13.1 : Salient highlights of Research

13.1.1 : GIS based Block level soil nutrient mapping

Spatial variability in soil parameters including nutrients has been attributed to the parent material, topography, landforms, cropping pattern and fertilization history. Blanket nutrient recommendations further widen the variability and enhanced the risk of soil degradation in terms of soil organic carbon and nutrient depletion, acidity, green house gas emission, water and environmental pollution. Unfavorable economics on account of blanket recommendation are bound to adversely influence the enthusiasm of farmers to enhance investments in new technologies. This results in low farm productivity and poor soil health will jeopardize food security and agricultural sustainability.

Soil nutrient mapping at district level was attempted in the past by collecting soil samples at the interval of two and half kilometer. The resultant map is being utilized for district planning. However, for translating the map information for farm planning soil sampling at closer interval (500 meter) is appropriate to capture all kind of variability in nutrient status. For bridging the outlined gaps NBSS & LUP, Nagpur and Regional Centre, Kolkata in collaboration with the Department of Soil Science and Agricultural Chemistry, BAU, Ranchi and Department of Agriculture & cane Development, Govt. of Jharkhand, has taken up a model project in Jharkhand state entitled "Assessment and Mapping of Some Important Soil Parameters including Macro & Micro Nutrients for Dumka, Jamtara and Hazaribagh districts for Optimum Land Use Plan".

The objective of the project is to prepare GIS aided block wise soil parameters maps including nutrients (Organic carbon, available N, P, K, S and available Fe, Mn, Zn, Cu, B and Mo) along with the maps of soil pH and surface texture block wise for Dumka, Jamtara and Hazaribagh districts of Jharkhand for helping in formulating optimum land use plan.

Around forty seven thousand samples (8090 Jamtara, 21000 Hazaribagh and 18000 Dumka) has been collected at 500 meter grids on the base of topographical sheet of Govt. of India on 1:50,000 scale. Geographical location of each sampling point will be collected through Global positioning system (GPS). Samples are being analyzed for soil pH, surface texture and macro and micro nutrients. Database consisting of geographic location, nutrient status and management history of each collected samples is being developed in GIS. Appropriate geo-statistics will be used for depicting spatial distribution of nutrients on the maps. Conceptual model of the project is shown.

Table 1. District wise fertility status of Jharkhand soils.

District	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	L	M	H	L	M	H	L	M	H
Bokaro	14.3	57.6	24.2	66.0	30.1	0.0	21.5	57.9	16.7
Chatra	20.7	63.1	15.3	78.3	20.5	0.3	7.3	49.6	42.2
Deogarh	33.9	56.1	8.3	12.8	54.8	30.7	10.7	26.7	60.9
Dhanbad	4.1	74.2	17.0	68.8	26.5	0.0	48.4	37.9	9.0
Dumka	15.7	74.7	7.3	53.4	30.7	13.6	11.8	42.1	43.8
East Singhbum	8.6	83.9	5.1	88.7	8.9	0.0	35.0	53.0	9.6
Garhwa	16.6	73.7	8.6	36.6	48.8	13.5	8.6	65.1	25.2
Giridih	8.3	82.4	8.2	79.0	19.8	0.1	19.2	43.7	36.0
Godda	1.8	88.7	7.7	92.2	6.0	0.0	25.5	58.6	14.1
Gumla	33.3	64.8	1.2	80.4	18.0	0.9	17.5	57.8	24.0
Hazaribagh	17.9	69.4	10.5	57.8	38.5	1.5	11.6	48.1	38.0
Jamtra	20.2	76.5	0.0	73.1	23.6	0.0	21.3	61.3	14.1
Koderma	22.1	62.1	14.7	76.8	22.1	0.0	22.0	32.8	44.1
Latehar	24.3	63.1	11.7	46.3	46.7	6.1	9.2	42.0	47.9
Lohardaga	72.6	25.7	0.4	15.6	19.3	63.8	25.8	47.1	25.8
Pakur	3.1	87.9	7.0	75.3	22.5	0.2	25.1	46.3	26.6
Palamu	15.8	68.3	11.3	46.8	43.4	5.2	5.5	55.9	34.0
Ranchi	26.1	67.2	4.5	40.1	56.2	1.5	13.0	57.1	27.7
Sahebganj	8.5	66.1	17.5	70.9	21.2	0.0	26.6	41.2	24.3
Saraikela	12.4	80.2	5.1	94.9	2.7	0.1	27.4	64.8	5.5
Simdega	56.6	41.6	0.8	90.5	8.2	0.3	6.1	43.9	49.0
West Singhbhum	5.8	86.4	6.9	95.3	3.8	0.0	30.9	57.3	10.9
Jharkhand	19.6	70.0	8.3	65.8	27.7	4.5	17.9	50.9	29.2

Table 2. District wise fertility status of Jharkhand soils

	Organic carbon (%)			Available Sulphur (%)		
	Low	Medium	High	Low	Medium	High
Bokaro	15.9	14.8	65.4	28.3	30.4	37.4
Chatra	26.2	35.8	37.1	28.1	38.3	32.7
Deogarh	29.9	20.5	47.9	35.3	21.5	41.5
Dhanbad	4.5	7.4	83.4	13.9	31.7	49.7
Dumka	24.6	25.3	47.8	42.2	44.3	11.2
East Singhbum	9.9	26.1	61.6	46.6	31.3	19.7
Garhwa	15.0	37.1	46.8	29.5	31.3	38.1
Giridih	35.4	23.5	40.0	25.2	23.7	50.0
Godda	2.7	11.7	83.3	36.6	42.1	19.5
Gumla	37.3	33.5	28.5	34.8	35.1	29.4
Hazaribagh	15.9	17.4	64.5	33.8	30.4	33.6
Jamtra	24.6	24.7	47.4	25.8	39.7	31.2
Koderma	30.6	16.1	52.2	33.1	19.1	46.7
Latehar	22.1	21.2	55.9	70.9	25.7	2.5
Lohardaga	37.6	28.2	32.9	77.9	20.4	0.4
Pakur	8.6	20.9	69\8.5	42.2	41.4	14.4
Palamu	15.4	37.4	42.6	20.4	26.1	48.9
Ranchi	25.3	28.7	43.8	36.7	30.5	30.6
Sahebganj	11.6	15.8	64.7	56.3	19.5	16.3
Saraikela	15.1	22.2	60.4	40.9	26.2	30.6
Simdega	46.2	39.4	13.4	25.8	42.3	30.9
West Singhbhum	9.8	21.6	67.7	61.6	28.9	8.6
Jharkhand	21.8	25.6	50.6	38.0	31.1	28.8

Table 3. District wise micronutrient status of Jharkhand soils

	Zinc (%)		Copper (%)		Boron (%)	
	Deficient	Sufficient	Deficient	Sufficient	Deficient	Sufficient
Bokaro	1.1	95.0	4.7	91.4	22.5	73.6
Chatra	7.2	91.9	1.5	97.6	35.4	63.7
Deogarh	6.6	91.7	7.5	90.8	45.1	53.2
Dhanbad	2.1	93.2	0.3	95.0	9.1	86.2
Dumka	6.7	91.0	5.5	92.2	27.3	70.4
East Singhbum	1.1	96.5	0.9	96.7	77.3	20.3
Garhwa	3.9	95.0	4.5	94.4	70.8	28.1
Giridih	14.7	84.2	9.9	89.0	46.6	52.3
Godda	8.7	89.5	0.7	97.5	24.7	7.35
Gumla	0.7	98.6	2.4	96.9	48.8	50.5
Hazaribagh	4.2	93.6	5.5	92.3	38.9	58.9
Jamtra	3.8	92.9	0.9	95.8	23.0	73.7
Koderma	16.9	82.0	9.9	89.0	23.9	75.0
Latehar	3.5	95.6	6.9	92.2	84.5	14.6
Lohardaga	13.8	84.9	16.8	81.9	71.5	27.2
Pakur	13.5	84.5	0.7	97.3	27.2	70.8
Palamu	9.7	85.7	1.3	94.1	67.7	27.7
Ranchi	4.1	93.7	5.6	92.2	42.8	55.0
Sahebganj	2.3	89.8	1.8	90.3	38.5	53.6
Saraikela	3.6	91.1	5.4	92.3	54.9	42.8
Simdega	0.4	98.6	2.3	96.7	45.7	53.3
West Singhbhum	5.5	93.6	2.2	96.9	38.0	61.1
Jharkhand	7.4	90.6	4.3	93.6	44.5	53.4

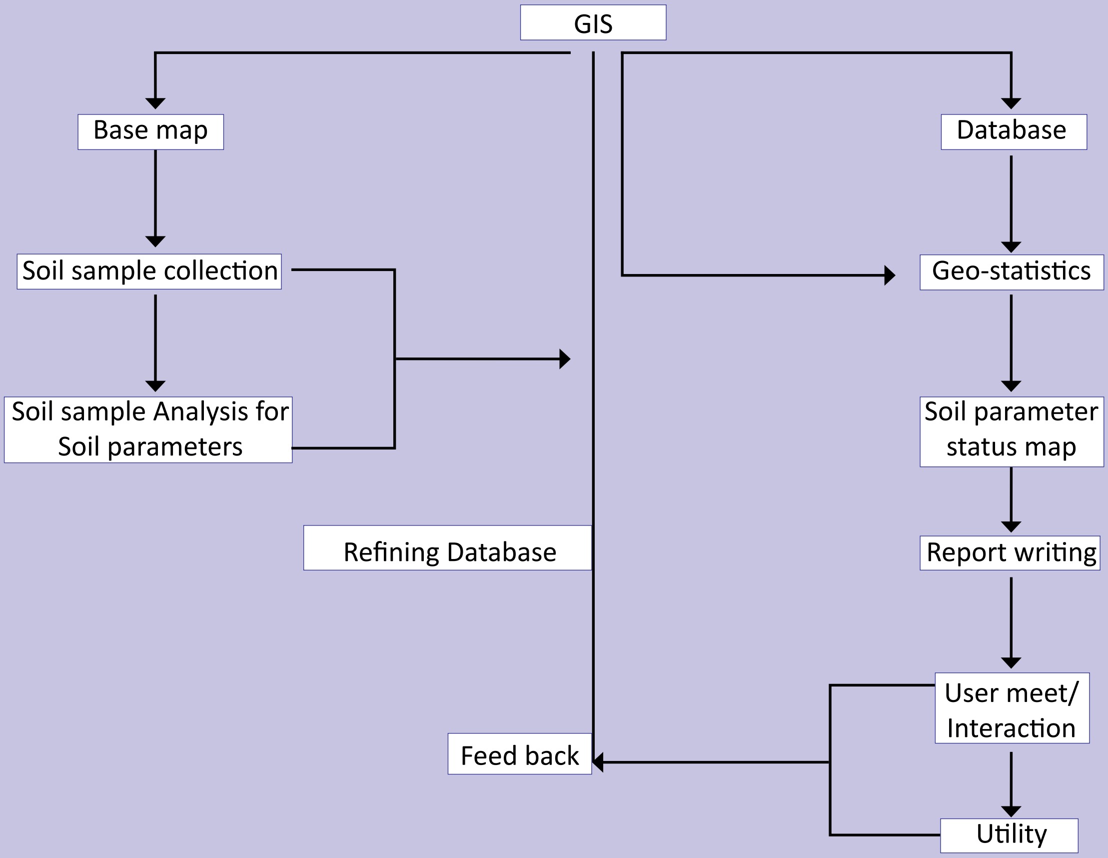

Fig. 1. Conceptual model

District level soil maps of the State reveal that wide spread variations among districts in the status of soil acidity, soil organic carbon and available N, P, K, S, B, Zn, Cu, Fe,Mn.

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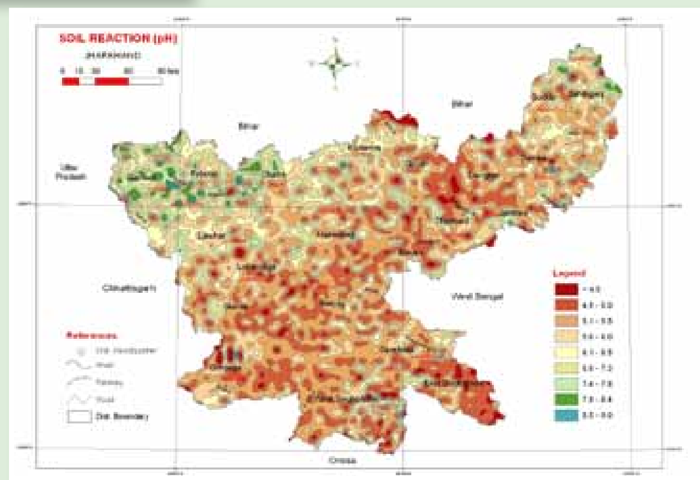
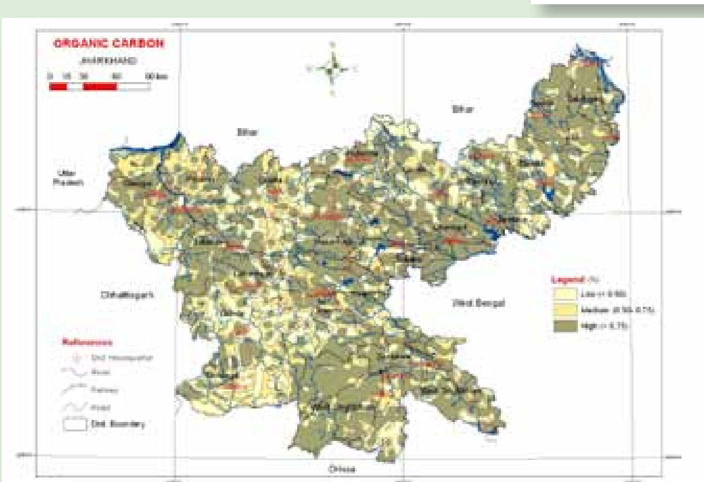
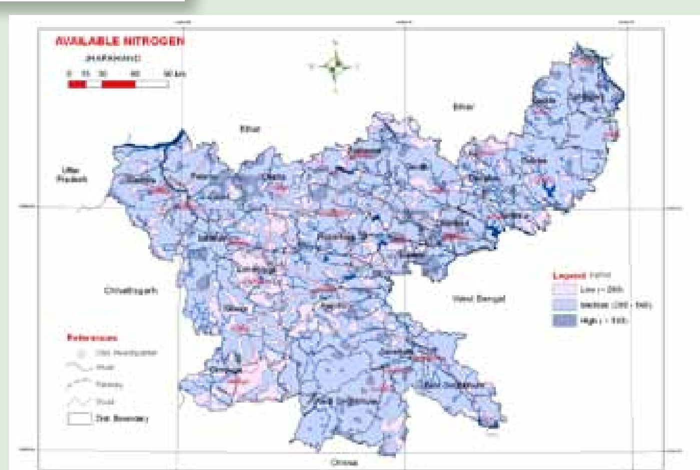
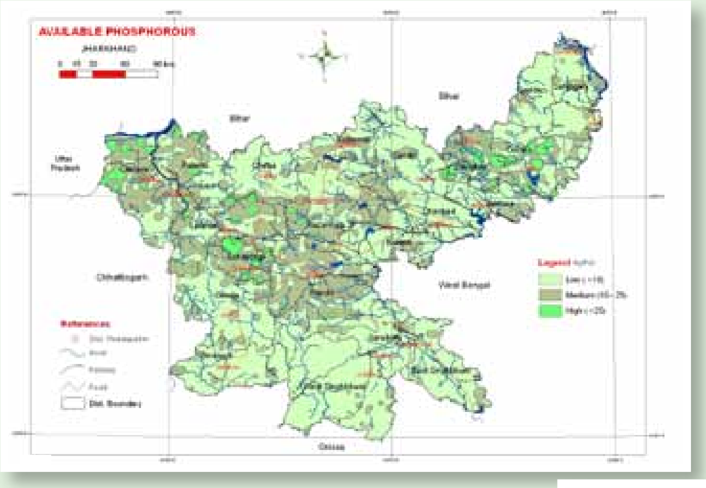
GIS based State level soil nutrient map

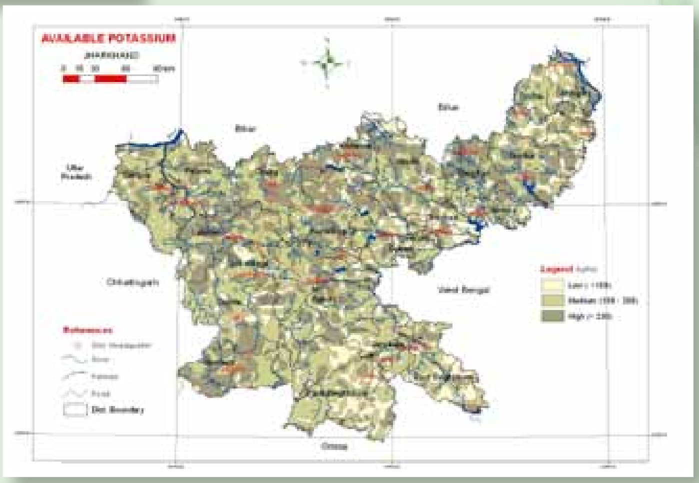


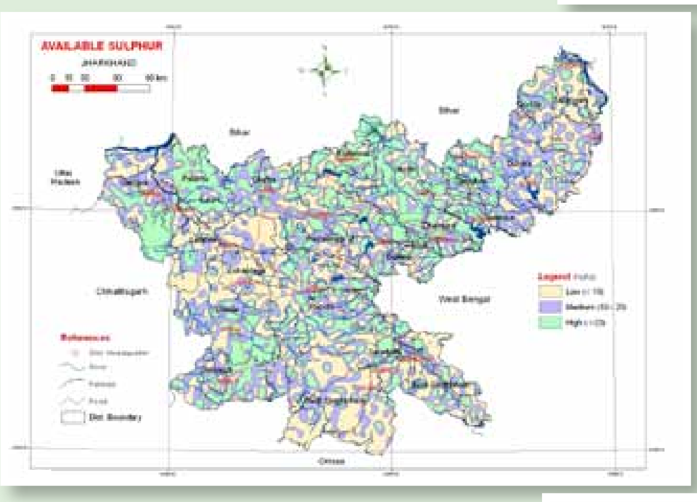


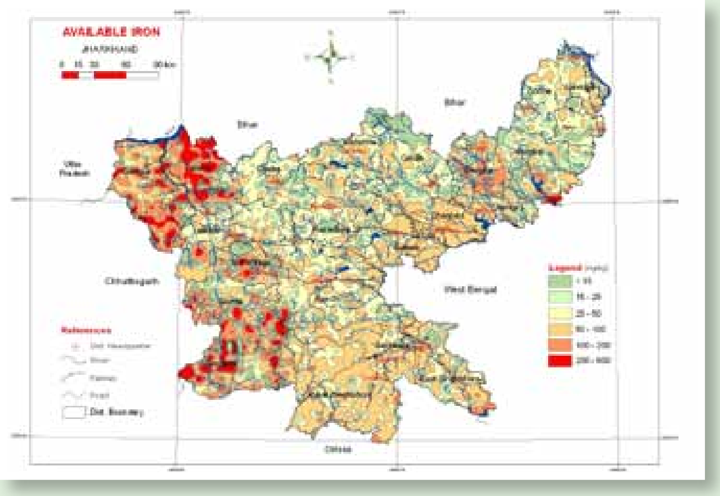


GIS BASED STATE LEVEL SOIL NUTRIENT MAP









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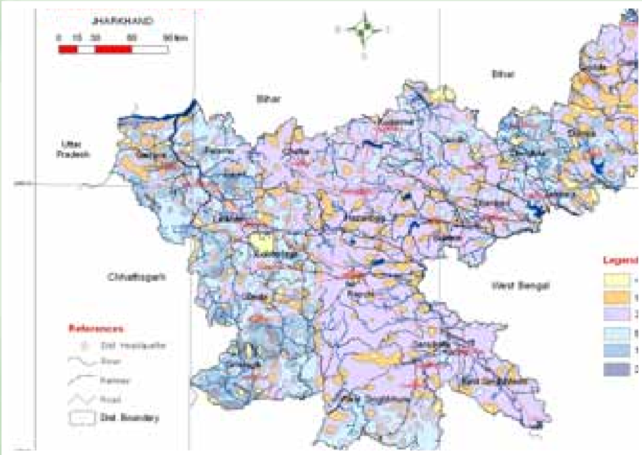
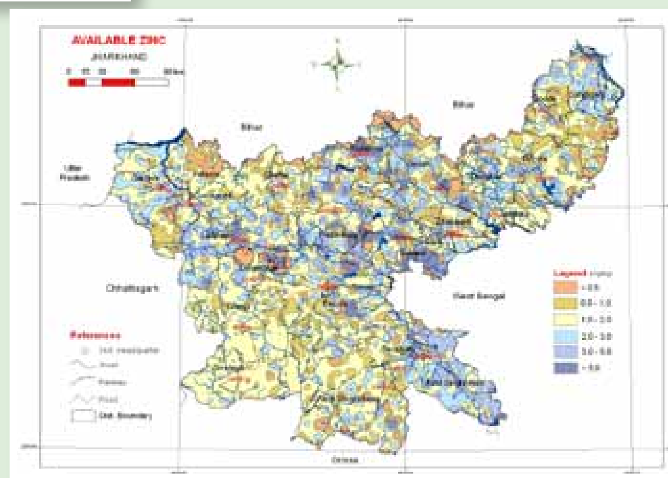
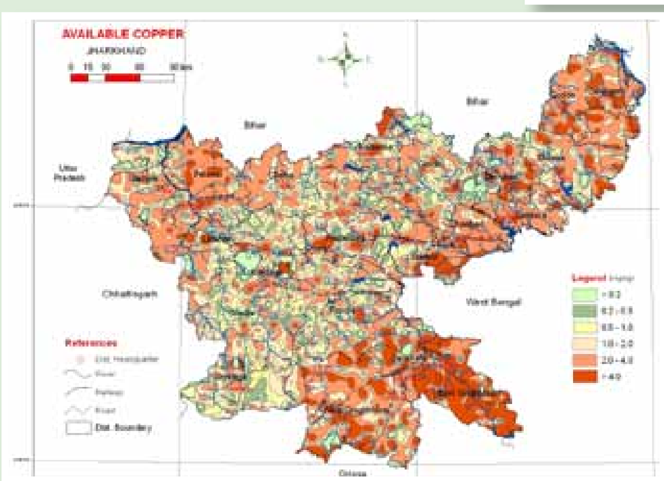
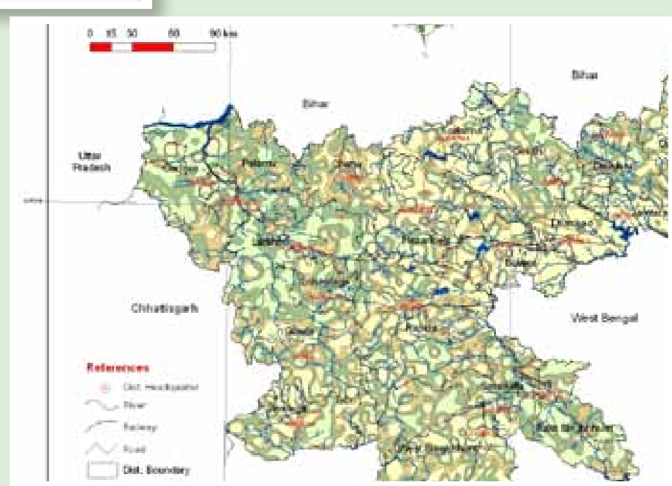
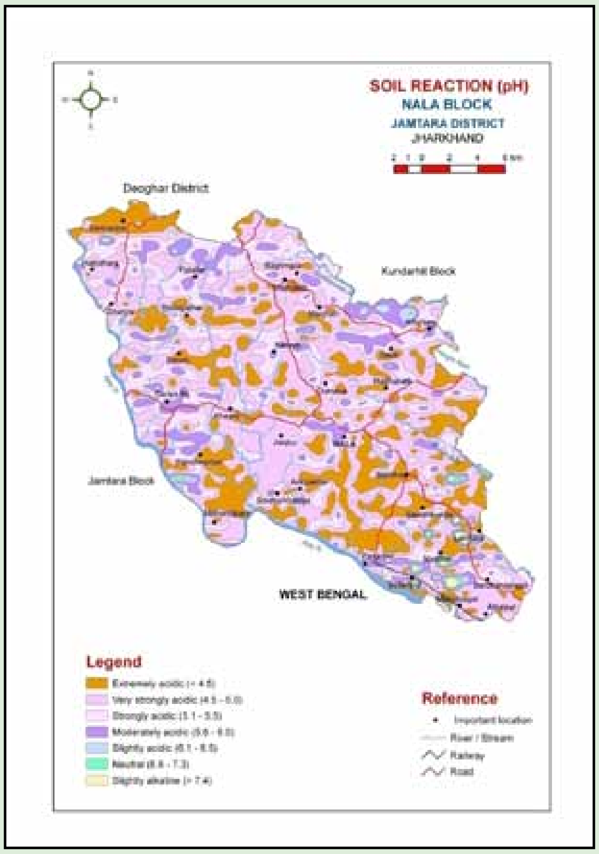


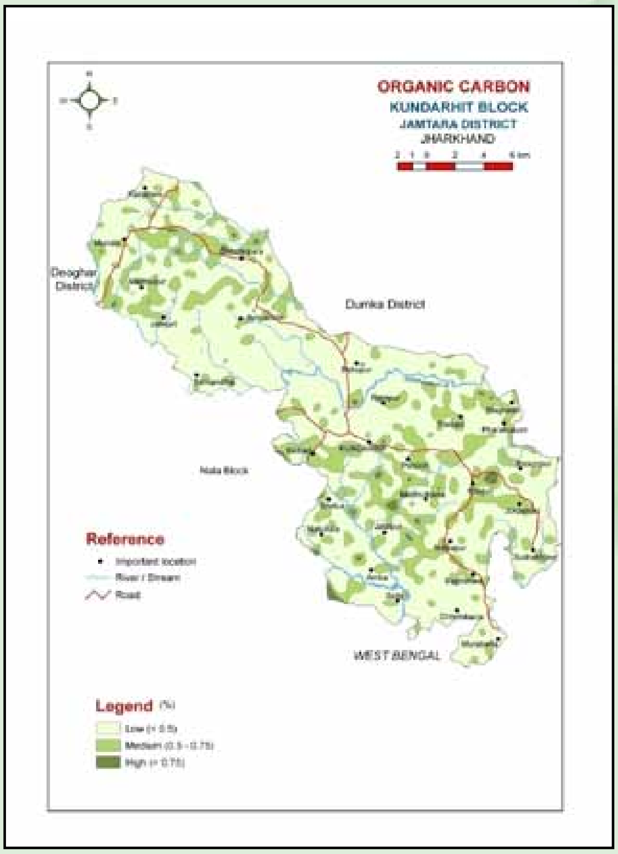


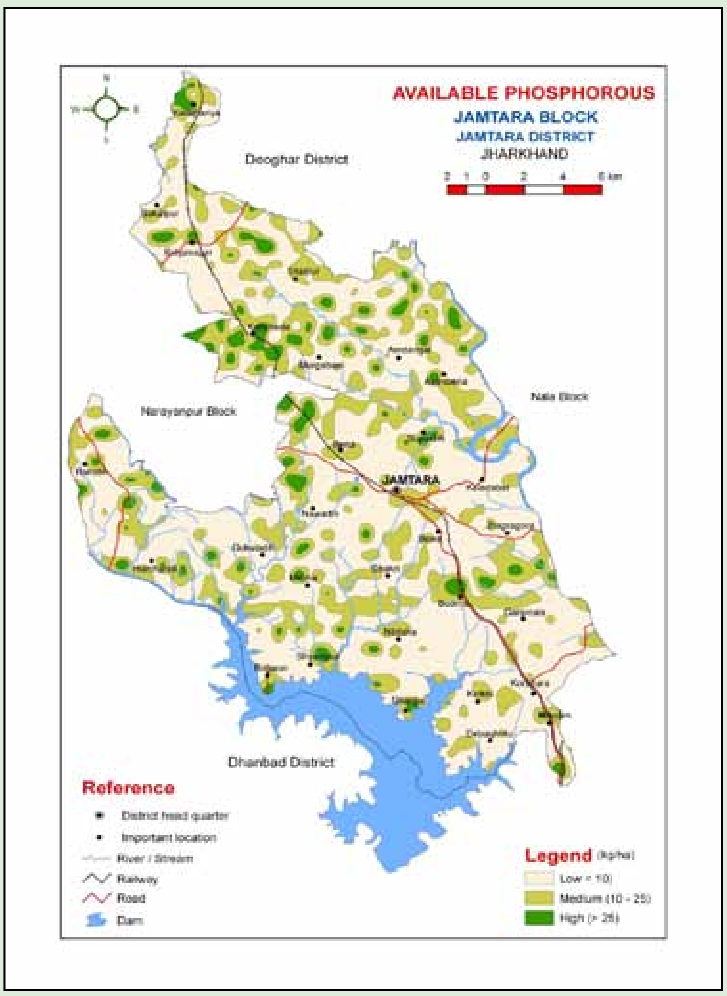




GIS BASED BLOCK LEVEL SOIL NUTRIENT MAP







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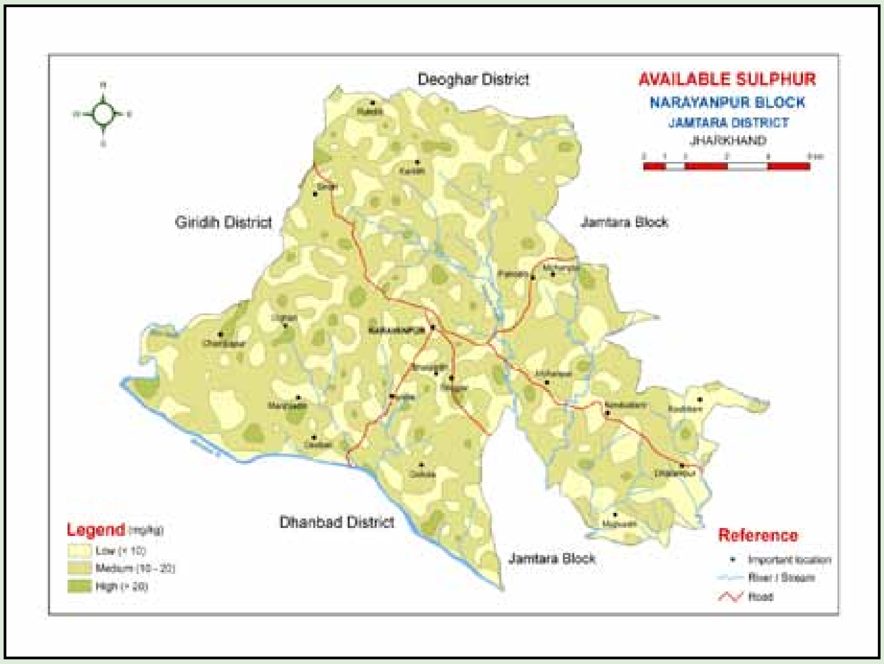
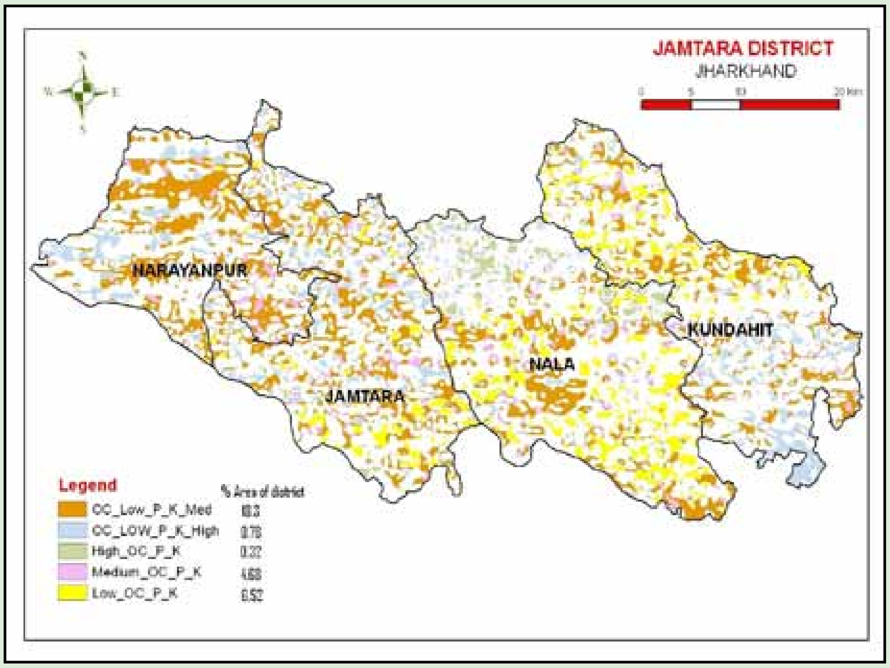
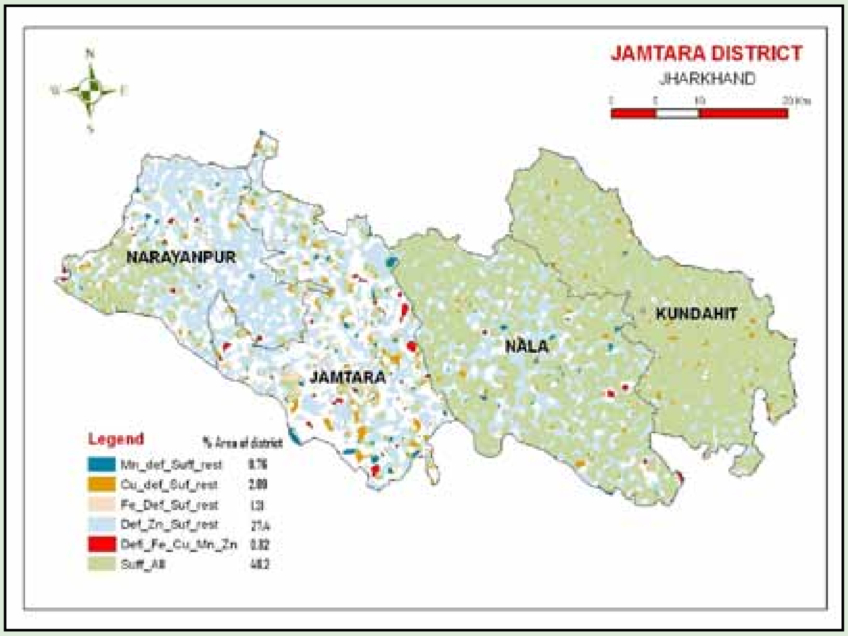


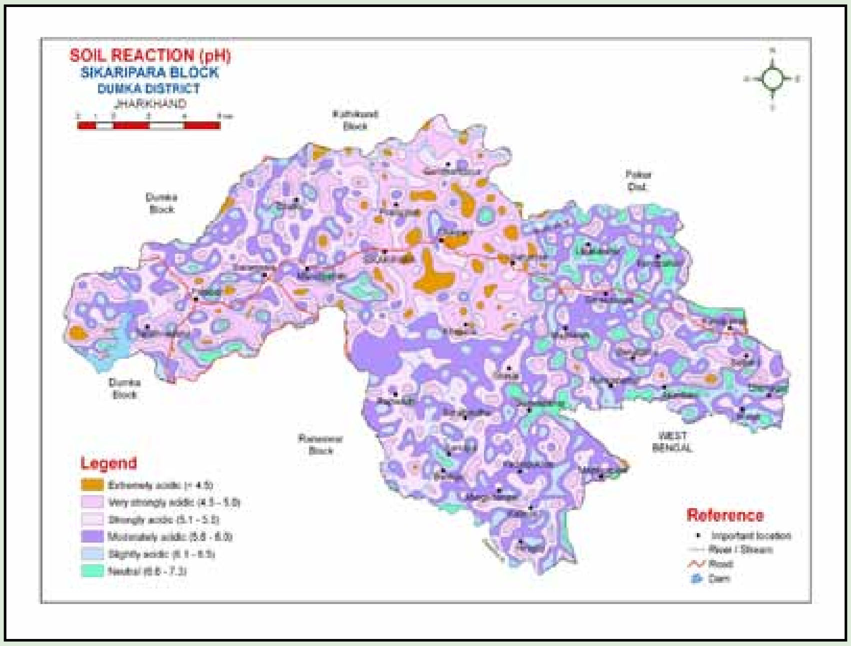


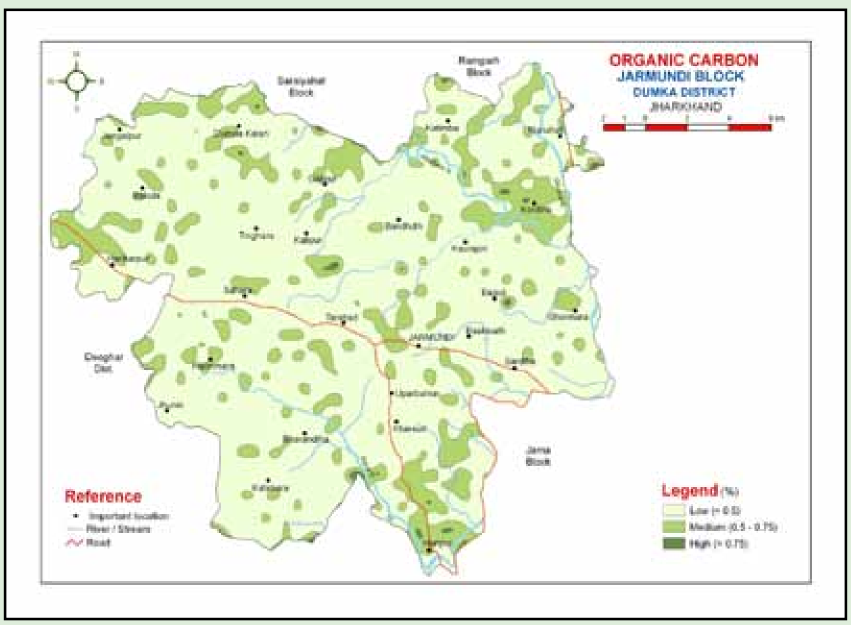
NUTRIENT STATUS OF DUMKA DISTRICT

Attributes	Jama	Sikaripara	Saraiyahat	Kathikund	Jarmundi
	Area in sq. km. (%)				
pH (<5.5)	217.6 (57.3)	248.9 (54.8)	164.7 (53.2)	212.2 (63.1)	148.1 (37.4)
OC (<0.5%)	257.1 (67.7)	330.2 (72.8)	188.2 (60.8)	275.4 (81.9)	316.1 (79.9)
Available P (<10 kg/ha)	125.1 (32.9)	75.6 (16.6)	59.9 (19.3)	98.3 (29.2)	34.2 (8.6)
Available K (<108 kg/ha)	40.7 (10.7)	51.1 (11.3)	31.3 (10.1)	31.5 (9.4)	5.7 (1.4)

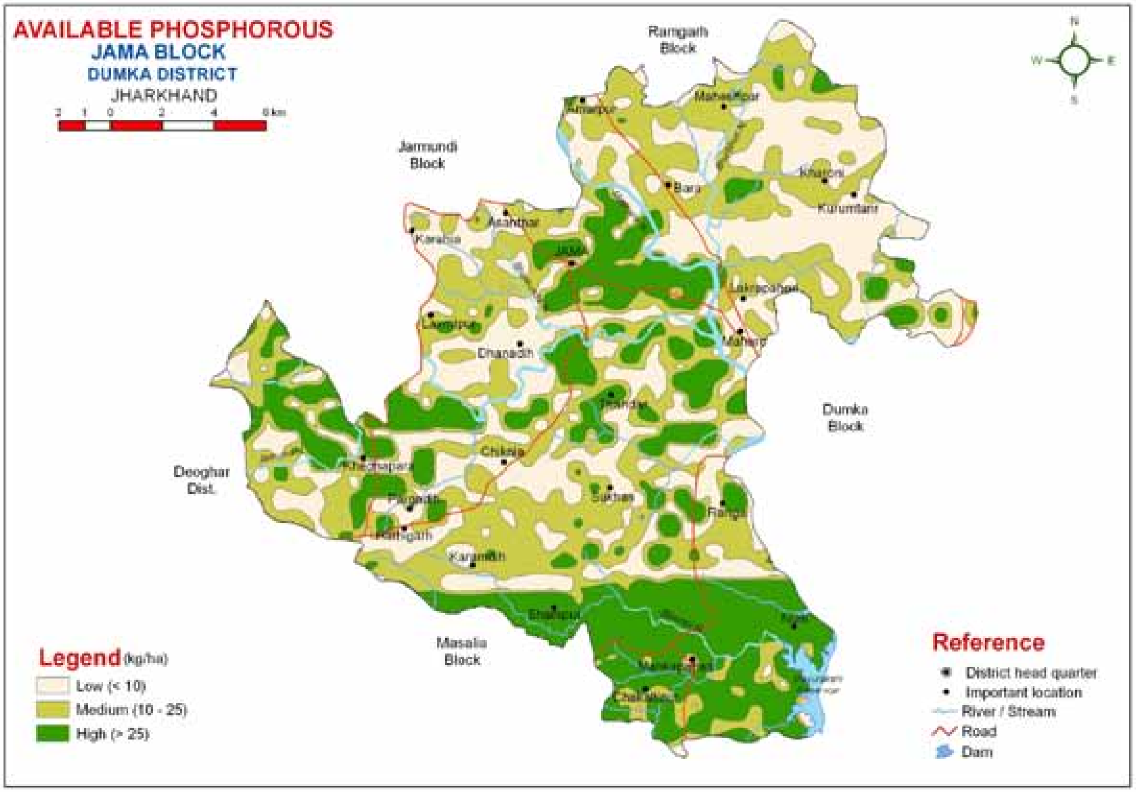
GIS based Block level soil nutrient map

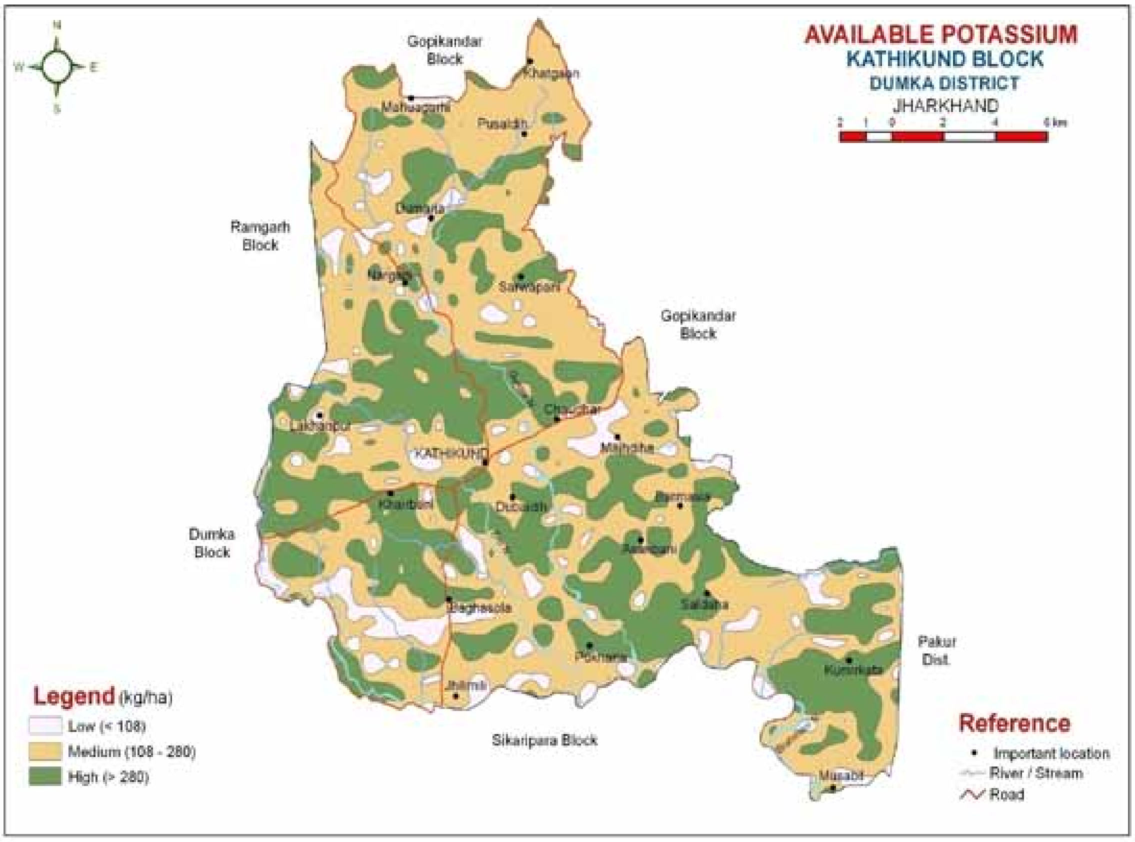






GIS based Block level soil nutrient map





Block level maps for Jamtara and Dumka have been developed. Some of the results of Jamtara are given in table 4 to 7.

Table 4. Organic Carbon (%) in Jamtara Block.

Classes	Area (ha)	(%)
Low (<0.5)	33737	71.6
Medium (0.5-0.75)	10043	21.3
Miscellaneous	3320	7.0
Total Area	47100	100.0

Table 5. Available P status of Jamtara Block

Range (ppm)	Area (sq. km)	TGA (%)
<10	284.3	60.4
10-25	133.6	28.4
>25	19.9	4.2
Total	437.8	93.0
Miscellaneous	33.2	7.0
Total area	471.0	100.0

Table 6. Available Sulphur status of Narayanpur Block.

Range (ppm)	Area (sq. km.)	TGA (%)
<10	112.9	33.0
10-20	210.9	61.7
>20	12.5	3.7
Total	336.3	98.4
Miscellaneous	5.5	1.6
Total area	341.8	100.0

Table 7. Available Potassium status of Kundahit Block.

Range (kg K2O/ha)	Area (sq. km.)	TGA (%)
<108	138.5	30.5
108-280	187.6	41.3
>280	122.7	27.0
Total	448.8	98.8
Miscellaneous	5.5	1.2
Total area	454.3	100.0

13.1.2 : Soil quality, crop productivity & Sustainability of important rainfed cropping systems (Long Term Studies)

Nutrient balance in soybean-wheat cropping sequence

It is essential to study the apparent nutrient balance in soil to see the depletion or buildup of soil fertility due to cropping and nutrient use. Nutrient balance was calculated on the basis of the removal by grain and straw of the plants which, were harvested. Perusal of data (Table-8) on inputs (nutrient applied) and output (nutrient uptake) indicated a positive balance of P in 100% NPK, 150% NPK, 100% NP & 100% N(S)PK plots while negative balance in other treatments. There was negative balance of N and K in soil even under the best management practice (NPK with lime or NPK with FYM) for soybean-wheat cropping system.

Table 8. Nutrient balance under soybean-wheat cropping sequence

Treatments	Nutrient additions through fertilizers (kg ha^{-1} yr^{-1})			Nutrient removal by soybean -wheat (kg ha^{-1} yr^{-1})			Nutrient balance after harvest of wheat(kg ha^{-1} yr^{-1})		
	N	P	K	N	P	K	N	P	K
50% NPK	72.5	13.2	33.3	162.59	18.34	79.14	-90.09	-5.14	-45.84
100% NPK (T_2)	145	26.2	66.7	218.47	22.93	99.52	-73.47	3.27	-32.82
150% NPK	217.5	39.4	100.0	235.45	26.17	143.58	-17.95	13.23	-43.58
T_2 + HW	145	26.2	66.7	209.11	22.24	138.45	-64.11	3.96	-71.75
T_2 + Lime	145	26.2	66.7	270.97	30.98	132.48	-125.97	-4.78	-65.78
100% NP	145	26.2	0.0	139.98	16.66	89.98	5.02	9.54	-89.98
100% N	145	0.0	0.0	60.05	5.96	22.31	84.95	-5.96	-22.31
T_2 + FYM	145	26.2	66.7	295.67	35.69	184.97	-150.67	-9.49	-118.27
100% N(S) PK	145	26.2	66.7	172.01	18.64	91.66	-27.01	7.56	-24.96
Control	0.0	0.0	0.0	42.83	4.04	21.43	-42.83	-4.04	-21.43

Soil samples were collected from the three on-going permanent experiments viz., Permanent manurial trial (PMT) (since, 1956); Long term fertilizer experiment (LTFE) (since, 1972) and Crop Residue Management (CRM), (since, 1991) experiments under maize-wheat, soybean-wheat and maize-wheat cropping systems, respectively.

Soil

The soil of the experimental sites is acidic red loam with low to medium in available nutrients. Some of the important initial soil properties of the experimental sites are given in Table-9.

Table 9. Some of the initial soil properties of the experimental sites

Physical properties	
Textural class	Sandy loam
Bulk density (g/cc)	1.43-1.47
Specific gravity (g/cc)	2.67
Total pore space (%)	37-40
Hydraulic conductivity (cm/hr)	3.7-4.0
pH	5.5-5.6
C.E.C. (c mol (p+) kg^{-1})	7.8-10.5
Exch. Ca (c mol (p+) kg^{-1})	2.5-6.0
Exch. Mg (c mol (p+) kg^{-1})	1.7-2.5
Organic carbon (%)	0.45-0.52
Total N (%)	0.05-07
Available N (%)	0.025-0.07
Available P (ppm)	6.0-8.0
Available K(ppm)	120-360

Of the above three on-going permanent experiments, eight treatments each of these three experiments were selected. Details of the treatments selected for the above study are listed in Table 10.

Table 10. Details of the treatments under these three experiments.

PMT (Since, 1956)

Tr.No.	Treatments	Source of nutrients			
		N	P	K	
T_1	Control	-	-	-	A and B stand for full dose of P and K i.e. 90 kg P_2O_5 and 70 kg K_2O q ha^{-1} respectively and X and Y represent these amount present in full dose of FYM applied on N basis to meet 110 kg N qha^{-1}. Lime was applied @4q/ha to *kharif* crop only.
T_2	N	Urea	-	-	
T_3	NP	Urea	SSP	-	
T_4	NPK	Urea	SSP	MOP	
T_5	FYM	FYM	-	-	
T_6	Lime + NPK	Urea	SSP	MOP	
T_7	Lime + N	Urea	-	-	
T_8	½ (N+FYM) + $P_{(A-X/2)}$ + $K_{(B-Y/2)}$	FYM & Urea	SSP	MOP	

Long term fertilizer experiment (since, 1972)

Treatments	N	P	K	FYM/Lime
T_1 Control	-	-	-	No
T_2 100%N	Urea	-	-	No
T_3 100%NP	Urea	DAP	-	No
T_4 100%NPK	Urea	DAP	MOP	No
T_5 50% NPK	Urea	DAP	MOP	No
T_6 150% NPK	Urea	DAP	MOP	No
T_7 100% NPK+lime	Urea	DAP	MOP	Lime @4q/ha to *kharif* crop only
T_8 100% NPK+FYM	Urea	DAP	MOP	FYM @15t/ha to *kharif* crop only
The recommended dose of fertilizer (100%NPK) for soybean and wheat is 25:60:40 and 80:60:40 $N:P_2O_5K_2O$ kg/ha for soybean and wheat, respectively.				

Crop residue management (since, 1991)

Treatments	N	P	K	Crop residue of preceding crop incorporated
T_1 Control	-	-	-	No
T_2 Crop waste (CW)	-	-	-	Yes
T_3 50% NPK + CW	Urea	SSP	MOP	Yes
T_4 75% NPK + CW	Urea	SSP	MOP	Yes
T_5 100% NPK + CW	Urea	SSP	MOP	Yes
T_6 50% NPK	Urea	SSP	MOP	No
T_7 75% NPK	Urea	SSP	MOP	No
T_8 100% NPK	Urea	SSP	MOP	No
The recommended dose of fertilizer (100%NPK) for both the crops maize and wheat was 80:60:40 $N:P_2O_5K_2O$ kg/ha.				

Results of the study:

Crop productivity

In long term experiments conducted on crop sequence the residual effect of the treatments affected the second crop so the treatment effect on crop productivity of the system was estimated in monetary terms and the wheat equivalent yield was calculated for all the three cropping systems (Table 11). As the climatic condition is subtropical subhumid and soils are having marginal acidity problems, so it is suggestive of integrated use of lime/FYM/crop waste along with inorganic fertilizers for achieving mean grain yield of 50-68 q/ha/yr of grains under different cropping systems. From the on going experiments it was observed that incorporation of crop residue *in situ* results saving of 25 to 50% fertilizer N. Thus poor farmers can get the produce equivalent to 50% of recommended dose of fertilizer by crop residues incorporation alone, while marginal farmer can save 25% N with residue incorporation & a big farmer may achieve higher yield target by crop residue incorporation along with recommended NPK fertilizers. Substitution of 50% chemical fertilizers through FYM or crop waste in maize-wheat cropping system is not a viable option as there was reduction in grain yield of the crops over the years.

Table 11. Long term effect of continuous cropping fertilizer, manure and lime application on Wheat Equivalent Yield (q/ha) in three long term experiments of Ranchi.

	Maize-wheat		Soybean-wheat		Maize-wheat	
Tr. No.	PMT	WEY	LTFE	WEY	CRM	WEY
T_1	Control	13.1	Control	16.0	Control	24.1
T_2	N	4.7	100%N	8.2	Crop waste (CW)	34.4
T_3	NP	22.5	100%NP	37.5	50% NPK + CW	40.6
T_4	NPK	28.8	100%NPK	51.2	75% NPK + CW	49.8
T_5	FYM	46.7	50% NPK	39.4	100% NPK + CW	59.6
T_6	Lime + NPK	68.3	150% NPK	51.5	50% NPK	32.3
T_7	Lime + N	38.6	100% NPK+lime	58.6	75% NPK	43.6
T_8	½ (N+FYM) + **P** $_{(A-X/2)}$ **+ K** $_{(B-Y/2)}$	57.3	100% NPK+FYM	61.7	100% NPK	50.0

Sustainability

The sustainable yield index (SYI) is the derivative of actual yield over the years. The SYI of individual crops of different crops kharif as well as rabi crops was calculated following the equation.

$$SYI = (Y-\sigma_{n-1})/Y_m$$

Where Y is mean yield of respective treatment, σ_{n-1} is the standard deviation and Y_m is the maximum yield obtained under a set of management practice in any of the treatment in any of the years in a given experiment. SYI is a quantitative measure of sustainability and implies minimum guaranteed yield that can be obtained relative to maximum yield and presented in Table 12 and Table 13 for *kharif* and *rabi* crops, respectively. For all the three situations higher sustainable yield index was observed where application of lime/FYM/crop waste was applied along with recommended NPK. Imbalanced and continuous use of N alone produced greatest decline in yield and had deleterious effect on long term yield sustainability and soil quality, indicating that other major and micronutrients were becoming limiting factors and adequate response of N could not be obtained unless those factors limiting yield were taken care of.

Table 12. Sustainable Yield Index (SYI) of *kharif* crops in three long term experiments of Ranchi.

	Maize-wheat		Soybean-wheat		Maize-wheat	
Tr. No.	PMT	SYI	LTFE	SYI	CRM	SYI
T_1	Control	0.03	Control	0.10	Control	0.18
T_2	N	-0.05	100%N	0.01	Crop waste (CW)	0.31
T_3	NP	-0.02	100%NP	0.21	50% NPK + CW	0.35
T_4	NPK	0.02	100%NPK	0.37	75% NPK + CW	0.43
T_5	FYM	0.32	50% NPK	0.48	100% NPK + CW	0.56
T_6	Lime + NPK	0.50	150% NPK	0.46	50% NPK	0.24
T_7	Lime + N	0.28	100% NPK+lime	0.60	75% NPK	0.37
T_8	½ (N+FYM) + **P** $_{(A-X/2)}$ + **K** $_{(B-Y/2)}$	0.41	100% NPK+FYM	0.62	100% NPK	0.49

Table 13. Sustainable Yield Index (SYI) of *rabi* crop in three long term experiments of Ranchi.

	Maize-wheat		Soybean-wheat		Maize-wheat	
Tr. No.	PMT	SYI	LTFE	SYI	CRM	SYI
T_1	Control	0.09	Control	0.03	Control	0.21
T_2	N	-0.01	100%N	0.02	Crop waste (CW)	0.22
T_3	NP	0.10	100%NP	0.28	50% NPK + CW	0.35
T_4	NPK	0.16	100%NPK	0.35	75% NPK + CW	0.42
T_5	FYM	0.23	50% NPK	0.25	100% NPK + CW	0.47
T_6	Lime + NPK	0.38	150% NPK	0.35	50% NPK	0.29
T_7	Lime + N	0.16	100% NPK+lime	0.40	75% NPK	0.36
T_8	½ (N+FYM) + **P** $_{(A-X/2)}$ + **K** $_{(B-Y/2)}$	0.32	100% NPK+FYM	0.42	100% NPK	0.44

Soil Quality

Analysis of post harvest soil samples for soil quality parameters show that application of lime/FYM/crop waste along with balanced fertilizer application creates a favourable chemical and biological environment leading to enhancement of soil quality. In addition to the nutrients, addition of lime/FYM/crop waste is essential which not only controls hidden hunger of secondary and micronutrients but also act as ameliorant which improves the nutrient supplying capacity of soils as well as soil quality (Table 14-20). N, P and K were found to be the most yield contributing inputs. These are costly inputs so due care on application of these inputs is essential. Excess application of P may be avoided to avoid wasteful expenditure.

Soil microbial biomass study reflects energy flow, acts as an agent of transformation of all substances and reflects on a labile pool of C, N, P, S and micronutrients. These processes are governed by enzymatic activity of soil. Activities of enzymes are correlated with microbial respiration and total biomass in soil. To assess nutrient and energy flow in soil systems, role of soil microbial biomass is very important.

Post harvest soil samples were analysed for soil microbial biomass carbon (SMBC) by chloroform fumigation method using Kc value of 0.45. For microbial biomass nitrogen (SMBN), fumigated and unfumigated soil samples were extracted with 2M KCl (1:10) and NH4-N and NO3-N, the values were determined by the method outlined by Brookes et al. (1985) using Kw value of 0.54. Potentially mineralizable nitrogen was estimated by anaerobic incubation and estimated for NH4-N and NO3-N. Labile carbon was estimated by permanganate oxidizable carbon and permanganate oxidizable soil carbon POSC) and estimated colorimetrically.

Results :

- Manuring resulted in higher SMBC compared to inorganic plant nutrient sources. Lime application in acid soils increased SMBC. Crop residue incorporation also increased the SMBC.
- Soil microbial biomass nitrogen (SMBN) showed similar trend as in case of SMBC. Manure or residue incorporation increased SMBN as compared to inorganic nutrient sources.
- Potentially mineralizable N in soil with continuous cropping and fertilizer use showed increased value in NPK + lime plots. Imbalanced use f plant nutrients drastically reduced the PMN in both LTFE and PMT experiments. Residue incorporation in soil over the years had a positive impact on this parameter.
- Application of FYM or crop residues improved the labile carbon in continuously cropped & fertilized soil. This indicates that organic manures give extra benefit of carbon, carbohydrate and enzyme activities in soil.
- The rate of respiration can be used as an index of the biological activity of soil as it reflects the physiological efficiency of the organisms. Monitoring of dehydrogenases, which are respiratory enzymes and integral part of the soil organisms, will give a measures of biological activity of soil at a given time. The dehydrogenase was assayed and expressed as rate of formation of TPF from TTC. Higher the biological activity, faster will be the formation of TPF.

Results thus point out that SMBC, SMBN, PMN, Dehydrogenase activity & labile carbon were higher in FYM/lime treated acid soils of the region. Thus for sustained use of soil for improved crop productivity, soil microbial biomass and enzymatic activities need to be at a high level. This is possible by integrated plant nutrient management involving well decomposed compost, lime as amendment for acidic soils & balanced NPK use.

Table 14. Soil pH after harvest of *rabi* crops in three long term experiments of Ranchi.

	Maize-wheat		Soybean-wheat		Maize-wheat	
Tr. No.	PMT	pH	LTFE	pH	CRM	pH
T_1	Control	5.54	Control	5.56	Control	5.49
T_2	N	4.27	100%N	4.53	Crop waste (CW)	5.37
T_3	NP	5.92	100%NP	4.81	50% NPK + CW	5.30
T_4	NPK	5.89	100%NPK	4.75	75% NPK + CW	5.25
T_5	FYM	4.06	50% NPK	5.12	100% NPK + CW	5.15
T_6	Lime + NPK	5.21	150% NPK	4.53	50% NPK	5.01
T_7	Lime + N	5.28	100% NPK+lime	5.77	75% NPK	5.10
T_8	½ (N+FYM) + **P** $_{(A-X/2)}$ + **K** $_{(B-Y/2)}$	5.21	100% NPK+FYM	5.03	100% NPK	5.15
Initial						

Table 15. Long term effect of continuous cropping fertilizer, manure and lime application on organic carbon (g/kg) content of soil after harvest of *rabi* crops in three long term experiments of Ranchi.

	Maize-wheat		Soybean-wheat		Maize-wheat	
Tr. No.	PMT	O.C.	LTFE	O.C.	CRM	O.C.
T_1	Control	5.48	Control	3.25	Control	6.09
T_2	N	6.51	100%N	4.31	Crop waste (CW)	6.42
T_3	NP	5.81	100%NP	3.73	50% NPK + CW	6.34
T_4	NPK	6.79	100%NPK	3.87	75% NPK + CW	6.88
T_5	FYM	11.77	50% NPK	3.71	100% NPK + CW	6.75
T_6	Lime + NPK	8.85	150% NPK	4.68	50% NPK	6.04
T_7	Lime + N	9.53	100% NPK+lime	3.96	75% NPK	6.72
T_8	½ (N+FYM) + **P** $_{(A-X/2)}$ + **K** $_{(B-Y/2)}$	8.22	100% NPK+FYM	5.53	100% NPK	6.47

Table 16. Hot water soluble - B (mg kg^{-1}) in soil after harvest of *rabi* crops in the three long term experiments of Ranchi.

	Maize-wheat		Soybean-wheat		Maize-wheat	
Tr. No.	PMT	HWS-B	LTFE	HWS-B	CRM	HWS-B
T_1	Control	0.28	Control	0.31	Control	0.87
T_2	N	0.68	100%N	0.40	Crop waste (CW)	0.81
T_3	NP	0.45	100%NP	0.40	50% NPK + CW	0.66
T_4	NPK	0.55	100%NPK	0.44	75% NPK + CW	0.68
T_5	FYM	0.50	50% NPK	0.34	100% NPK + CW	0.62
T_6	Lime + NPK	0.55	150% NPK	0.38	50% NPK	0.54
T_7	Lime + N	0.99	100% NPK+lime	0.60	75% NPK	0.59
T_8	½ (N+FYM) + **P** $_{(A-X/2)}$ **+ K** $_{(B-Y/2)}$	0.75	100% NPK+FYM	0.39	100% NPK	0.88

Table 17. SMBC (mg kg^{-1}) after harvest of *rabi* crops in the three long term experiments of Ranchi.

	Maize-wheat		Soybean-wheat		Maize-wheat	
Tr. No.	PMT	SMBC	LTFE	SMBC	CRM	SMBC
T_1	Control	126.0	Control	139.5	Control	233.7
T_2	N	205.0	100%N	182.0	Crop waste (CW)	243.7
T_3	NP	134.7	100%NP	180.0	50% NPK + CW	231.7
T_4	NPK	359.7	100%NPK	199.0	75% NPK + CW	228.7
T_5	FYM	148.7	50% NPK	153.0	100% NPK + CW	222.7
T_6	Lime + NPK	165.0	150% NPK	172.0	50% NPK	267.0
T_7	Lime + N	298.0	100% NPK+lime	269.5	75% NPK	233.7
T_8	½ (N+FYM) + **P** $_{(A-X/2)}$ **+ K** $_{(B-Y/2)}$	226.0	100% NPK+FYM	284.0	100% NPK	239.0

SMBC - Soil microbial biomass carbon

Table 18. SMBN (mg kg^{-1}) after harvest of *rabi* crops in the three long term experiments of Ranchi.

	Maize-wheat		Soybean-wheat		Maize-wheat	
Tr. No.	PMT	SMBN	LTFE	SMBN	CRM	SMBN
T_1	Control	17.50	Control	34.79	Control	32.38
T_2	N	22.63	100%N	37.88	Crop waste (CW)	29.46
T_3	NP	22.04	100%NP	34.33	50% NPK + CW	25.83
T_4	NPK	20.58	100%NPK	30.33	75% NPK + CW	25.42
T_5	FYM	22.08	50% NPK	33.17	100% NPK + CW	26.04
T_6	Lime + NPK	16.58	150% NPK	26.88	50% NPK	29.58
T_7	Lime + N	16.75	100% NPK+lime	39.08	75% NPK	25.46
T_8	½ (N+FYM) + $P_{(A-X/2)}$ + $K_{(B-Y/2)}$	20.96	100% NPK+FYM	42.88	100% NPK	30.00

SMBN - Soil microbial biomass nitrogen

Table 19. PMN (mg kg^{-1}) in soil after harvest of *rabi* crops in the three long term experiments of Ranchi.

	Maize-wheat		Soybean-wheat		Maize-wheat	
Tr. No.	PMT	PMN	LTFE	PMN	CRM	PMN
T_1	Control	15.20	Control	13.92	Control	12.95
T_2	N	8.05	100%N	12.68	Crop waste (CW)	11.78
T_3	NP	8.82	100%NP	13.73	50% NPK + CW	10.33
T_4	NPK	3.23	100%NPK	12.13	75% NPK + CW	10.17
T_5	FYM	8.83	50% NPK	13.27	100% NPK + CW	10.42
T_6	Lime + NPK	6.63	150% NPK	10.75	50% NPK	11.83
T_7	Lime + N	6.15	100% NPK+lime	12.30	75% NPK	10.18
T_8	½ (N+FYM) + $P_{(A-X/2)}$ + $K_{(B-Y/2)}$	7.65	100% NPK+FYM	12.78	100% NPK	12.00

PMN - Potentially mineralisable nitrogen.

Table 20. Dehydrogenase activity (TPF/g soil/24hrs) in soil after harvest of *rabi* crops in the three long term experiments of Ranchi.

	Maize-wheat		Soybean-wheat		Maize-wheat	
Tr. No.	PMT	DHA	LTFE	DHA	CRM	DHA
T_1	Control	13.20	Control	19.4	Control	26.3
T_2	N	8.17	100%N	14.3	Crop waste (CW)	26.3
T_3	NP	27.57	100%NP	15.0	50% NPK + CW	29.5
T_4	NPK	16.67	100%NPK	16.0	75% NPK + CW	24.1
T_5	FYM	26.25	50% NPK	20.1	100% NPK + CW	29.4
T_6	Lime + NPK	23.34	150% NPK	17.6	50% NPK	18.6
T_7	Lime + N	25.25	100% NPK+lime	23.3	75% NPK	21.5
T_8	½ (N+FYM) + **P** $_{(A-X/2)}$ **+ K** $_{(B-Y/2)}$	24.44	100% NPK+FYM	19.2	100% NPK	19.6

DHA - Dehydrogenase activity

Soil properties and Yield Sustainability

The regression analysis using SYI as dependent variable and soil quality parameters as independent variables were analyzed to study which parameter contributes significantly for the SYI under different cropping systems & management practices in acid soils (Fig. 2 to 7).

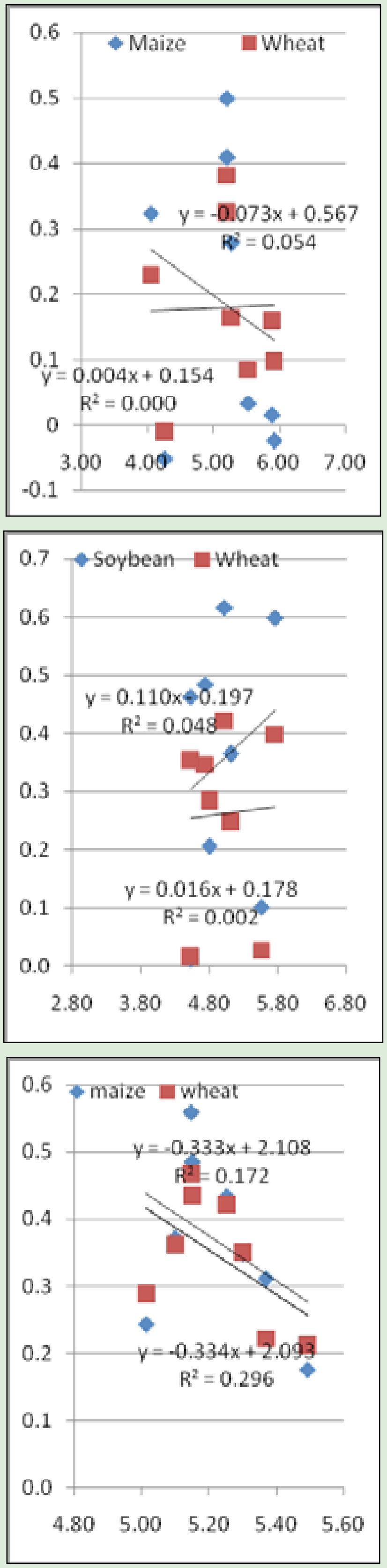


Fig. 2. Influence of pH on SYI of crops as influenced by continuous cropping in acid soils of Ranchi.

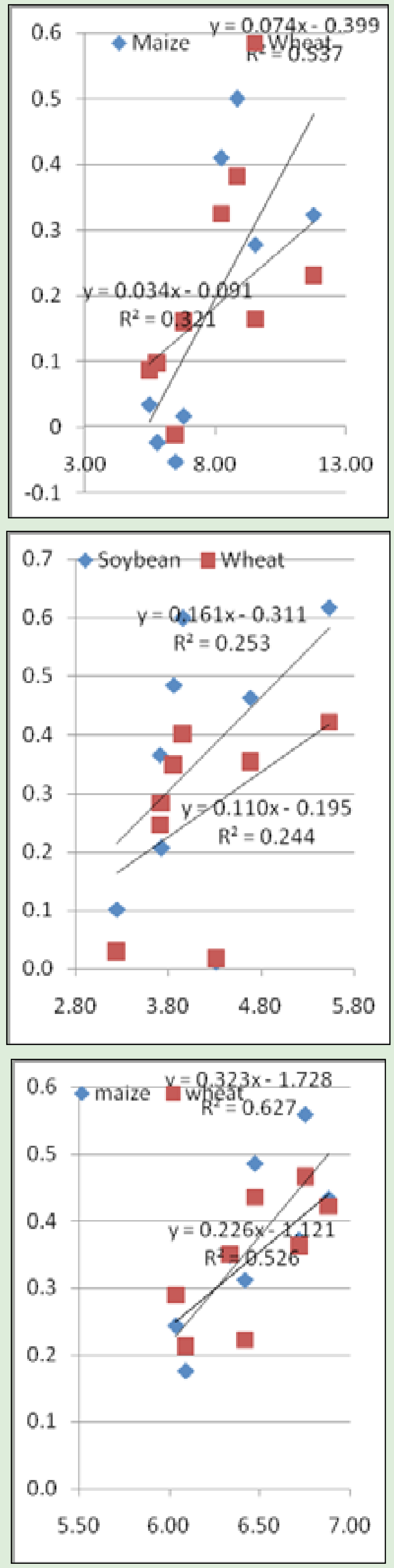


Fig. 3. Influence of organic carbon content of soil (g/kg) on SYI of crops as influenced by continuous cropping in acid soils of Ranchi.

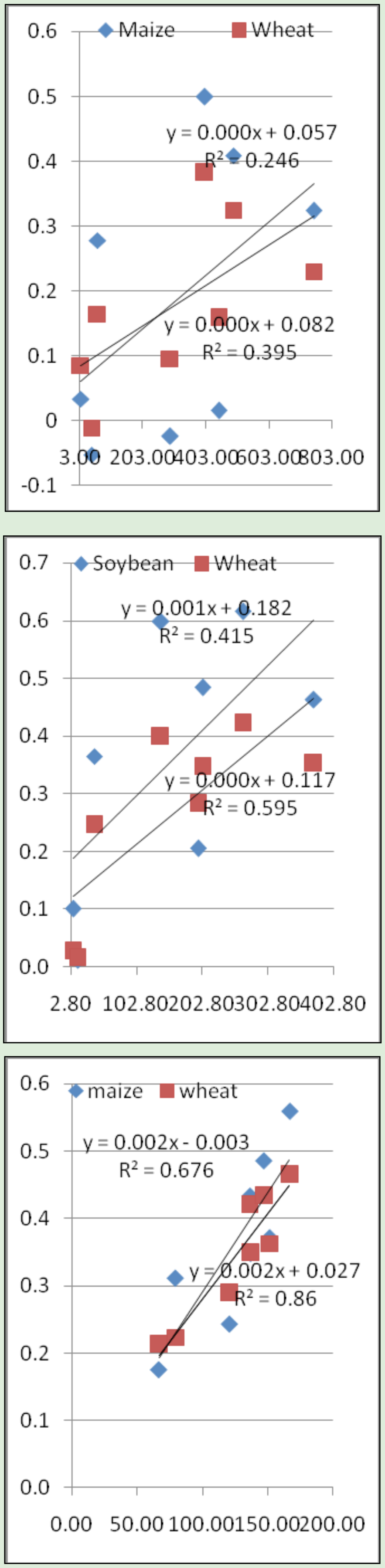


Fig. 4. Influence of available P content of soil (kg/ha) on SYI of crops as influenced by continuous cropping in acid soils of Ranchi.

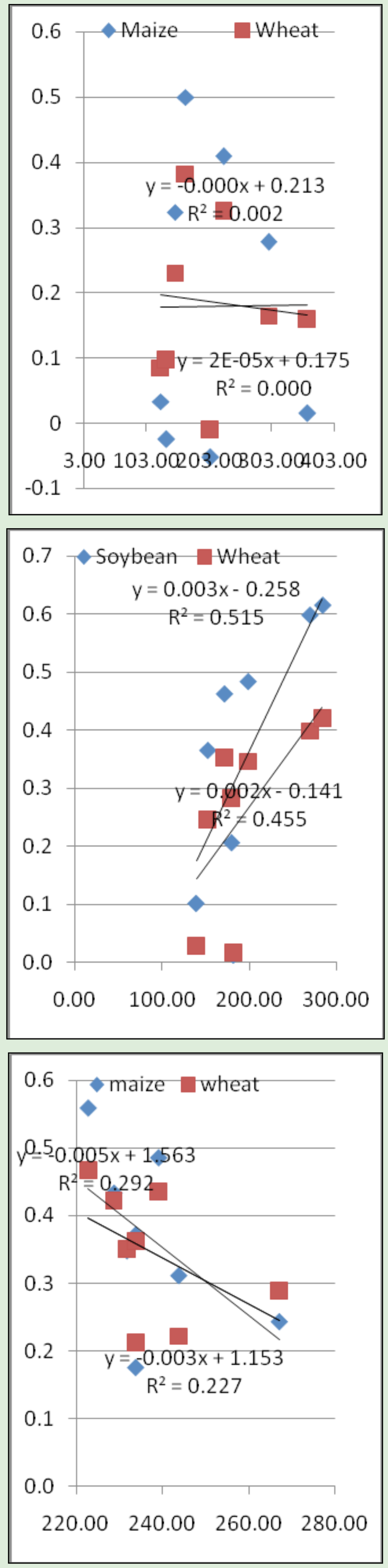


Fig. 5. Influence of SMBC of soil (ppm) on SYI of crops as influenced by continuous cropping in acid soils of Ranchi.

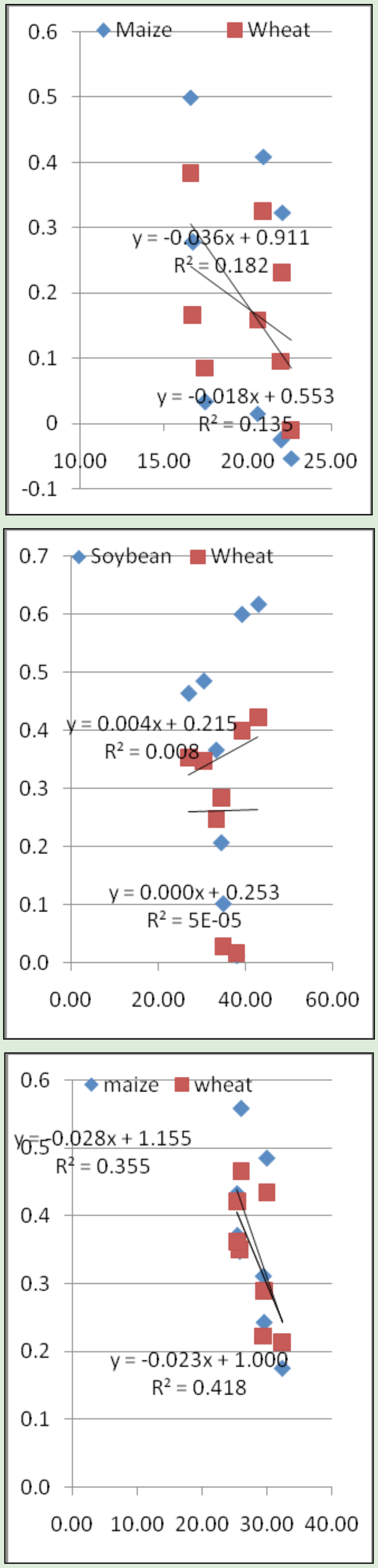


Fig. 6. Influence of SMBN of soil (ppm) on SYI of crops as influenced by continuous cropping in acid soils of Ranchi.

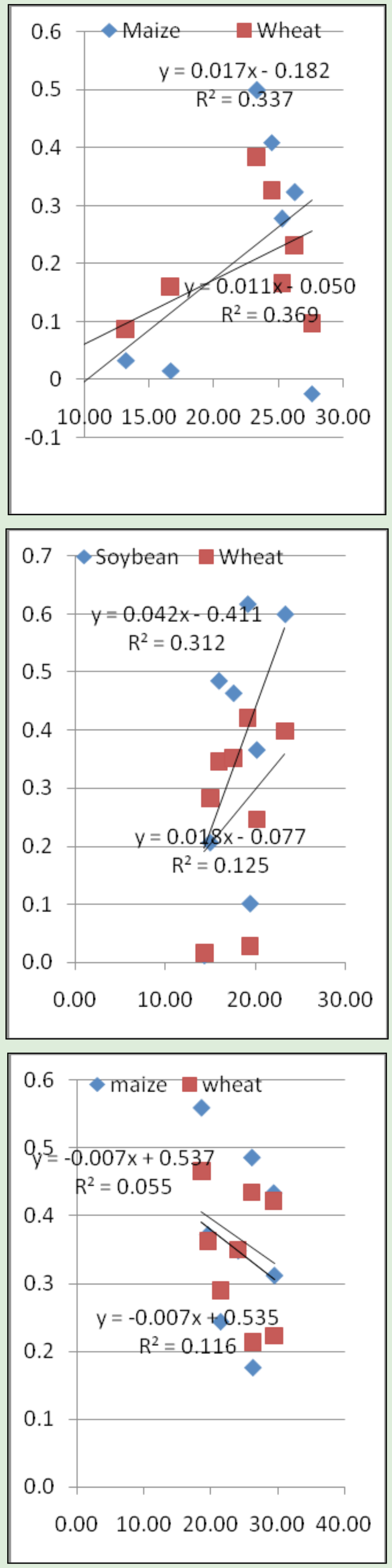


Fig. 7. Influence of DHA activity in soil (TPF/gsoil/24 hrs) on SYI of crops as influenced by continuous cropping in acid soils of Ranchi.

Carbon Management

Traditionally, Organic carbon (Walkley and Black method) or TOC were used in the studies on SOM dynamics. Ability to detect at an early stage the SOC change in response to management and land-use change is important to make decisions on appropriate management interventions. But, changes in TOC as a result of management practices or land use are small in short period of few cropping seasons and hence seldom detectable because of high background levels and natural soil variability. In contrast, labile C fractions (readily decomposable; susceptible to microbial breakdown; easily oxidizable pool) generally have high turnover rates (short turnover time) and are sensitive to management-induced changes in SOC. Labile or active C pools fuel soil food web and hence influence nutrient cycling and many other biologically related soil properties. Labile C fractions serve as early and sensitive indicators of management induced change in SOC and hence soil quality and sustainability

Determination of labile C by permanganate oxidation (POSC) The method of Blair et al., 1995 for determination of labile soil carbon using potassium permanganate is based on the principle that the oxidative action of $KMnO_4$ (under neutral condition) is comparable to the oxidative process associated with the microbiological decomposition of organic matter in soil. The readily decomposable or labile C in soil (POSC) is determined by the quantity of oxidizing agent (potassium permanganate) consumed during reaction with soil.

Carbon Pool Index (CPI): The loss C from a soil with a small C pool size is of greater consequence than the loss of same quantity of C loss from a soil with a large C pool size. To account for this, a CPI (ratio of total C pool in sample soil to total C pool in reference soil) is calculated as:

Total C in sample

CPI = Total C in reference

The results obtained are presented in tables 21 and 22. In PMT, Lime + NPK and in LTFE, NPK + FYM recorded higher carbon pool index in maize-wheat and soybean-wheat cropping systems respectively.

Table 21. Permanganate soil organic carbon (ppm) in soil of the three long term experiments of Ranchi.

	Maize-wheat		Soybean-wheat		Maize-wheat	
Tr. No.	PMT	POSC	LTFE	POSC	CRM	POSC
T_1	Control	455	Control	267	Control	317
T_2	N	538	100%N	271	Crop waste (CW)	370
T_3	NP	503	100%NP	278	50% NPK + CW	435
T_4	NPK	755	100%NPK	255	75% NPK + CW	443
T_5	FYM	503	50% NPK	383	100% NPK + CW	431
T_6	Lime + NPK	602	150% NPK	294	50% NPK	368
T_7	Lime + N	623	100% NPK+lime	299	75% NPK	442
T_8	½ (N+FYM) + **P** $_{(A-X/2)}$ **+ K** $_{(B-Y/2)}$	523	100% NPK+FYM	356	100% NPK	360

Table 22. Long term effect of continuous cropping fertilizer, manure and lime application on carbon pool index (CPI) of the three long term experiments of Ranchi.

	Maize-wheat		Soybean-wheat		Maize-wheat	
Tr. No.	PMT	CPI	LTFE	CPI	CRM	CPI
T_1	Control	0.55	Control	0.63	Control	0.61
T_2	N	0.65	100%N	0.84	Crop waste (CW)	0.64
T_3	NP	0.58	100%NP	0.73	50% NPK + CW	0.63
T_4	NPK	0.68	100%NPK	0.75	75% NPK + CW	0.69
T_5	FYM	1.12	50% NPK	0.72	100% NPK + CW	0.68
T_6	Lime + NPK	0.89	150% NPK	1.05	50% NPK	0.60
T_7	Lime + N	0.96	100% NPK+lime	0.77	75% NPK	0.67
T_8	½ (N+FYM) + **P** $_{(A-X/2)}$ **+ K** $_{(B-Y/2)}$	0.75	100% NPK+FYM	1.08	100% NPK	0.65

13.1.3 : Temporal and axial variability of nutrients in Litchi leaves.

Objectives:

- To study the changes in temporal & axial variability of nutrients (N, P, K, Ca, Mg, S, Fe, Cu, Mn & Zn) in Litchi leaf.
- To determine the most suitable time & pair of leaves for fertilizer recommendation for Litchi in this region.
- To study the temporal changes on soil properties in a year.
- To find out the relationship between the Soil & Plant nutrients levels during the growth period of Litchi
- To determinate the relationship between the leaf nutrient levels & crop productivity

Details of the field experiment

27 years old plants of Litchi cultivar Shahi and China were used for the experiment. All the plants were almost uniform, healthy and free from pest and diseases. All the trees were subjected to uniform cultural practices during the period of experimentation.

Observations were recorded from healthy and bearing litchi trees of uniform growth and vigour. All the experimental plants were subjected to uniform cultural practices. Leaf sample were collected from 6th March 2006 to 6th February 2007. Twenty plants of litchi (10 Plants of Shahi & 10 Plants of China) were selected randomly for leaf nutrient analysis from the experimental farm of HARP, Plandu (Ranchi).

The leaves were collected from the mid section of terminal shoots located on different sides of the tree. Leaf was collected from the interior portion of the tree at shoulder height or higher, no more than two leaves from any one shoot. 30 leaves will be collected from a single tree and the different pairs of leaves were separated and to be analyzed for the nutrients.

Total No. of Plants = 20

Total No of Leaf Samples = 960

{No of trees (20) x pairs of Leaves (4) x Months (12)}

Leaf samples were collected from each tree and washed with acidified detergent solution, rinsed in distilled water, dried in hot air circulation oven at 60^{0}C and pulverized in stainless steel blade warring blender. The powdered samples were stored in small polythene bags for further chemical analysis.

Analytical Procedure :

Plant Analysis

- The leaves were separated as per the pair number and kept for air drying followed by oven dried at 70ºC.
- Diacid digestion for P, K, Ca, Mg, S, Fe, Cu, Mn and Zn. First of all, 0.5 gm of plant material was transferred to a neatly washed and dried test tube and 10 ml of diacid mixture was added to it.
- The powdered plant materials were digested in diacid mixture consisting of 10 parts HNO_3 and 4 parts $HClO_4$ (Jackson, 1967). Then it was placed on a hot plate for digestion on slow heat and continued the digestion till white residue was left. The residue was dissolved in glass distilled water and final volume was made to 50ml. the dissolved material was filtered through filter paper. A blank was also carried out in the same way having no plant material.

P : It was determined calorimetrically.

K : It was determined with the help of flame Photometer.

Ca & Mg : It was determined titrimetrically by versenate titration method.

Sulphur : It was determined Turbidimetrically as described by Chesnin and Yien, 1971.

Fe, Cu, Mn & Zn : Determined by Atomic Adsorption Spectrophotometer.

Nitrogen: Sulphuric acid digestion in presence of digestion mixture comprising of K_2SO_4, $CuSO_4$ and Selenium Powder (100:10:1). It was determined with the help of Kjeldahl digestion and distillation method.

Result

Results indicate that yield of Litchi varied from 40 to 46 & 62 to 85 kg /plant respectively in Shahi & China cultivars of litchi. Concentration of N, P & K varied from 1.08 to 1.2 %, 0.08 to 0.16% & 0.69 to 0.79%, respectively in litchi leaves. Higher concentration of N was observed for the second pair of leaves where as P & K was higher in 1st pair of leaves. The concentration of secondary nutrients varied from 0.098 to 0.225%, 0.050 to 0.114% & 0.069 to 0.76% for Ca, Mg & S, respectively in different pair of Litchi leaves. Concentration of Fe, Cu, Mn & Zn varied from 192 to 614 ppm, 5 to 46 ppm, 75 to 175 ppm & 58 to 140 pmm respectively, and there was no significant difference among different pairs of litchi leaves. Critical nutrient concentration was 1.1%, 0.12%, 0.72%, 0.16%, 0.06% & 0.075% for N, P,K, Ca, Mg & S respectively, for micronutrients critical concentration was 25 ppm, 400 ppm, 125 ppm & 100 ppm for Cu, Fe, Mn & Zn, respectively. Available nutrient in soil was 194 to 269, 18 to 85 and 300 to 415 kg ha^{-1} for N, P and K respectively for primary nutrients. Exchangeable Ca & Mg was 1.2 to 1.8 and 0.07 to 1.4 C mol (P^+) kg^{-1} respectively while available S varied from 6 to 39 ppm.

- Critical nutrient concentration was 1.1%, 0.12%, 0.72%, 0.16%, 0.06% & 0.075% for N, P, K, Ca, Mg & S respectively.
- For micronutrients critical concentration were 25 ppm, 400 ppm, 125 ppm & 100 ppm for Cu, Fe, Mn & Zn respectively.
- Coefficient of correlation (r) value between yield and concentration in leaves revealed that 2nd pair of leaves during the month of Feb-April is ideal for plant analysis in litchi.

For the purpose of interpretation of plant analysis results to recognize the effect of one element on the other, the ratios of different leaf nutrient concentrations were computed (Table 23 & 24).

The ratios obtained from the present studies were 13.4:1.0 (N:P), 1.6:1.0 (N:K), o.1:1.0 (P:K) and 13.4:1.0:10.0 (N:P:K) for primary nutrients, 2.0:1.0 (Ca:Mg), 2.3:1.0 (Ca:S), 1.2:1.0 (Mg:S) and 2.0:1.0:0.8 (Ca:Mg:S) for secondary nutrients and 61.9:1.0 (Fe:Cu), 3.3:1.0 (Fe:Mn), 23:1.0 (Fe:Zn), 0.1:1.0 (Cu:Mn), 0.5:1.0 (Cu:Zn), 7.6:1.0 (Mn:Zn) and 61.9:10.0:1.3:1.0 (Fe:Mn:Zn:Cu) for micronutrients.

Table 23. Temporal variability in Leaf Nutrient concentration ratio of Litchi during the year 2007 & 2008

Nutrient ratio	January	February	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Mean
N/P	13.757	12.424	11.258	12.445	13.027	13.302	13.652	13.945	14.133	13.700	14.174	14.641	13.372
N/K	1.590	1.552	1.528	1.531	1.570	1.601	1.597	1.594	1.622	1.624	1.564	1.567	1.578
P/K	0.120	0.129	0.144	0.131	0.128	0.128	0.125	0.122	0.121	0.124	0.118	0.113	0.125
Ca/Mg	1.989	1.976	1.966	2.014	2.035	1.975	2.033	1.963	1.909	2.101	1.910	2.109	1.998
Ca/S	3.035	3.231	1.403	1.767	1.981	2.019	2.089	2.032	2.286	2.541	2.658	2.801	2.320
Mg/S	1.527	1.636	0.714	0.877	0.973	1.024	1.029	1.036	1.198	1.211	1.397	1.328	1.162
Fe/Cu	44.197	28.753	79.329	92.222	137.271	96.663	79.996	37.716	31.291	31.569	51.796	31.665	61.872
Fe/Mn	2.435	1.375	5.902	2.635	3.329	4.302	4.788	2.427	4.052	2.216	3.469	2.226	3.263
Fe/Zn	20.944	6.226	27.473	16.685	21.203	24.899	29.950	30.205	34.053	15.875	28.035	20.127	22.973
Cu/Mn	0.060	0.051	0.134	0.058	0.047	0.068	0.072	0.070	0.138	0.080	0.071	0.075	0.077
Cu/Zn	0.500	0.233	0.545	0.401	0.309	0.392	0.449	0.879	1.084	0.569	0.563	0.665	0.549
Mn/Zn	8.896	4.647	5.013	6.577	6.506	6.157	7.211	12.940	8.602	7.196	8.026	9.201	7.581

Table 24. Axial variability in Leaf nutrient concentration ratio of litchi during the year 2007 & 2008

Nutrient ratio	Mean value				
	1st Pair	2nd Pair	3rd Pair	4th Pair	Mean
N/P	12.788	14.119	13.210	13.361	13.372
N/K	1.537	1.620	1.583	1.573	1.578
P/K	0.128	0.120	0.126	0.126	0.125
Ca/Mg	1.988	2.003	2.003	2.000	1.998
Ca/S	2.262	2.275	2.388	2.355	2.320
Mg/S	1.144	1.136	1.193	1.177	1.162
Fe/Cu	57.976	61.543	61.344	66.625	61.872
Fe/Mn	3.031	3.252	3.295	3.474	3.263
Fe/Zn	23.805	24.361	22.494	21.231	22.973
Cu/Mn	0.077	0.076	0.076	0.079	03.077
Cu/Zn	0.611	0.570	0.534	0.481	0.549
Mn/Zn	8.284	8.036	7.311	6.692	7.581

Validation of experimental results

Validation of the experiment as data was done from the collected leaf samples of different cultivar orchards of litchi trees at different locations around Ranchi (HARP, Namkum, Kanke & R. K. Mission, Morabadi) during the year 2009-10. The data obtained show that the temporal and axial variability indifferent cultivars i.e. Purbi, Bedana, Kasava and Shahi for primary nutrient (N, P and K), secondary nutrient (Ca, Mg and S) and micronutrient (Fe, Cu, Mn and Zn) were similar to the results of the present study.

The ratios of different leaf nutrient concentrations during validation are presented in table 25 and 26. The ratios were 12.9:1.0 (N:P), 1.4:1.0 (N:K), 0.1:1.0 (P:K) and 12.9:1.0:10.0 (N:P:K) for primary nutrients, 1.9:1.0 (Ca:Mg), 3.2:1.0 (Ca:S), 1.7:1.0 (Mg:S) and 1.9:1.0:0.6 (Ca:Mg:S) for secondary nutrients and 51.3:1.0 (Fe:Cu), 3.8:1.0 (Fe:Mn), 21.4:1.0 (Fe:Zn), 0.1:1.0 (Cu:Mn), 0.5:1.0 (Cu:Zn), 5.8:1.0 (Mn:Zn) and 51.3:10.0:1.7:1.0 (Fe:Mn:Zn:Cu) for micronutrient.

Table 25. Validation of temporal variability in Leaf nutrient concentration ratio of litchi

Ratio	March	April	May	Sept.	Octo.	Nov.	Mean
N/P	10.538	11.669	12.485	14.800	13.972	13.742	12.868
N/K	1.362	1.377	1.383	1.449	1.431	1.386	1.308
P/K	0.130	0.118	0.111	0.099	0.103	0.101	0.110
Ca/Mg	1.891	1.894	1.908	1.919	1.924	1.930	1.911
Ca/S	2.363	2.348	2.668	3.575	3.889	4.422	3.211
Mg/S	1.249	1.238	1.396	1.860	2.020	2.288	1.675
Fe/Cu	50.651	51.961	97.261	34.020	30.830	43.374	51.350
Fe/Mn	6.020	3.292	4.114	4.065	2.468	3.133	3.849
Fe/Zn	22.832	14.911	21.334	32.028	15.520	21.879	21.417
Cu/Mn	0.124	0.074	0.061	0.122	0.086	0.079	0.091
Cu/Zn	0.462	0.328	0.301	0.946	0.537	0.547	0.520
Mn/Zn	3.775	4.524	5.144	7.863	6.288	6.949	5.757

Table 26. Validation of axial variability in Leaf nutrient concentration ratio of litchi

Ratio	Mean value				
	1st Pair	2nd Pair	3rd Pair	4th Pair	Mean
N/P	12.258	13.558	12.641	13.014	12.868
N/K	1.377	1.411	1.398	1.407	1.398
P/K	0.114	0.106	0.112	0.110	0.110
Ca/Mg	1.905	1.904	1.916	1.918	1.911
Ca/S	3.215	3.213	3.197	3.219	3.211
Mg/S	1.682	1.681	1.663	1.675	1.675
Fe/Cu	38.311	46.501	62.317	58.269	51.350
Fe/Mn	3.671	3.984	3.724	4.015	3.849
Fe/Zn	19.743	20.607	22.463	22.857	21.417
Cu/Mn	0.104	0.098	0.076	0.086	0.091
Cu/Zn	0.574	0.525	0.471	0.510	0.520
Mn/Zn	5.531	5.379	6.225	5.893	5.757

Results thus reveal that from the foregoing results of the present investigation, the following conclusions can be drawn:

- Correlation coefficient between yield and nutrient concentration in litchi leaves were positive.
- Soil sampling at 2/3rd canopy distance from the trunk was observed to be ideal for soil analysis.
- Sampling for both leaf and soil during the month February to April or September to November was most suitable time for soil and plant analysis. Thus, leaf tissue analysis in litchi can serve as a guide to nutrient use in the crop grown the region.

13.1.4 : Water quality & water balance studies

13.1.4.1 : Water quality in Palamu and Garhwa districts

This study involved collection of 65 drinking and irrigation water samples from all blocks of Palamau as well as Garhwa districts during post monsoon (September 2009) and pre monsoon (April 2010). All together 260 water samples from different sources viz. surface water (ponds and rivers) and groundwater (open wells and bore wells) were collected and analysed for fluoride and nitrate content.

Evaluation of nitrate content in surface and ground water indicate that 40.0 ;and 42.8 per cent respectively crossed the safe limit (45 mg/l) in Palamau districts. The extent of nitrate contamination in water samples of Garhwa district was comparatively low.

Fluoride concentration in surface water was very low in both districts during present study. However, the open and bore well samples contained fluoride between 1.0 to 1.5 mg/l (prescribed safe limit) were 31.58 and 23.91 per cent, respectively in Palamau district and 30.00 and 42.22 per cent, respectively in Garhwa district. The open and bore well samples crossed the safe limit to the tune of 42.11 and 56.52 per cent, respectively in case of Palamau while, 15.00 and 24.40 per cent, respectively in case of Garhwa district. Fluoride contaminated blocks were Daltonganj, Chhatarpur, Satbarwa and Vishrampur in Palamau district and were Nagar Untari, Ramna, Garhwa and Dhurki in Garhwa district.

Table 27. Nitrate concentration (mg/l) in drinking and irrigation water of Palamu and Garhwa districts of Jharkhand.

Source	SURFACE WATER		GROUND WATER			
	POND	RIVER	OPEN WELL		BORE WELL	
	SEPT	SEPT	SEPT	APRIL	SEPT	APRIL
PALAMU						
Range	35.0-46.0	38.6-66.0	25.0-58.3	20.2-53.7	15.0-52.2	3.7-45.2
Mean	40.33	52.30	37.00	30.71	32.01	20.30
SD±	5.51	19.37	8.43	7.97	8.73	9.41
GARHWA						
Range	40.0-49.02	35.1-56.0	33.0-64.3	12.8-39.5	14.0-58.0	3.9-35.6
Mean	45.61	43.43	43.40	25.89	30.13	16.26
SD±	4.89	8.95	7.77	8.10	9.76	9.07

Table 28. Fluoride concentration (me/l) in drinking and irrigation water of Palamu and Garhwa districts of Jharkhand.

Source	SURFACE WATER		GROUND WATER			
	POND	RIVER	OPEN WELL		BORE WELL	
	SEPT	SEPT	SEPT	APRIL	SEPT	APRIL
PALAMU						
Range	0.12-0.35	0.25-0.42	0.06-0.37	0.42-3.20	0.07-1.25	0.65-3.9
Mean	0.24	0.33	0.24	1.49	0.36	1.71
SD±	0.11	0.12	0.09	0.74	0.20	0.93
GARHWA						
Range	0.13-0.90	0.25-0.66	0.11-1.58	0.55-5.32	0.14-1.60	0.8-7.62
Mean	0.43	0.38	0.35	1.39	0.48	1.59
SD±	0.41	0.19	0.34	1.26	0.37	1.26

13.1.4.2 : Water quality in Sahebganj district:

The problems caused by arsenic contamination in ground water have reached alarming levels over the years. The people exposed to arsenic contaminated water are suffering from skin lesion, muscular disorder including cancer. Arsenic sources in the soil are mainly geogenic. Arsenic is often described as a metalloid, but its chemical behaviour in soil, is as a non metal. It exits in soil in oxy-anionic form in the +5 or +3 oxidation state as arsenate and arsenite, respectively. The latter being more mobile and toxic than the former one. Although arsenic pollution in agriculture production system may not be so severe, but its contamination in the ground water leading to the pollution of drinking water is very serious and wide spread, particularly when ground water withdrawal exceeds the recharge.

A team of scientists of Birsa Agricultural University led by Dr. A. K. Sarkar, Dean, Agriculture along with Dr. R. P. Singh (Chief Scientist, Soil Science), Dr. P. B. Saha (Senior Soil Scientist, ZRS, Dumka) and Dr. Arvind Kumar (Asstt. Professor, Soil Science) visited the affected villages (Dehari, Patwartola, Bholiyatala, Badikoderjana, Chhotikoderjana, Hazipurbitha, Rajgaon etc.) of Sahebganj district (in Sahebganj – Bhagalpur road) of Jharkhand.

The salient features of the visit may be outlined as below:

Team members visited a number of villages and interacted with villagers about the Arsenic problem. The farmers contacted were :

Name of Villagers/Farmers	Village
Sh. Trithnath Yadav	Dehari
Sh. Rampresh Yadav	Dehari
Sh. Manoj Yadav	Dehari
Sh. Vidhya Mandal	Patwartola
Sh. Mahabir Ram	Bholiyatola
Sh. Ram Kailash Mandal	Hazipurbitha
Sh. Chheno Mandal	Hazipurbitha
Sh. Bhim Paswan	Hazipurbitha
Sh. Rajak Malik	Hazipurbitha
Sh. Jaldhar Rajak	Hazipurbitha
Sh. Ashok Paswan	Hazipurbitha
Sh. Ram Pujan Paswan	Hazipurbitha
Sh. Dhiru Rajak	Hazipurbitha
Sh. Ram Lakhan	Rajgaon
Sh. Ganesh Mandal	Hazipurbitha
Sh. Jagarnath Paswan	Hazipurbitha
Sh. Umesh Chaurasia	Hazipurbitha
Sh. Anandi Mandal	Hazipurbitha

Name of Villagers/Farmers	Village
Sh. Saintlal Paswan	Hazipurbitha
Sh. Dashrath Mandal	Hazipurbitha
Sh. Shivlal Mandal	Badi koderjana
Sh. Satya Mandal	Chhoti koderjana
Sh. Awadhesh Mandal	Chhoti koderjana

Qualitative testing of Arsenic in water samples/water quality parameters:

Water samples of different village were analyzed by Arsenic Testing Kit during visit. Water from most of the deep tube-wells and hand pumps exceeded (100 to 250 µg L^{-1}) to maximum permissible concentration of 50 µg L^{-1} permissible limit in drinking water WHO, 1993).

Report on water quality analysis :

Water quality parameters like pH, CO_2, alkalinity, EC and TDS varied from 6.28 to 7.62, 2.0 to 10.0 (mg/l), 340 to 596 (mg/l) as $CaCO_3$, 0.94 to 2.77 (mmhos/cm) and 0.504 to 1.469 (g/l), respectively in water samples collected from Arsenic affected area of Sahebganj district of Jharkhand. EC was found slightly in higher range and not suitable for salt sensitive crops.

Trace and heavy metals like Fe, Cu, Zn, Mn, Pb and Arsenic in collected water samples ranged from 0.17 to 0.87, 0.035 to 0.075, 0.040 to 0.420, 0.040 to 0.640, 0.110 to 0.410 ppm and 30.0 to 250 µg/l, respectively. Arsenic concentration in water source of Hazipurbitha was high as judged by its critical permissible limit 0.10 (µg/l). It was less than permissible limit in recently constructed well of Dehari village and installed hand pumps of Rajgaon village.

Fe, Cu, Zn, Mn, Pb, Ni and Co content in plants collected from Arsenic affected area varied from 218 to 821, 15 to 37, 36 to 95, 24 to 65, 15 to 50, 7 to 12 and 1 to 6 ppm.

Content of Fe, Cu, Zn, Mn, Pb, Ni and Co were varied from 18.60 to 46.40, 1.84 to 4.56, 1.26 to 3.94, 9.42 to 12.38, 1.48 to 3.10, 0.20 to 0.50 and traces to 0.18 ppm, respectively in soils of Arsenic affected areas of Sahebganj.

Visible impact of Arsenic contaminated drinking water on human health:

Arsenic is the causal factor of severe physiological disorders in human beings. In the Arsenic affected area of Sahebganj district of Jharkhand, several villagers were found having skin problems. Villages reported severe skin lesions at acute level in some persons.






ARSENICOSIS

Governmental and NGO's effort Initiated

Governmental as well as Non-Governmental organization efforts have been initiated in these areas, which is mainly limited to fitting up of arsenic filters with in hand pumps. But post fitting management and monitoring has remained major bottle neck. Interesting it was to note that in the Hazipurbitha village, one side of the village divided by a narrow concrete road (Patwar tola) had no Arsenic. Contamination in drinking water, while other side of village had very high Arsenic concentration (100 to more than 250 µg L^{-1}) in drinking water. Jharkhand Government has started the plan to set up non contaminated water supply system in Arsenic affected areas but the project any how could not be completed. This needs immediate attention of Jharkhand Government. In almost all locations, fitted filters in tube-well were not operative and villagers were forced to drink Arsenic contaminated water.


Present situation of Arsenic contaminated water utilization

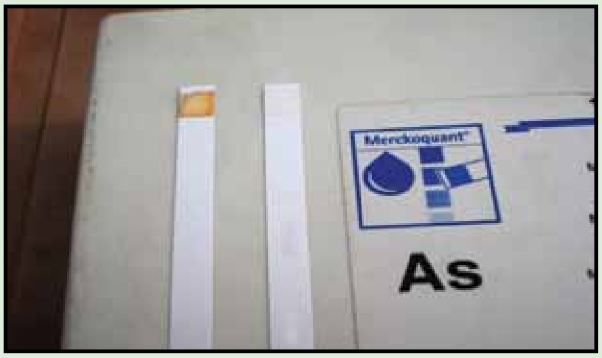
Awareness and consciousness among the some villagers about this acute problem have been created. They avoid drinking the Arsenic contaminated water and carrying safe water from far away (2 to 3 Km) to their village. No doubt this is a hard task, so most of the villagers utilize contaminated water frequently in house hold work, for their cattle, irrigation of crops and even drinking purpose. This will have a far reaching consequence in years ahead when water – soil – plant – human – animal chain will be affected.

Initiatives of Scientist Team :

- Created awareness among the villagers through group discussion and advised to use drinking water after quantitative testing of Arsenic in water sources.

- Number of water and soil samples were collected to analyse various parameters of pollution in laboratory.

- In Rabi, major standing crops in the farmers field were wheat, mustard, Sugarcane, vegetables etc. Plant samples of wheat, mustard, and vegetable have been collected from the farmer's field for analysis in laboratory to know the concentration and build up of Arsenic and heavy metals (Pb, Ni, Co, Fe, Cu, Mn, Zn etc.) in plant.
- Quantitative testing of Arsenic in drinking water have been done in the villages by Arsenic KIT and found Arsenic level more than permissible limit in most of the drinking water sources.



Detail analysis of collected water, plant and soil samples in laboratory will reflect an actual idea of translocation of this poisoning element through Soil – Plant – Animal – Human continuum.

Suggested Remedies :

To solve Arsenic problem to a considerable extent in Shahebganj following steps are suggested.

- Awareness programme in affected villages for use of safe and Arsenic free water.
- Rain water harvesting to utilise adequate rainfall.
- Damming on rivulet for storage water.
- Participation of people, NGOs & Government agencies to protect and maintain water resources.
- Minimise use of ground water and avoiding over – exploitation for growing crops.
- Use of other available resources (well, pond, lake, rivulet) through up gradation and treatment with regular monitoring of water quality.
- Installation of Arsenic Removal Plant with people participation for proper maintenance and upkeep.
- Field trials by Agril. Scientists to devise Arsenic removal techniques from water, soil & plants.
- Analysis of water of new tube-wells for Arsenic before commissioning.
- A System of periodic monitoring of Arsenic content in the tube well in and around known as arseniferous area.
- Preparation of detail map of Arsenic infected zones of Sahebganj & other districts.

Long Term Strategies:

- Construction of overhead reservoirs to store Arsenic free water
- Project on water supply to affected areas installing supplylines.
- Public health monitoring.

13.1.4.3 : Water balance studies in upland rice in red & lateritic soils

Weekly water balance

FAO water balance model ad crop coefficient were used to determine the water requirement of rice, water requirement satisfactory index and amount and duration of surplus and deficit water on weekly basis during entire growing period under three sowing dates. The capacity of sandy loam soil to hold 150 mm water per meter depth was taken into account. Crop water requirement was satisfactory from sowing to maturity for D1 (24th June) in contrast to 2 and 1 week adequacy for D2 (6th July) and D3 (15th July). Water deficit commenced during vegetative stage of D2 for 3 weeks whereas one week water deficit was observed at germination and vegetative stage for D3 sown crop. Crop water requirement was y highest for D1 (359 mm) followed by D2 (353.3 mm) and D3 (345.5 mm) sown crops (Table 29).

Table 29. Weekly water balance pertaining to upland rice under different sowing date

	24th June							6th July						15th July					
Stages	Ppt	PET	Ker	WR	Spl	Def.	WRSI	Ppt	PET	WR	Spl	Def	WRSI	Ppt	PET	WR	Spl	Def	WRSI
Sow-ing	120	27	0.90	24	0	0	100	30	29	26.1	0	0	100	46	30	27	0	0	100
Germi-nation	30	29	0.90	26	0	0	100	46	30	27	0	0	100	5	34	30.6	0	6.6	98.09
Vege-tative	46	30	0.90	27	0	0	100	5	34	30.6	0	2.7	99.24	40	30	27	0	0	98.09
	5	34	1.10	37	0	0	100	40	30	33	0	0	99.24	36	29	31.9	0	0	98.09
	40	30	1.10	33	0	0	100	36	29	31.9	0	0	99.24	20	33	36.3	0	0	98.09
	36	29	1.10	32	0	0	100	20	33	36.3	0	5.2	97.76	23	28	30.8	0	7	96.06
	20	33	1.10	36	0	0	100	23	28	30.8	0	7.8	95.56	28	24	26.4	0	0	96.06
	23	28	1.10	31	0	0	100	28	24	26.4	0	0	95.56	46	24	26.4	0	0	96.06
	28	24	1.05	25	0	0	100	46	24	25.2	0	0	95.56	10	24	25.2	0	0	96.06
Flower –ing	46	24	1.05	25	0	0	100	10	24	25.2	0	0	95.56	257	22	23.1	90	0	96.06
Milk-ing	10	24	0.95	23	0	0	100	257	22	20.9	93	0	95.56	376	19	18.05	358	0	96.06
	257	22	0.95	21	170	0	100	376	19	18.05	358	0	95.56	0	23	21.85	0	0	96.06
Matu-rity	376	19	0.95	18	358	0	100	0	23	21.85	0	0	95.56	15	22	20.9	0	0	96.06
Total	359							353.3						345.5					

Yield and yield attributes

Important yield attributing parameters like effective tillers, plant height, no. of fertile and chaffy grains per panicle, 1000 grain weight, total dry matter (TDM) ad yield were studied (table 30). Among the three date of sowing, yield of D2 (6th July) was found highest (8.98 q/ha) followed by 7.24 q/ha for D1 (24th June). Numbers of effective tillers, 1000 grain weight and fertile grains per panicle in D2 were much higher from the rest two date sown crops resulted maximum grain yield. Among the three varieties of paddy, performance of Vandana and Birsa Vikas Dhan 109 was foud better (14.22 q/ha).

Table 30. Yield and yield attributes of Paddy varieties under different sowing dates.

Treatments	Effective tillers/ sq.mt.	Fertile grain/ panicle	Chaffy grain/ panicle	1000 grain wt. (gm)	Plant ht. (cm)	Yield (q/ha)	TDM (gm/mt)
Date of sowing							
24th June	309	36	28	15.44	83	7.24	259
6th July	315	41	189	15.67	80	8.98	234
15th July	115	28	33	10.91	81	5.52	137
Variety							
Vandana	235	38	24	14.22	84	7.33	145
BV Dhan 109	264	33	29	14.22	82	7.48	207
BV Dhan 111	240	33	25	13.57	78	6.49	164

All the three paddy varieties were affected by the Brown spot disease but paddy crops sown on 24th June were severely affected due to higher temperature associated with high RH (RHI 86-88% & RH II 68-79%) at the time of tillering and vegetative stages which caused quantitative and qualitative yield reduction. Disease intensity was found highest for vandana variety followed by Birsa Vikas Dhan 111 under all the three dates of sowing.

Delay in onset of monsoon and uneven distribution of rainfall followed by dry spells, all varieties sown under different dates, yielded very low as compared to their potential yield (30-35 q/ha). Reduction in yield was mainly due to stunted growth of paddy due to brown spot disease infestation and formation of chaffy grains.

13.1.5 : Site specific nutrient management studies

Experiment A :

Long term system evaluation of ecological intensification management and farmers fertilization practice in maize-wheat cropping system

Maize

Treatments:

T_1 : 0 kg N, 90 kg P_2O_5 & 100 kg K_2O

T_2 : 180 kg N (50/0/50), 90 kg P_2O_5 & 100 kg $_{K2O}$

T_3 : FFP-N

T_4 : FFP***

***FFP : Farmer's fertilization practice

Design	:	RBD
Replications	:	3
Plot size	:	10 x 6 m^2
Spacing	:	70 x 18 cm
Variety	:	Pioneer 30 V92
Date of sowing	:	22.6.2010
Date of harvesting	:	28.9.2010

Wheat

Treatments for wheat:

T1 : 0 kg N, 70 kg P_2O_5 & 60 kg K_2O/ha

T2 : 130 kg N (50% at basal & 50% at CRI), 70 kg P_2O_5 & 60 kg K_2O/ha

T3 : FFP-N

T4 : FFP***

***FFP : Farmer's fertilization practice

(FYM @ 2 t/ha and top dressing of urea twice @ 60 kg/ha)

Design : RBD

Replications : 3

Plot size : 10 x 6 m2

Spacing (R-R) : 25 cm (R-R)

Variety : DBW-17

Date of sowing : 1.12.2010

Date of harvesting : 11.4.2011

Materials & Methods

Long term system evaluation of ecological intensification management and farmers fertilization practices comprised 4 treatments. Experiment was carried out with maize Var. Pioneer 30 V92 during June to October in loamy – sand textured soil having plH 5.1, organic carbon 4.3 gm/kg, and available N, P, K, S viz. 242 kg/ha, 32.0 kg/ha, 162 kg/ha and 13.5 mg kg/ha respectively. Yield data of grain and straw were recorded from net plot area. Nutrient concentration of plant and grain samples from each plot was analysed and total uptake was calculated. Soil samples were collected from each plot to know the soil fertility status of soil after harvest of crop. This was followed by wheat (Var. DBW-17).

Expt. B

Effect of different rate and timings of nitrogen application in maize-wheat cropping system.

MAIZE

Treatments:

T1 : 0 kg N

T2 : 80 kg N (33-33-33)

T3 : 160 kg N (33-33-33)

T4 : 240 kg N (33-33-33)

T5 : 0 kg N

T6 : 80 kg N (33-33-33 LCC)

T7 : 160 kg N (33-33-33 LCC)

T8 : 240 kg N (33-33-33 LCC)

T9 : 0 kg N

T10 : 80 kg N (50-0-50)

T11 : 160 kg N (50-0-50)

T12 : 240 kg N (50-0-50)

Note : 100 kg P_2O_5 and 100 kg K_2O/ha applied to all the treatments.

Design : RCBD

Replications : 3

Plot size : 10 x 4.8 m^2

Spacing : 70 x 18 cm

Variety : Pioneer 30V92

Date of sowing : 23.6.2010

Date of harvesting : 2.10.2010

Experiment B : N timing X N rate

Wheat

Treatments:

T_1	:	0 kg N
T_2	:	50 kg N (33 B – 33 CRI – 33 PI)
T_3	:	100 kg N (33 B – 33 CRI – 33 PI)
T_4	:	150 kg N (33 B – 33 CRI – 33 PI)
T_5	:	0 kg N
T6	:	50 kg N (33 B – 33 CRI – 33 PI LCC)
T_7	:	100 kg N (33 B – 33 CRI – 33 PI LCC)
T_8	:	150 kg N (33 B – 33 CRI – 33 PI LCC)
T_9	:	0 kg N
T_{10}	:	50 kg N (50 B – 50 CRI)
T_{11}	:	100 kg N (50 B – 50 CRI)
T_{12}	:	150 kg N (50 B – 50 CRI)

Note : 90 kg P_2O_5 and 80 kg K_2O/ha applied to all the treatments

Design	:	RCBD
Replications	:	3
Plot size	:	10 x 4.8 m^2
Spacing (R-R)	:	25 cm (R – R)
Variety	:	DBW-17
Date of sowing	:	2.12.2010
Date of harvesting	:	12.4.2011

Materials & Methods

The experiment (comprising of 12 treatments) was conducted with Maize Var. Pioneer 30V92 during June to October in sandy-loam texture soil having pH 5.43, organic carbon 4.3 g/kg and available N, P, K and S was 252, 46.0, 133.0 and 13 kg/ha respectively. The maize crop (Pioneer 30V92) was sown in June and harvested in the month of October. Yield data, nutrient concentration and uptake of plant samples were recorded. After harvesting fertility status of soils of each plot were examined. This was followed by wheat (Var. DBW-17).

Experiment C :

Omission plot/quefts' calibration in maize-wheat cropping system

MAIZE

Treatments:

T_1	:	NPK 250 kg N (50-0-50), 120 kg P_2O_5 & 120 kg K_2O
T_2	:	(-N), 120 kg P_2O_5 & 120 kg K_2O
T_3	:	(-P), 250 kg N (50-0-50) & 120 kg K_2O
T_4	:	(-K), 250 kg N (50-0-50) & 120 kg P_2O_5
T_5	:	SSNM (200 kg N, 90 kg P_2O_5 & 100 kg K_2O)

Design	:	RCBD
Replications	:	4
Plot size	:	10 x 6.6 m2
Spacing	:	70 x 18 cm
Variety	:	Pioneer 30V92
Date of sowing	:	24.6.2010
Date of harvesting	:	3.10.2010

WHEAT

Treatments:

T1	:	NPK 150 kg N (50% at basal & 50% at CRI), 110 kg P_2O_5 & 100 kg K_2O
T2	:	(-N), 110 kg P_2O_5 & 100 kg K_2O
T3	:	(-P), 150 kg N (50% at basal & 50% at CRI) & 100 kg K_2O
T4	:	(-K), 150 kg N (50% at basal & 50% at CRI) & 110 kg P_2O_5
T5	:	SSNM 120 kg N (50% at basal & 50% at CRI), 70 kg P_2O_5 & 60 kg K_2O

Design	:	RCBD
Replications	:	4
Plot size	:	10 x 6.6 m^2
Spacing (R-R)	:	25 cm (R-R)
Variety	:	DBW-17
Date of sowing	:	3.12.2010
Date of harvesting	:	14.4.2011

Materials & Methods

Experiment was carried out during the month of June to October. The experimental soil was sandy loam in texture having 5.2, organic carbon 4.9 g/kg and available N (272.0 kg/ha), P (32.0 kg/ha), K (139.0 kg/ha) and S (14 kg/ha). Necessary plant protection measures were taken care of. Maize crop was protected from Stem-borer by the application of Furadon. Yield data, nutrient uptake and fertility status of post harvested soil were recorded. This was followed by wheat (DBW-17).

Results :

Experiment A :

Results reveal that maize grain yield (70.9 q ha^{-1}) was highest with 180 kg N, 90 kg P_2O_5 and 100 kg K_2O/ha yield of wheat at 130 kg N, 70 kg P_2O_5 and 60 kg K_2O/ha was 41 q ha^{-1}. System yield was 135 (maize equivalent yield) q ha^{-1} with NPK application in both crops. Omission of N brought about 52.4 per cent reduction in yield of the system. FFP produced 66 q ha^{-1} MEY while FFP-N produced only 39.28 q ha^{-1} signifying that N was the most limiting plant nutrient in Maize-wheat system in Alfisols. Plant uptake of N, P, K and S by the system was drastically reduced with the omission of N application.

Experiment B :

Maximum grain yield (6.8 t ha^{-1}) of maize was recorded at 160 kg N ha^{-1} applied in three splits guided by leaf colour chart (LCC) (Table 32). Wheat yield was highest (5 t ha^{-1}) at application of 150 kg ha^{-1} of N in three splits. Post harvest nutrients status of soil after one cycle of maize and wheat showed that higher level of N application in two and three split doses decreased the N, K and S status by 11 to 19% from its initial status. Per cent increase (254) in maize-wheat system yield (Table 32), as compared to the check treatment, was highest with application of 240 and 150 kg N ha^{-1} in maize and wheat respectively, applied in two or three splits based. Results suggest the need for N application based on periodic assessment the plant N status to minimize losses of fertilizer N, save environment and improve NUE.

Conclusion

Maize-wheat system yield can be doubled in the rainfed tracts of eastern India through optimization of N management, along with balanced application of other limiting nutrients. The rate and timing of N application is critical to improve yields as well as to increase nutrient use efficiency for better farm economics.

Experiment C :

Maize yield was highest (6.4 t/ha) in the prototype SSNM plot. Omission of nutrients from the ample NPK treatment showed that N was the most limiting nutrient, followed by P and K (Table 33) in the location. Omission of nutrients caused uptake restrictions for all the major nutrients (Table 33). The results showed that expected N, P and K yield responses at the experimental site are 4.3 t/ha, 1.9 t/ha and 1.3 t/ha, respectively. When combined with a target agronomic efficiency and the reciprocal internal efficiency (nutrient content in above-ground plant dry matter per 1000 kg of economic produce) of maize, the response data obtained from the experiment could provide an alternate approach of estimating nutrient rate to achieve a target yield. We expected higher yield response for K considering the low soil available nutrient content in the soil. However, K contribution from irrigation water masked the actual response. This suggests that such external nutrient contribution (residue, irrigation water) need to be taken into account while formulating SSNM rates for maize. System yield of maize-wheat clearly indicate that there was no significant difference in SSNM and NPK plots, thereby saving 50 kg N, 30 kg P_2O_5 and 20 kg K_2O/ha in maize & 30 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha in wheat by following SSNM.

Conclusion

One of the advantages of omission plot approach of estimating soil nutrient supplying capacity is that it circumvents the infrastructural issues associated with soil testing and provides an alternate method of estimating site specific nutrient rates for maize. This can help disseminate site specific nutrient management strategies to maize farmers in Eastern India for higher productivity, farm profit and environmental sustainability.

Table 31. Grain yield and total nutrient uptake by maize-wheat system as affected by ecological intensification management.

Treat-ments	Grain yield (q/ha)			% increase/ decrease	Nutrient uptake (kg/ha) in system			
	Maize	Wheat	System (MEY)		N	P	K	S
PK(-N)	16.9	9.35	31.44	-52.4	37.9	16.71	69.45	8.41
NPK	70.9	41.25	135.07	104.6	145.68	38.01	180.92	30.96
FFP-N	21.8	11.24	39.28	-40.5	54.79	14.31	70.28	8.48
FFP	32.4	21.60	66.00	-	82.76	19.65	100.48	14.85
CD (0.05)	4.53	4.20	11.06		25.28	7.39	18.74	5.12

Selling price of maize – 900/q, wheat – 1400/q

Table 32. Effect of rate and time of nitrogen application on yield and total nutrient uptake of maize-wheat system.

Treatments	Grain yield (q/ha)			% increase	Nutrient uptake (kg/ha) in system			
	Maize	Wheat	System (MEY)		N	P	K	S
0/0 kg N	19.75	11.81	38.12	-	53.88	10.85	88.37	14.65
80/50 kg N (33-33-33)	52.56	21.54	86.07	125.8	105.56	20.94	115.94	21.67
160/100 kg N (33-33-33)	67.56	34.53	121.27	218.1	175.84	30.06	167.21	29.02
240/150 kg N (33-33-33)	66.2	44.32	135.14	254.5	173.19	30.68	179.79	33.25
0/0 kg N	27.96	11.18	45.35	19.0	57.37	12.86	89.36	14.67
80/50 kg N (33-33-33 LCC)	48.1	24.94	86.90	128.0	117.7	22.23	139.31	24.6
160/100 kg N (33-33-33 LCC)	68.67	35.85	124.44	226.4	162.1	28.98	173.45	30.51
240/150 kg N (33-33-33 LCC)	59.26	46.13	131.02	243.7	161.87	27.61	181.91	32.18
0/0 kg N	26.16	11.8	44.52	16.8	71.69	13.96	93.1	14.4
80/50 kg N (50-0-50)	54.70	23.13	90.68	137.9	120.24	22.37	132.99	21.73
160/100 kg N (50-0-50)	67.07	40.98	130.82	243.2	166.15	30.67	172.64	31.03
240/150 kg N (50-0-50)	71.29	50.77	150.27	294.2	180.56	31.82	198.03	38.38
CD (0.05)	9.21	6.7	19.63	-	44.4	8.1	39.5	8.1

Table 33. Effect of site-specific nutrient management on yield and total nutrient uptake of maize-wheat system.

Treatment	Grain yield (q/ha)			% increase/ Decrease	Nutrient uptake (kg/ha) in system			
	Maize	Wheat	System (MEY)		N	P	K	S
NPK	61.72	47.39	135.44	20.4	17.92	38.72	306.07	60.34
(-N)	9.89	8.17	22.60	-79.9	35.08	9.09	72.19	13.43
(-P)	31.14	25.99	71.57	-36.4	106.05	19.13	171.28	33.47
(-K)	45.82	32.22	95.94	-14.7	161.72	28.21	21.36	52.66
SSNM	64.76	37.13	122.52	-	164.81	34.51	258.04	47.92
CD (0.05)	6.4	6.36	16.29					

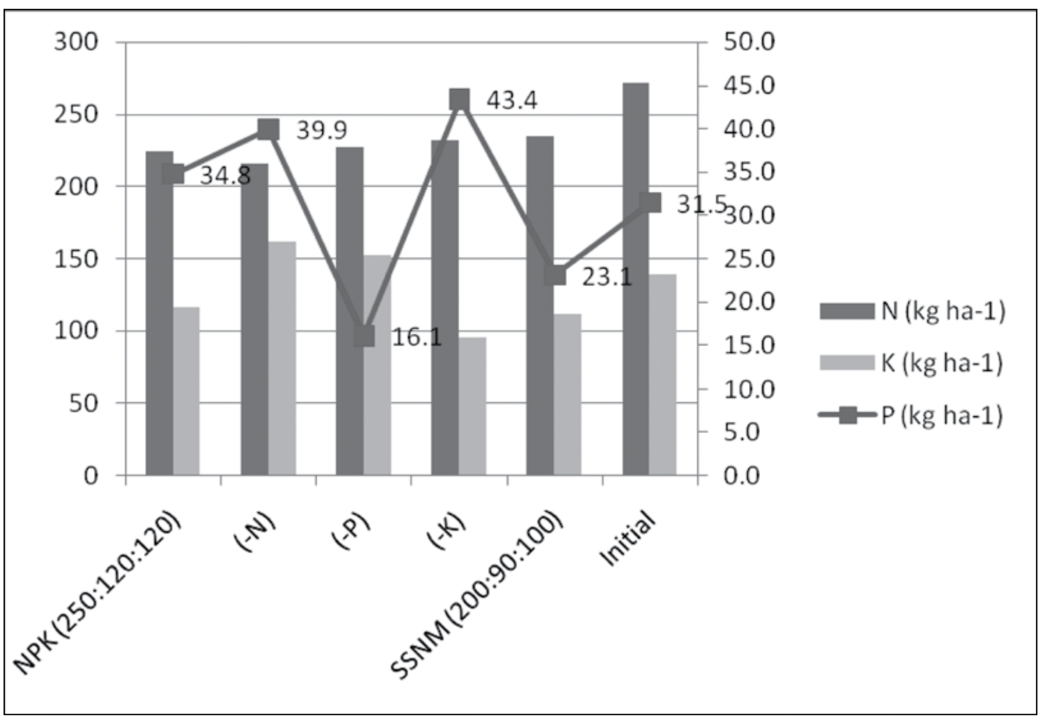


Fig. : Available nutrient supply in fertilized and nutrient omission plots