttar Pradesh

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ABSTRACT

India has long experience in implementing employment generation programs. However the programs had little success in generating employment for sustainable development to address the poverty issue. National Rural Employment Guarantee Act (NREGA), with its rights-based framework and demand driven approach, marks a paradigm shift from the previous wage programs to address causes of poverty through natural resource management for sustainable development. The Ministry of Rural Development, Government of Uttar Pradesh requested International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to prepare five-year perspective plan of NREGA for Sitapur district for creating self sustaining economy to reduce poverty and make visible impact on major problems at each *gram panchayat*,. Based on *gram panchayat* level survey results, secondary data and consultation with gram panchayat various works were proposed to enhance productivity of natural resources and employment. Proposed works include water conservation, tree plantations, drainage and flood protection, land improvement for eroded lands and rural connectivity. The perspective plan for five-year period would result in 33,334 works for district and an average of 25 works per *gram panchayat.* Potential employment of 12.92 million person-days would be generated which would benefit 2, 58,324 households to employ a person in each household for 100 days.This would result in benefiting 49% of total households of the district at an average cost of 495.1 crores per year. A total of 11,048 ha-m additional storage capacity would be created through water conservation which would help increasing cropping intensity and productivity, flood protection and rise of water table. The monetary value of the expected benefits of the proposed works would be significant, when implemented. NREGA works would provide fillip to create increased employment opportunities through better management of natural resources for increased and sustained production which would be multiplier and productivity and employment accelerator process to transform livelihood of rural community.

Key words: poverty, Gram Panchayat, productivity, households, NREGA, employment

INTRODUCTION

In agricultural based rural Indian economy there are sections of rural population which depend on the earned, unskilled and casual manual labor wages. Inadequate labor demand or unpredictable crisis such as natural disaster or personal ill- health impact their employment opportunity and they are vulnerable to sink into transient poverty to chronic poverty. Workfare programs had been important interventions for many years in developed and developing countries to overcome poverty and employment. These programs typically provided unskilled manual workers with short-term employment on public works such as irrigation infrastructure, afforestation, soil conservation and road construction. The rationale for workfare programs was based on basic considerations of income transfers to the poor household, enable consumption and prevent poverty from worsening during slack agricultural seasons or lean periods.

The Government of India recognized early, during development planning, the need to evolve

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a mechanism to supplement existing livelihood sources in rural areas. The country has long experience in implementing workfare programs like Rural Manpower (1960-61), Crash Scheme for Rural employment (1971-72), Pilot Intensive Rural Employment Program (1972), Small Farmers Development Agency (1971-72), Marginal Farmers and Agricultural Labor Scheme (1971-72) and Small Farmers, Marginal Farmers and Agricultural Labors Project (1971-72). After 1980 there were many employment generation programs including National Food for Work Program in 2005 launched in rural India. Major Weaknesses of many of the past employment generation programs have been the inadequate emphasis on creating community capabilities and durable assets that enhance the livelihood security and augment the natural resources.

National Rural Employment Guarantee Act

The National Rural Employment Guarantee Act (NREGA-2005) was brought into force by the government of India in February 2006. The NREGA, now renamed as Mahatma Gandhi National Rural Employment Guarantee Act, had come at a crucial time, when rural economy in the country is facing erosion of livelihoods due to rural unemployment. NREGA aims at enhancing the livelihood security of people in rural areas by guaranteeing hundred days of wage-employment in a financial year to a rural household whose members volunteer to do unskilled manual work. The NREGA faces a two-pronged challenge: addressing immediate unemployment crisis in rural areas and a longer-term objective of contributing to village economy in a sustained manner**.**

NREGA puts major emphasis on generation and enhancement of ecosystems services through enhancement of quantity and quality of natural resources such as water and soil thus helping in increasing agricultural productivity and crop diversification. The focus was also given for afforestation and rural connectivity for access to markets and various services to enhance systems productivity and income levels of the community. Past experiences suggest that to mitigate arrest or reverse acute rural distress there has to be greater emphasis on systematic and comprehensive rural area development focusing on the regeneration of the agro-ecological resources like land, water and bio resources for sustainable livelihoods.

Instruments for providing employment under NREGA are permissible works which are mentioned in NREGA guidelines (GOI, 2008). These works include water conservation, drought proofing including plantation and horticulture, irrigation works, development of land owned by schedule caste and tribes, land reforms and Indira Awas Yojana beneficiaries, flood control and protection works and rural connectivity.

The Act attempts to unlock the potential of the rural poor to contribute to the development and protection of their environment through creation of productive assets in the villages. Out of permissible works under the NREGA guidelines, most focus on water and soil conservations and poverty issues such as drought, deforestation etc . NREGA marks a paradigm shift from the previous wage programs with its rights-based framework and demand driven approach. Outcomes include strengthening the grassroots processes of democracy by giving a pivotal role to the *panchayat raj* institutions in planning, monitoring and implementation, infusing transparency and accountability in governance.

Effective implementation of the Act requires planning labor-intensive works for the needy poor in a slack agricultural season or lean periods. These works must build the appropriate, sustainable and durable assets and manage them to generate benefits and economic growth to the poor. Thus NREGA should be seen more as a livelihood-generating program than a wage-earning scheme. It also offers a unique opportunity to reform rural development.

The Ministry of Rural Development, Government for Uttar Pradesh, requested International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to prepare five-year NREGA perspective plan of Sitapur district in the state. The district perspective plan was intended to facilitate advance planning and provide a development perspective for the district. The main objectives of the district perspective plan were:

- To identify the types of works that should be promoted to develop , manage and strengthen livelihood resource base of *gram panchayat.*
- To ensure that the district is prepared well in advance to offer employment on demand by developing annual plan consisting of shelves of projects.

District profile

Location and demography

The Sitapur district of Uttar Pradesh is located between 27^{0} 05’ and 27 ^{0}54’ N latitude and 80^{0}18E and 81^{0} 25’ E longitude and has geographical area of 5743 km^{2}. The district topography is a vast plain sloping mildly from an elevation of 150 m above mean sea level (msl) in the northwest to 100 m above msl in the southeast. Gomti and Ghagra are major rivers of the district. The administrative set up of the district consists of 6 *tehsils* (revenue divisions) and 19 community development blocks (*kshetra) panchayats* and 1329 *gram panchayats.*

Total population of the district is 36, 19,661 persons (Census of India, 2001), which constitutes 1.9 percent of the state. The sex ratio of the district is only 865 female per 1000 male, which is lower than the state (898). The population density is 630 in 2001 (689 for the state), which is twice that of the country average. Literacy rate is 35.4% in 2001. Presently, the district has negligible industrial activities except for five sugar mills, some flour and rice mills and cottage industries making cotton and woolen mats.

Agro-climatic features of Sitapur district

Soils

The district is typically hot dry sub humid with mostly loam alluvium-derived soils. Inceptisols dominate the western and central parts of the district and the eastern part is dominated by Entisols. There is a small patch of Mollisols in the easternmost region of the district (figure 1).

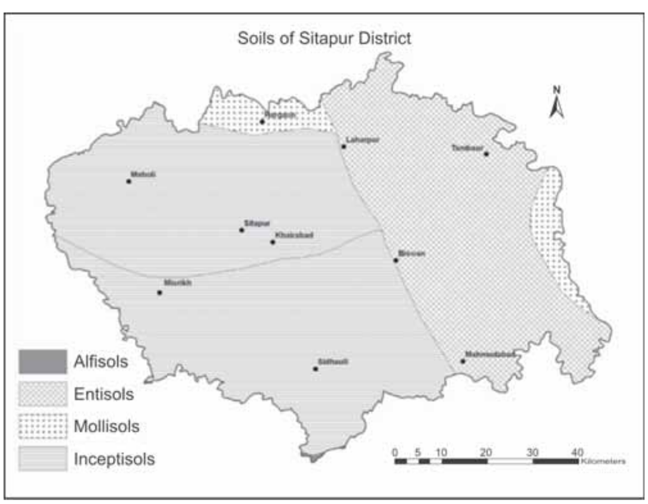

Figure 1. Soils of Sitapur district

Figure 2 shows the Agro-Ecological Sub Regions (AESR) of the district according to classifications made by National Bureau of Soil Survey and Land Use Planning (NBSS&LUP, 1996). Major portion of the district falls under the AESR 9.2. This AESR is defined as ‘Rohilkhand, Avadh and south Bihar Plains, hot dry sub humid ESR with deep loamy alluvium-derived soils, medium to high available water capacity (AWC) and length of growing period (LGP) 150-180 days’. Eastern parts of the district fall under the AESR 13.1 and are described as “North Bihar and Avadh Plains, hot dry to moist sub humid ESR with deep, loamy alluvium-derived soils, low to medium AWHC and LGP 180-210 days” (Velayutham, *et al.*, 1999).

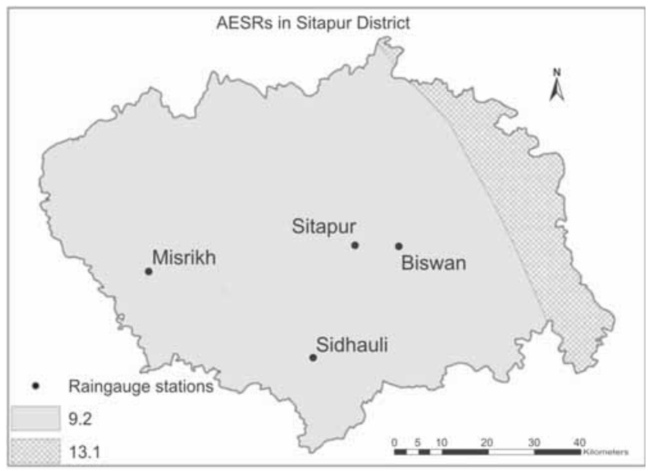

Figure 2. Ecological sub-regions of Sitapur district

Climate

Normal annual rainfall of the district is 978 mm (Table 1) received in about 50 rainy days. About 87% of the annual rainfall is received during the southwest monsoon period of June to September. July and August are the wettest months, receiving more than 65% of the monsoon rainfall. In the post-monsoon season, winter and summer, rainfall is generally low and contributes about 15% of the annual rainfall. April to June is the summer period (max average temperature 40°C). Winter is during December to February (min average temperature 10°C).

Weekly rainfall distribution at Biswan (Figure 3) shows that the rainfall is well distributed during the southwest monsoon season. The total rainfall during the season is about 1000 mm. Average weekly rainfall begins to reach above 20 mm from

Table 1. Rainfall (mm) characteristics of the Sitapur district

Period	Biswan	Misrikh	Sidhauli	Sitapur
Annual	1062	989	881	978
Southwest monsoon (June-Sept)	920	860	761	839
Post-monsoon (Oct-Nov)	56	49	51	59
Winter (Dec-Feb)	47	47	42	44
Summer (March-May)	39	33	27	36

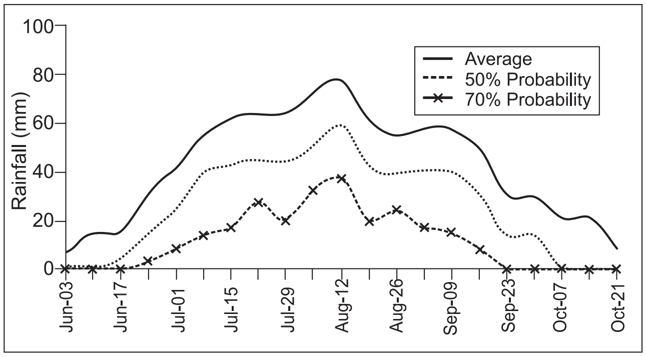

Figure 3. Rainfall characteristics of Biswan, Sitapur district (IMD, 1995)

June 20th onwards and continues up to October 20. The probability analysis indicates that assured rainfall begins only by first week of July and ends by the 3rd week of September. Probability of occurrence of dry spells during the season is low. Water harvesting potential is high during the period from middle of July to the middle of August. Other locations in the district show similar rainfall distribution.

Climatic water balance of Sitapur is presented in the figure 4. At Sitapur, the annual rainfall is 975 mm of which about 840 mm is received in the monsoon period. Annual potential evapotranspiration (PET) is about 1400 mm. During November to February, the weekly PET is generally below 20 mm. During summer, the weekly PET may total up to 40 mm and in the monsoon season the weekly PET is in between 30-40 mm.

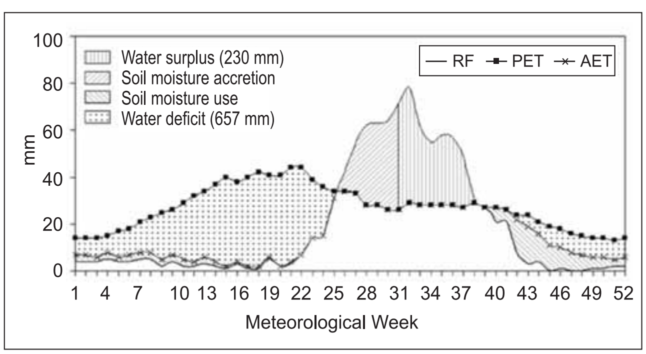

Figure 4. Climatic normal water balance of Sitapur

The annual actual evapotranspiration is about 750 mm, indicating good moisture availability to crops. Rainfall begins to exceed the PET from the middle of June and the excess rainfall starts to recharge the soil and by the end of July, soil is fully recharged and water surplus begins. The total water surplus is about 230 mm and the annual water deficit is about 655 mm. Though the rains cease by the first week of November, moisture stored in the soil meets the partial water requirements of the crops till the middle of December.

Crop productivity and irrigation sources

The district is endowed with rich and fertile soil and plain lands and about 77% of the land is under cultivation. Total agricultural land of the district is 4, 33,000 ha and about 22,200 ha (3.9%) is wasteland. Seasonal floods due to major rivers, minor rivulets and plain lands affect about 21% of geographical area of the district. Approximately 91.4% of land holdings belong to small and marginal farmers (<2 ha) and such land holdings cover 66.4% of total cultivated lands.

Predominant crops of the district are paddy, wheat, sugarcane, maize, pulses and oilseeds. Sugarcane is major cash crop in the district. Though the district is endowed with abundant fertile and productive soil and sufficient rainfall, the productivity of most crops are far below their potential yields. The average yields of wheat, paddy sugarcane are 2450, 1720 and 5300 kg ha^{-1}respectively (Sankhikiya Patrika, 2003). Cropping intensity in the district is approximately 150%. About 69% of cultivated area is irrigated in which major source of irrigation is groundwater (NABARD, 2008). Irrigation is required after January for the *Rabi* crops and also for cultivation of summer crops. There are some 89 reservoirs in the district which are spread over 5 ha each.

Opportunities to enhance livelihoods in the district

There are plenty of opportunities for creating livelihood and increasing income. Water balance results show that there is surplus water available for water harvesting which can be stored by construction of new ponds and de-silting of existing ponds. Low- land rice cultivation is feasible where there is flooding for longer time. The additional water can be used for intensification of cropping systems. By using improved technologies the rice-wheat cropping system yields can be raised up to

18 t ha $^{-1}$ year $^{-1}$ (Aggarwal, , et al. 2000, Aggarwal, et al., 2000a). Rice-chickpea-mint and pigeonpea-wheat-mint could be profitable compared to rice-wheat system in the central Indo- Gangetic Plains (Singh et al, 2003). Poplar plantation in the field and lemon grass in the inter space can be taken up for increasing income (Jain and Singh, 2000). Practice such as zero tillage for rice-wheat cropping system, sugarcane intercropped with onion/cucurbits/ marigold, legume based cropping system, seed production seed bank for chickpea, pigeonpea and groundnut can enhance the income. Cultivation of horticultural crops, preparation of vermicomposting and other income generating activities would further enhance livelihood opportunities (Anonymous, 2004).

MATERIALS AND METHODS

Primary information through structured questionnaire on socio-economic and biophysical parameters was collected from each *gram panchayat*. The data collected include demography, land use, area under different crops and their productivity, water sources, flood prone areas, degraded and erosion susceptible lands, de-silting needs, road connectivity, access within village, land owned by SC/ST**,** land reforms and Indira Awas Yojana beneficiaries.

Secondary information on soils, climate, on- going development activities, schedule rate of works and wages in the district were collected from different sources. Remote sensing data and satellite imageries were used for demarcating degraded lands, wet lands, forest cover and other physical infrastructures such as roads, water bodies and drainage networks in the district. Historical weather and soils data from the district were used to estimate the occurrence of drought using water balance (ICRISAT, 2008).

Taking into consideration the resources, needs, feasibility and NREGA guidelines, various works were proposed. The work proposals were discussed in the *gram sabha* and which made the recommendation for works to be taken up in the *gram panchayat*. The recommended works in *gram panchayats* were assembled at community development block (*kshetra*) *panchayat* wise and finally for the district. The recommended works were discussed by *kshetra panchayat* and *zila (*district*) panchayat* and their final suggestions, if any, were incorporated in list of proposed works. The Figure 5 shows the flow chart of the process of preparation of the perspective plan of the Sitapur district.

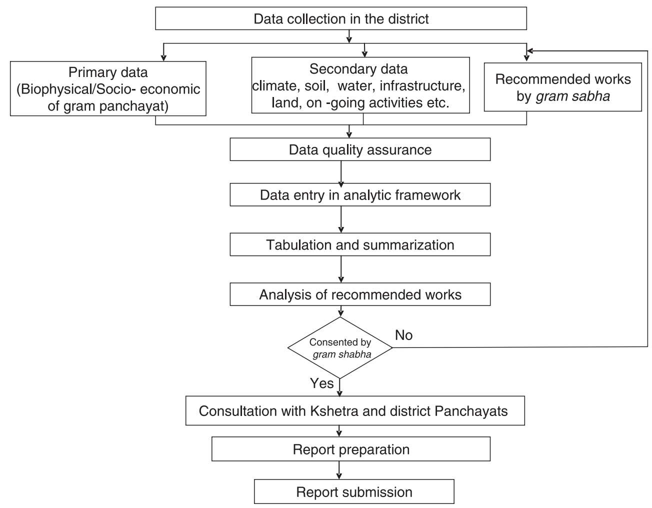

Figure 5. Process flow chart for preparation of NREG perspective plan.

Various works were categorized into permissible works under NREGA. The activities were prioritized for five-year plan period. Works under water conservation were accorded highest priority followed by soil conservation and land improvement, irrigation, forestry and plantation, flood protection, drainage, access and drainage within village and rural connectivity. Details of each work by their type, category, description, year of beginning, labor, material and total costs, person days generated for five-year plan period provided for each *gram panchayat*. The types of works proposed works were as follows.

- De-silting of existing ponds for increasing storage capacity ,flood protection and groundwater recharge
- Construction of new ponds for water harvesting ,flood protection and groundwater recharge
- Construction of bathing *ghats* on existing pond and rejuvenation of *ghats*
- Cleaning and de-silting of drains in the village for sanitation
- Construction of drains in the village for sanitation
- De-silting and shaping of burrow pits on both side of roads for drainage and water conservation
- Construction of drains for waterlogged areas
- De-silting of canal and irrigation channels
- Field bunding of eroded land and flood - prone areas

- Leveling of degraded and eroded lands
- Plantation on community lands ,avenue roads , school ground and private lands and field bunds of rural poor
- Connectivity to main road
- Culverts and causeway culverts on drains and roads
- Link road between villages
- Internal brick road for access in the village

Table 2 provides the details of typical works for Chandra *gram panchayat* in Pisawan community block of the district. Original tables were prepared in *Hindi* (local language) of the district for easy understanding by the village community. Cost details were estimated by taking into consideration the estimate of works quantity and their schedule work rates, schedule wage rates (Rs100 day $^{-1}$), number of household in the village and cost escalation (10% year^{-1}) and 15% maintenance cost of sum of labor and material cost for the particular year. The total cost of the work was estimated as sum of labour, material and maintenance costs.

RESULTS AND DISCUSSION

A total of 33,334 works were proposed for the district. On an average 25 works per *gram panchayat* for the five -year period (Table 3) were created. Maximum works were proposed for Behta block (3312) and minimum for Misrikh (1051). These

Table 2. An example of works proposed, estimated costs, person days generated under NREGA in Chandra village in Pisawan community development block of the Sitapur district, UP

Work type	Work description	Work category	Starting year	Estimated total cost (Rs lakh)	Estimated labour cost (Rs lakh)	Estimated material cost (Rs lakh)	stimated person days
De-silting of ponds	De-silting of Haria talab	Water conservation	1	17.07	14.85	0.00	14846
De-silting of drains on both side of roads	From Chandra to Pisawan approach road	Drainage	1	0.31	0.27	0.00	267
De-silting of canal	Grant culvert to next culvert	Irrigation	1	0.93	0.81	0.00	809
De-silting of irrigation channels	From Ramprasad to Gaya Prasad house	Irrigation	1	0.16	0.14	0.00	136
Plantation on common lands	Near *gram* panchayat bhawan	Forestry and plantation	1	0.93	0.77	0.04	770
Plantation on approach roads	On main road of Chandra	Forestry and plantation	1	0.41	0.34	0.02	340
Land leveling on private lands	On Gaya Prasad field	Soil conservatori and Land improvement	1	0.04	0.01	0.03	5
Earth work for road	On east side of Chandra village	Rural connectivity	1	2.10	1.83	0.00	1830
Culvert	On West side of the village Chandra	Rural connectivity	1	1.24	0.45	0.63	450
Inter village connectivity	From hamlet to Chandra	Rural connectivity	1	53.25	19.00	27.30	19000
Brick road in the village	From Rajendra to Virendra house	Access & drainage with in the village	1	3.11	1.13	1.58	1125
Repair of Brick road in the village	From Vinod house to open well	Access & drainage with in the village	1	0.21	0.08	0.11	75
Bathing *ghat* construction on the pond	*Kanua* talab *Purva* ghat	Water conservation	1	1.46	0.67	0.60	667

contd...

Work type	Work description	Work category	Starting year	Estimated total cost (Rs lakh)	Estimated labour cost (Rs lakh)	Estimated material cost (Rs lakh)	stimated person days
Rejuvenation and *ghat* construction	*Jamuna* talab	Water conservation	1	5.83	2.67	2.40	2667
De-silting of ponds	*Hansi Talab Purva*	Water conservation	2	23.48	20.41	0.00	18558
De-silting of drains on both side of roads	From *Purva* to Chandra	Drainage	2	1.13	0.98	0.00	890
De-silting of irrigation channels	From west side to approach road	Irrigation	2	0.22	0.19	0.00	170
Plantation on common lands	Near *Durga* Temple	Forestry and plantation	2	1.02	0.85	0.04	770
Land leveling on private lands	On Ganga Prasad field	Soil conservaton and Land improvement	2	0.04	0.01	0.03	5
Culvert	Near Chandra village	Rural connectivity	2	1.37	0.50	0.69	450
Repair of Brick road in the village	From Ramprasad house to Ganga Prasad	Access & drainage with in the village	2	0.46	0.17	0.23	150
De-silting of ponds	*Guda* pond	Water conservation	3	21.69	18.86	0.00	15588
De-silting of irrigation channels	From East side to Rajendra field	Irrigation	3	0.09	0.08	0.00	68
Plantation on common lands	On Primary School land	Forestry and plantation	3	0.56	0.47	0.02	385
Land leveling on private lands	On Chote lal field	Soil conservation and Land improvement	3	0.04	0.01	0.03	5
De-silting of ponds	*Kapat Talab* of *Purva*	Water conservation	3	15.49	13.47	0.00	11135
Land leveling on private lands	On Hemraj field	Soil conservation and Land improvement	3	0.04	0.01	0.03	5
De-silting of ponds	*Samera talab*	Water conservation	4	34.09	29.64	0.00	22269
De-silting of ponds	*Jangi talab*	Water conservation	4	23.86	20.75	0.00	15588
			Total	210.61	149.36	33.78	129022

works would generate 129,161,978 person-days of employment for 5–year period, which would benefit 49% of the total households in the district. The total cost of the proposed NREGA works for the 5–year period in the district was Rs 2475.5 crores and averaged Rs 37.3 lakhs for a gram *panchayat* per year.

About 73% of proposed works and 59% of total cost relate to natural resource management (Table 4). About 63% employment generated through water conservation activities. Due to heavy population pressure on land, limited common lands are available for construction of new ponds and reservoirs in the district and hence most recommended water conservation works were related to de-silting of existing ponds. About 41% of total cost of all NREGA works was for rural connectivity. Similarly, 81% of the total material cost of all proposed works was towards the connectivity in Sitapur district. Historically dominant paradigm of development works executed by government agencies for rural employment programs have been related to road connectivity, access and drainage works within village and hence the village community preferred such type of works. The rural community needs to be oriented towards common land re-generation, and development of natural resources which would lead to increased productivity and creation of livelihood opportunity.

Table 3. Estimated person days, percent household benefited, total cost and no of projects for various community development blocks in the Sitapur district.

S.No.	Community Development Block Name	Estimated person days	Estimated Percent household benefited	Estimated total cos.(Rs , lakhs)	No. of projects
1.	Pisawan	64,22,989	42	11,375.56	1,279
2.	Biswan	95,42,614	52	18,776.27	2,594
3.	Maholi	40,58,346	36	7,026.02	1,316
4.	Khairabad	64,74,699	49	13,900.62	1,742
5.	Parsendi	70,75,804	49	14,776.54	2,168
6.	Mishrikh	56,39,058	43	10,889.03	1,051
7.	Hargaon	55,07,708	39	10,269.10	1,427
8.	Sidhauli	75,66,943	54	12,686.67	1,751
9.	Machrehta	54,92,281	41	9,834.77	1,521
10.	Mahmudabad	39,45,299	35	6,386.61	1,073
11.	Gondlamau	73,18,101	49	14,134.37	1,968
12.	Laharpur	53,65,620	47	9,730.30	1,695
13.	Reusa	92,94,810	51	18,796.58	2,709
14.	Sakran	61,63,272	44	12,893.18	1,614
15.	Rampur Mathura	62,56,375	44	12,088.35	1,158
16.	Pahla	92,19,153	71	16,460.41	1,831
17.	Aliya	66,73,343	52	12,671.60	1,871
18.	Kasmanda	73,50,949	53	13,097.51	1,254
19.	Behta	97,94,614	67	21,762.68	3,312
District Total		129,16,1978	49 (average)	247,556.20	33,334

Table 4. Estimated Number of Projects, Person days , labour, material and Total costs for various work categories under NREGA in Sitapur district

Work category	No. of projects (% of total)	Estimated person days (% of total)	Estimated labour cost, Rs. Lakhs (% of total)	Estimated Material cost, Rs. Lakhs (% of total)	Estimated total cost including maintenance, Rs. Lakhs (% of total)
Water conservation	4,718 (14)	812,58,582 (62.9)	97,105 (62.9)	3,047 (5.0)	115,175 (46.5)
Land development	1,720 (5)	1,36,733 (0.1)	163 (0.1)	184 (0.3)	398 (0.2)
Irrigation	1,451 (4)	16,12,279 (1.2)	1,787 (1.2)	nil	2,056 (0.8)
Forestry and plantation	4,555 (14)	25,08,633 (1.9)	3,042 (2.0)	154 (0.3)	3,676 (1.5)
Flood protection	428 (1)	10,83,651 (0.8)	1,232 (0.8)	nil	1,417 (0.6)
Drainage	4,437(13)	45,63,893 (3.5)	5,147 (3.3)	nil	5,919 (2.4)
Access & drainage within the village	7,181 (22)	49,51,313 (3.8)	6,043 (3.9)	8,316 (13.7)	16,513 (6.7)
Rural connectivity	8,844 (27)	330,46,893(25.9)	39,967 (25.9)	49,078 (80.7)	1,02,402 (41.4)
District total	33,334	1291,61,978	154,486	60,780	2,47,556

Impact assessment

Figure 6 provides the Google imageries of village Khagasia Mau in Aliya block on two dates : March 3, 2006 (before implementation of NREGA works) and June 3 ,2011(after implementation of NREGA works) for better appreciation of the impact, The imagery taken on June 3, 2011 shows more number of ponds compared to March 2006.

Table 5 provides quantitative estimates of outcomes of various works. De-silting of the existing ponds and construction of new ponds would result in additional storage capacity of 11,048 ha-m at the end of plan period. It is expected that increased water availability would result in increased irrigated area and increasing cropping intensity by 19%, additional yields of paddy by 25,072 metric tons and wheat by 39,327 metric tons over existing production. Total cost incurred on

Table 5. Expected outcomes of various works in Sitapur district

Category and NREGA works	Estimated Work Quantity
Water conservation	
Increased runoff storage capacity through de -silting of existing ponds	10,687.5 ha m
Creation of new storage facility through digging new ponds	1,110 ha-m
Drainage	
De-silting of drains in the field	611.5 km
Construction of new drains in the field	936.5 km
De-silting / reshaping of drainage channels on both side of access road	2,318 km
Construction of new drainage channels for canal seepage	364 km
Soil conservation and land improvement	
Field bunding on rural Poor's field	238 ha
Field leveling on rural Poor's fields	450 ha
Forestry and tree plantation	
Tree plantation on community lands	1,461 ha
Tree plantation on both sides of roads	3,106 km
Tree plantation on rural poor' s field bunds	470 ha
Irrigation	
Canal de-silting	478 km
Irrigation channel de-silting	1,946 km
Rural connectivity	
Earth work for road	1,34,172 m^3
Connectivity to main road	382 km
Culverts	1,800 no
Causeway culvert	213 no
Connectivity within village in *gram panchayats*	2,400 km
Road connectivity to the villages of other *gram panchayats*	2,228 km
Construction and repair of brick road within villages	234.9 K m
Access and drainage within villages	
Drain de-silting and drain repair in the village	248.3 km
Flood protection	
Construction of bunds	428 km
Total household likely to benefit each year (100 days) under non-NREG work	52,962 households
Total employment created under NREGA work, for 5 years	1291,61,978 person days
Total household likely to benefit each year (100 days) under NREG works	2,58,324 households
Total cost for NREGA works	Rs 2,475.56 crores
Cost of NREGA works / village	1.863 crores

works related to water conservation during five years was estimated as Rs 1151.75 crores. Considering the minimum support price (MSP) for paddy and wheat in 2009 and 5% increase in MSP and yields of paddy and wheat per year, it is estimated that additional monetary return over 10 -year period totals Rs 1102 crores. The monitory benefits are in addition to employment generation, flood protection and arrest of ground water depletion. Land degradation and nutrient losses would also reduce with reduction in peak runoff rates.

Increasing storage capacity in ponds would also provide livelihood opportunities through seasonal fish cultivation. Research results elsewhere suggest that de-silted soil from existing ponds, when re-deposited on the agricultural fields, would provide, on an average, 730 mg nitrogen, 357 mg phosphorus and 11.64 gms organic carbon per kg of soil (Padmaja KV, et al., 2003). Approximately 176, 970 thousand metric tons of soil excavated from existing ponds would provide 111,703 thousand metric tones of N, about 5,724 thousand metric tons of P and 20, 600 thousand metric tons of organic C. Monetary value for recovered N and P amounts to Rs 12.3 crores and Rs 278 crores respectively at subsidized cost. Higher amount of organic carbon in soil would also help in increased mineralization of nutrients and their availability for improved crop production and increase income.

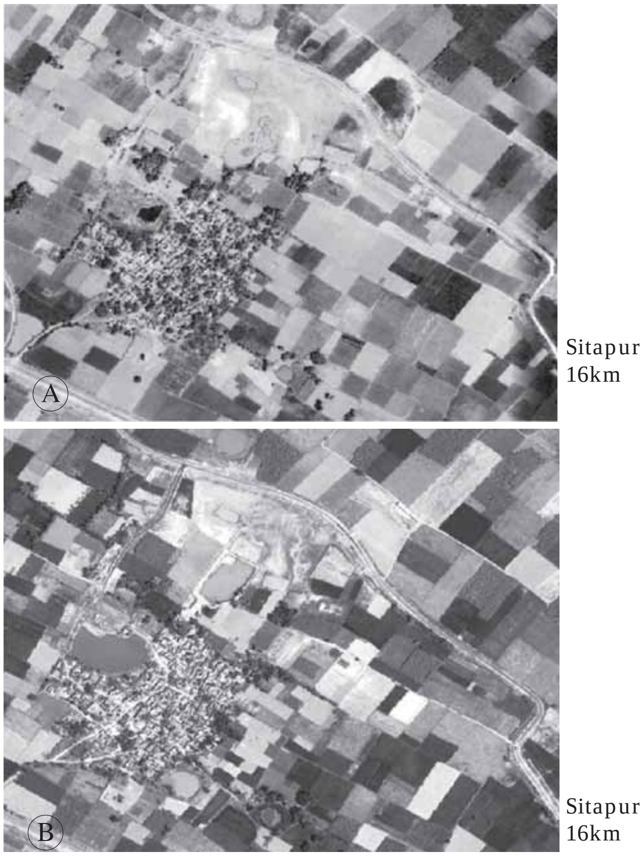

Figure 6. The aerial picture of Khagasiya Mau village,, Aliya block in Sitapur district. (a) 3 March 2006 (b) 3 June 2011

A World Bank impact study of ‘Uttar Pradesh Diversified Agriculture Support Project ‘in adjoining districts of Sitapur showed that construction of rural roads would result in internal rate of return of 24% and increase of traffic density by 14%. The study also showed that rural connectivity through improved road would result in increase of land value by 25% and crop diversification by 40 % through vegetables and horticulture on both sides of the roads (Anonymous, 2004). It is expected that the there would be similar impacts of rural connectivity in the Sitapur district also. afforestation and plantation of trees would increase employment and income of rural poor.

NREGA can enable to put money into the hands of the poor which would create purchasing power among workers. The spending of additional money would create demand for commodities, raw material and workers which again provides a stimulus to private investment, production, employment and demand and stimulate multiplier process for increased employment and income over time on the foundation of water security. NREGA works would also help in decline in the size of the work guarantee over time, as public investment under NREGA leads to higher rural incomes, which in turn spurs private investment, and greater incomes and employment.

Integration and Convergence with other development programs

The objective of the NREGA is not only to enhance the livelihood security of the people in rural areas by guaranteeing wage employment but also to create durable assets and strengthening the livelihood resource base of the rural poor on a sustainable basis.

Empowerment of workers and creation of durable assets depend to a great extent on the linkages between NREGA and other development programs. Substantial public investments are being made to strengthen the rural economy and the livelihood base of the poor. There is need to optimize efforts through inter- sectoral approaches to effectively address the issue of poverty alleviation, NREGA by encouraging works on water harvesting, flood protection, afforestation and plantation etc ,which are also interventions in the watershed development programs , helps to insulate local community from adverse effects of climate change The convergence of different programs like, Watershed Development Programs, rural connectivity through Pradhan Mantri Sadak Yojana, National Agriculture Development Program (Rashtriya Krishi Vikas Yojana), National Horticulture Mission , Scheme of Artificial Recharge of Ground Water through Dug wells , Accelerated Irrigation Benefit Program, Command Area Development and Water Management Program and scheme of Repair, Renovation and Restoration of Water Bodies of Water Resources Department, Backward Region Grant Fund with NREGA will enable better planning and effective investments in rural areas. Convergence also brings synergy between different government programs /schemes in term of planning, process and implementation of programs /schemes.

The permissible works under NREGA recognizes the possibility of a need arising for works other than those specifically indicated in the schedule of works. The NREGA Act specifies that the states may identify other works in conformity with the general principles of the Act and the rationale for them. government program/schemes in term of planning, process and implementation of program/Schemes.

Convergence through NREGA will have the advantage of: ?a wide range of works: almost all works required for watershed development in rain-fed area, command area development in irrigated areas and fair weather road for rural connectivity,???? untied funds for local area planning, the provision of decentralized planning which enables comprehensive need assessment at grassroots and greater ownership of projects, legal safeguard of the Act ,facilitating sustainable development through natural resource management???? effective targeting and development of human capital and physical capital through institutional linkages. Convergence of the NREGA funds with funds from other sources can help in creation of durable assets. Funds available with Panchayat Raj institutions from other sources for instance, can also be dovetailed with NREGA funds for the construction of durable community assets under the permissible works.

CONCLUSION

Earlier employment programs followed focused on quantitative approach which resulted in unproductive assets leaving people either unemployed or grossly underemployed. NREGA, with a focus on natural resource conservation and creation of productive assets, attempts to be relevant to local needs. The NREGA perspective plan for Sitapur district has shown that adequate employment can be created at each *gram panchayat* through creation of productive assets and development of natural resources for sustainable development.

The community development block and district perspective plans are result of collection and consolidation of *gram panchayat* level planning and needs to be done in planned manner at a landscape level so that discrepancies in *gram panchayat* level planning is taken care and concerns of inter- gram panchayat are addressed and contradiction are avoided.

Appropriate technology solutions have been worked out by various national and international research institutions in India to provide a rational database for agricultural and rural development which can be used for preparing NREGA plans and its technical norms and designs so that the choice of works is guided not just by the expediency of immediate employment provisioning but also by the logic of sustainable natural resource development giving primacy to water conservation.

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