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Energy, Land, WUE and Bio-Synthates Production in Rice Based Cropping System under Partially Reclaimed Sodic Soils of North Western Zone of Tamil Nadu

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Soil reclamation and cropping system evaluation experiments were conducted during September 2009 to September 2010 in the sodic soils of Mallasamudram series in Magudanchavadi block of Salem district, Tamil Nadu in two locations representing strongly sodic (pH <9.5) and very strongly sodic (pH >9.5) soils. Soil amendments such as gypsum, ferrogypsum, sugar factory pressmud and distillery spent wash were employed to reclaim the sodic soils. Three different cropping systems were tested in the above reclaimed sodic soils and evaluated. Among the treatments, distillery spent wash (DSW) @ 5 lakh litres ha^{-1} (T_3) required higher input energy in both the locations. Higher energy output in terms of economic and biological return was recorded under DSW treated plots in all the cropping systems tried at both the locations. Among the treatments T_3 recorded higher water use efficiency and higher land use efficiency under rice – finger millet – sesbania (S_3) cropping systems in both the locations. Among the cropping systems tried, S_3 sequence with T_3 treatment recorded higher production efficiency under both in Rs. ha^{-1} day^{-1} and kg ha^{-1} day^{-1} parameters at both the locations.

Key words: Sodicity, amendments, energy, bio synthates production, WUE and DSW.

India's population is expected to cross 1400 million by 2025 A.D, the country has to raise the annual food production by 5 million tonnes from the existing 205 million tonnes to reach the food grain requirement of 301 million tonnes by 2025 A.D. If the present growth rate of agriculture and population continues, India may have to import 45 million tonnes of food grains by 2025 A.D. (Kanwar and Sekhon, 1998). The feasible alternative is to increase the cultivated land area by bringing the wastelands and problem soils under cultivation

In India, it has been estimated that nearly 10 million ha of land remain barren and gone out of cultivation due to high soil salinity and sodicity. Out of this Tamil Nadu State alone has 0.43 million ha of salt affected soils. The reclamation and utilization of ten million hectare of salt affected soils can lead to an additional production of 30–50 million tonnes of food grain every year (Dargan *et al*., 1982). Current agricultural production level of sodic soils is very low because of high pH and ESP with preponderance of carbonates and bicarbonates of sodium (Abrol *et al*., 1980). Gypsum is primarily used for sodic soils as a source of calcium to displace sodium from the soil colloidal exchange complex (Ben-Hur and Latey, 1989). Recently other ameliorants and industrial wastes like ferrogypsum (effluent from titanium industry), distillery spent wash (effluent from alcohol industries) and pressmud (by product obtained from sugar industries) reported effectively reduce the soil pH.

The experimental study region has considerable area of sodic soils to the extent of 26,279 ha. Any study to reclaim such a large extent of sodic soils will go a long way to convert wastelands into productive lands. This apart, if the reclamation studies are combined with efficient cropping system identification and development, they will certainly go to augment the crop production further. The North Western Zone of Tamil Nadu comes under agriculturally potential area, but the presence of considerable extent of salt affected soils hampered the agricultural productivity as much as the salt affected soil farmers are poor. Thus, reclamation and evolving suitable cropping systems is utmost necessary to improve the status of the farming community of this region.

National Planning Commission and Agro-Climatic Regional Planning (ACRP) are involved in location specific technology to be followed for problems confined to the identified agro climatic zones. With this background, the present study was carried out to identify the effect of energy, land, WUE and bio-synthates production in rice based cropping system in partially reclaimed sodic soils of North Western zone of Tamil Nadu.

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Materials and Methods

The field experiments were conducted during September 2009 to September 2010 in the sodic soils of Mallasamudiram soil series of Magudan chavadi block. The experiments were taken up in two locations based on severity of sodicity namely strongly sodic (pH <9.5) and very strongly sodic (pH >9.5) soils suggested by Potentiomerty method. The selection of locations was based on the surface soil samples collected from different salt affected villages of North Western zone of Tamil Nadu. The results of surface soil sample analysis revealed that the samples from Sankari and Tiruchengode Taluk of Salem and Namakkal districts were found to record high range of sodicity. The profile studies also revealed the important basic properties of sodicity already established in Mallasamudram soil series and hence locations were selected in this soil series. The experimental soil had low available N (196 and 113 kg ha^{-1}), P (8.30 and 5.00 kg ha^{-1}) and medium available K (225 and 175 kg ha^{-1}) at both the locations. Rice variety CO 43 (139 days duration), cotton MCU 5 (165 days), chillies - K2 (161 days), finger millet - GPU 28 (105 days) and *sesbania* local (50 days) were used for the study. The experiment was laid out in randomized block design with three replications. All the nine treatment combinations were allotted at random to plots within each replication. During second and third crops there was no change in the allotment of treatments to different plots. Each treatment was continued and imposed in the same plot for all the three seasons. The treatments consisted of nine soil amendments *viz.,* T_1 : Gypsum, T_2 : Ferrogypsum, T_3 : Distillery spent wash @ 5 lakh litres ha^{-1}, T_4 : Pressmud @ 12.5 tonnes ha^{-1}, T_5 : Pressmud @ 6.25 t ha^{-1}+ Green leaf manure 6.25 t ha^{-1} *(Delonix alata).* T_6: Pressmud @ 6.25 t ha^{-1}+ Farmyard manure 6.25 t ha^{-1}, T_7: Gypsum + Green leaf manure @ 6.25t ha^{-1} (*Delonix alata),* T_8: Ferrogypsum + Green leaf manure @ 6.25 tones ha^{-1} *(Delonix alata)* and T_9: Untreated control. The quantity of gypsum and ferrogypsum was calculated at 50 per cent of gypsum requirement.

The calculated quantities of gypsum, ferrogypsum, distillery spent wash (DSW) and pressmud were applied either alone or in combination with farmyard manure (FYM) and green leaf manure (GLM) as per the treatment schedule to the respective plots. The powdered soil amendments were spread evenly on the surface of the plots and mixed thoroughly to a depth of 10 - 15 cm layer under submerged puddled condition. Water level was maintained to a height of 10 cm for 48 hours and then drained to wash out the salts. The process of impounding and draining the water was repeated twice in order to leach out the salts from the soil. The pressmud treated plots were irrigated and kept under water submergence for 25 days. The DSW @ 5 lakh litres ha^{-1} was applied to the respective plots. Then the plots were dug manually using spade and the field was allowed for sun drying for nine days. Then on tenth day of DSW application, the plots were impounded with water to a height to 10 cm and the water level was maintained for 24 hours and then the water was drained out. The process of impounding water and draining was done twice before transplanting of rice. On 18^{th} day after application of DSW, the rice seedlings were transplanted in the main field. Soil samples from these plots were drawn to measure pH, EC, available N, P, K and micronutrients to ascertain the extent of reclamation and soil fertility status.

The recommended dose of fertilizers for rice (150:50:50 N, P_2O_5 and K_2O Kg ha^{-1}), cotton (80: 40: 40 N, P_2O_5 and K_2O Kg ha^{-1}), chillies (75:35:35 N, P_2O_5 and K_2O Kg ha^{-1}) and finger millet (60:30:30 N, P_2O_5 and K_2O Kg ha^{-1}) were applied as urea, single super phosphate and muriate of potash. The planting was done with a spacing of rice 20 X 10 cm, cotton 75 X 30 cm, chillies 45 X 10 cm and finger millet 15 X 15 cm and other cultivation practices were normally followed as per crop production guide (CPG, 1998).

Observations were recorded on growth parameters, yield attributes, yield and quality characters, nutrient balance in the cropping systems, rice equivalent yield, microbial population, energetics in the cropping systems, production efficiency, land, water use efficiency and harvest diversity index (HDI). Other parameters such as soil available NPK balance in the cropping system as suggested by Sadanandan and Mahapatra (1973a & b, 1974), partial budgeting of cropping system as per Johl and Kapur (1977), energetic of each cropping system was calculated as per Paneshwar and Patnagar (1994) and production efficiency was calculated as suggested by Singh and Verma (1998).

Results and Discussion

Energetics in cropping sequences

Among the soil amendments, application of distillery spent wash (T_3) registered higher energy input followed by combined application of ferrogypsum + green leaf manure @ 6.25t ha^{-1} *(Delonix alata)* (T_8) irrespective of the cropping systems at both the locations (Table 1a, b & c and 2a, b & c) . In general organic amendments like pressmud, green leaf manure and FYM applied plots recorded lesser energy input than the rest of the amendments tried while untreated control invariably recorded lower energy input at both the locations. Among the cropping systems tried, rice-chillies -sesbania (S_2) sequence recorded higher energy input followed by S_1 and S_3 system at both in L_1 and L_2. This might be due to the energy input for the system must not be markedly high. In an improved sorghum based farming system in India, the total energy input per hectare was less than a comparable system in Kansas, USA as reported by

Table 1a. Effect of treatments on energy relationship - S_1 - L_1

T. No.	Energy output Mj ha^{-1} yr^{-1}	Energy input Mj ha^{-1} yr^{-1}		Energy use efficiency Mj ha^{-1} yr^{-1}		Energy productivity g Mj^{-1} ha^{-1}
		Eco	Bio	Eco	Bio	
T_1	71776	37105	82818	0.5	1.2	167.0
T_2	86776	35840	72832	0.4	0.8	125.2
T_3	169650	80165	148200	0.5	0.9	134.6
T_4	70142	25956	50964	0.4	0.7	109.6
T_5	66851	42395	79302	0.6	1.2	182.0
T_6	65334	26223	52659	0.4	0.8	120.7
T_7	75168	41885	96208	0.6	1.3	183.7
T_8	90168	45720	93115	0.5	1.0	153.9
T_9	56619	15569	28578	0.3	0.5	77.9

Table 1b. Effect of treatments on energy relationship – S_2 - L_1

T. No.	Energy input Mj ha^{-1} yr^{-1}	Energy output Mj ha^{-1} yr^{-1}		Energy use efficiency Mj ha^{-1} yr^{-1}		Energy productivity g Mj^{-1} ha^{-1}
		Eco	Bio	Eco	Bio	
T_1	76,626	27586	87136	0.4	1.1	149.7
T_2	91626	26394	82913	0.3	0.9	119.3
T_3	174501	64226	153230	0.4	0.9	124.6
T_4	74993	18513	60033	0.2	0.8	104.7
T_5	71702	33253	94230	0.5	1.3	177.8
T_6	70185	18007	62871	0.3	0.9	115.2
T_7	80019	31579	105956	0.4	1.3	171.8
T_8	95019	35653	105136	0.4	1.1	148.2
T_9	61469	9827	31215	0.2	0.5	66.7

Table 1c. Effect of treatments on energy relationship - S_3 - L_1

T. No.	Energy input Mj ha^{-1} yr^{-1}	Energy output Mj ha^{-1} yr^{-1}		Energy use efficiency Mj ha^{-1} yr^{-1}		Energy productivity g Mj^{-1} ha^{-1}
		Eco	Bio	Eco	Bio	
T_1	67620	41748	71990	0.6	1.1	168.2
T_2	82650	46893	67095	0.6	0.8	137.9
T_3	165495	96873	140804	0.6	0.9	143.6
T_4	65987	39249	55013	0.6	0.8	142.8
T_5	62696	56228	87694	0.9	1.4	229.5
T_6	61179	39617	55527	0.6	0.9	155.5
T_7	71013	57036	86360	0.8	1.2	201.9
T_8	86013	63578	96602	0.7	1.1	186.2
T_9	52463	24108	28579	0.5	0.5	100.4

Bukantis (1980). Dazhong and Pimental (1984) also reported that the energy input for soybean in China was five times greater than that for the same crop in India.

Higher energy output in terms of economic and biological return was recorded under DSW treated plot in all the cropping systems tried at both the locations. It was followed by T_8 in L_1 and T_7 in L_2 in all the cropping systems tried. Among the cropping systems tried S_2 system recorded higher energy output than S_1 followed by S_3. Lower energy output was recorded in control treatment in all cropping system in both the locations. It was observed that

Table 2a. Effect of treatments on energy relationship - S_1 - L_2

T. No.	Energy input Mj ha^{-1} yr^{-1}	Energy output Mj ha^{-1} yr^{-1}		Energy use efficiency Mj ha^{-1} yr^{-1}		Energy productivity g Mj^{-1} ha^{-1}
		Eco	Bio	Eco	Bio	
T_1	81776	23747	55303	0.3	0.7	96.6
T_2	106776	23424	48562	0.2	0.5	67.4
T_3	169650	60101	113573	0.4	0.7	102.4
T_4	70142	13645	34034	0.2	0.5	67.9
T_5	66851	20778	42436	0.3	0.6	94.5
T_6	65334	10691	31049	0.2	0.5	63.8
T_7	85168	31016	65978	0.4	0.8	113.8
T_8	110168	28163	58017	0.3	0.5	78.2
T_9	56619	7538	20307	0.1	0.4	49.2

Table 2b. Effect of treatments on energy relationship - S_2 - L_2

T. No.	Energy input Mj ha^{-1} yr^{-1}	Energy output Mj ha^{-1} yr^{-1}		Energy use efficiency Mj ha^{-1} yr^{-1}		Energy productivity g Mj^{-1} ha^{-1}
		Eco	Bio	Eco	Bio	
T_1	89626	18254	60965	0.2	0.7	88.4
T_2	111626	17879	52364	0.2	0.5	62.9
T_3	174501	48001	114674	0.3	0.7	93.2
T_4	74993	7868	35470	0.1	0.5	57.8
T_5	71702	13339	45381	0.2	0.6	81.9
T_6	70185	5834	34113	0.1	0.5	56.9
T_7	90019	21846	63331	0.2	0.7	94.6
T_8	115019	19927	60514	0.2	0.5	69.9
T_9	61469	3279	17310	0.1	0.3	33.5

Table 2c. Effect of treatments on energy relationship - S_3 - L_2

T. No.	Energy input Mj ha^{-1} yr^{-1}	Energy output Mj ha^{-1} yr^{-1}		Energy use efficiency Mj ha^{-1} yr^{-1}		Energy productivity g Mj^{-1} ha^{-1}
		Eco	Bio	Eco	Bio	
T_1	77620	35427	47090	0.5	0.6	106.3
T_2	102620	33810	43498	0.3	0.4	75.3
T_3	165495	75117	104688	0.5	0.6	108.6
T_4	65987	22197	29718	0.3	0.5	78.6
T_5	62696	27930	37257	0.4	0.6	103.9
T_6	61179	19992	27154	0.3	0.4	77.0
T_7	81013	43071	55148	0.5	0.7	121.2
T_8	106013	39984	53114	0.4	0.5	87.8
T_9	52463	13818	18909	0.3	0.4	62.4

Table 3a. Effect of treatments on water use efficiency (kg ha^{-1} mm)

T. No.	Location -1 system -1	Location -1 system -2	Location -1 system -3	Location -2 system -1	Location -2 system -2	Location -2 system -3
T_1	14.2	14.2	14.8	10.8	9.1	11.3
T_2	13.1	13.1	14.0	10.0	8.3	11.0
T_3	24.0	24.0	25.3	17.3	14.1	19.0
T_4	11.2	9.7	12.8	7.7	6.1	8.2
T_5	14.4	12.8	16.7	8.9	7.8	9.6
T_6	11.6	10.1	12.5	7.7	6.5	8.1
T_7	16.7	14.1	17.4	12.3	10.0	12.4
T_8	16.9	14.3	18.6	11.5	9.5	12.5
T_9	8.1	6.8	9.0	5.7	4.3	6.5

Table 3b. Effect of treatments on Harvest diversity index

T. No.	Location -1 system -1	Location -1 system -2	Location -1 system -3	Location -2 system -1	Location -2 system -2	Location -2 system -3
T_1	2.08	2.05	2.06	1.92	2.05	2.14
T_2	2.08	2.05	2.06	1.9	2.05	2.14
T_3	2.04	2.03	1.85	2.05	2.05	1.92
T_4	2.06	1.92	2.13	1.65	1.85	2.12
T_5	2.08	2.08	2.06	1.80	2.04	2.15
T_6	2.01	1.90	2.11	1.42	1.65	1.91
T_7	2.09	2.07	2.06	1.88	2.05	2.10
T_8	2.09	2.08	2.04	1.85	2.03	2.13
T_9	2.05	1.86	2.14	1.53	1.51	1.87

Table 3c. Effect of treatments on land use efficiency (per cent)

T. No.	Location -1 system -1	Location -1 system -2	Location -1 system -3	Location -2 system -1	Location -2 system -2	Location -2 system -3
	96.9	95.8	80.5	96.9	95.5	80.5

Table 4a. Effect of treatments on production efficiency (Rs. ha-1 day-1)

T. No.	Location -1 system -1	system -2	system -3	Location -2 system -1	system -2	system -3
T_1	8.0	14.2	25.3	-24.5	-22.7	-11.3
T_2	-1.8	6.0	13.9	-32.7	-32.9	-25.8
T_3	104.9	96.6	129.3	57.5	55.3	80.9
T_4	-12.4	-4.9	3.0	-40.8	-47.4	-34.2
T_5	20.3	25.5	41.9	-25.0	-34.5	-21.9
T_6	-9.3	-4.7	3.7	-44.1	-47.6	-38.7
T_7	16.9	22.9	40.6	-7.1	-11.6	1.7
T_8	14.9	28.4	48.9	-20.8	-23.2	-14.8
T_9	-35.2	-34.3	-25.7	-53.7	-54.5	-46.6

Table 4b. Effect of treatments on production efficiency (kg ha-1 day-1)

T. No.	Location -1 system -1	system -2	system -3	Location -2 system -1	system -2	system -3
T_1	14.2	14.2	14.3	9.2	10.1	10.2
T_2	13.3	13.7	13.5	9.2	9.85	9.6
T_3	26.2	25.4	27.9	20.6	20.9	21.5
T_4	11.6	11.5	11.4	6.3	5.9	6.4
T_5	16.2	16.1	16.7	8.6	7.9	7.8
T_6	11.9	11.7	11.4	5.8	5.9	5.8
T_7	16.2	15.9	16.6	12.1	11.3	10.9
T_8	17.6	17.4	18.5	11.3	11.6	11.0
T_9	7.0	6.9	6.8	3.8	4.3	4.0

sorghum - berseem rotation was the most efficient rotation recording higher energy output and the results of the present study is in agreement with the findings of Saini *et al*., (1998).

In general, higher energy use efficiency in terms of economical and biological values was recorded in T_5 treatment in S_3 system in L_1 and T_7 treatment in L_2. Among the treatments, T_7 recorded higher energy use efficiency in all the cropping system. Lower energy use efficiency was recorded in untreated control irrespective of locations and cropping systems. Singh and Sharma (2002) reported that wheat – maize + cowpea fodder-rice crop sequence was the highest energy producer. Energy productivity was higher in T_5 treatment followed by T_7 treatment in S_3 cropping system and lower under S_2 sequence in L_1 and T_7 treatment in S_3 sequence under L_2. Lower energy productivity was recorded in (T_9) untreated control in all cropping system tried in both the locations.

In the present study, among the different cropping sequences evaluated, S_3 sequence recorded higher energy output, energy use efficiency and energy productivity both in economical and biological consideration at both the locations followed by S_1. Energy use efficiency was least in S_2. However in terms of energy productivity, S_1 system recorded higher values followed by S_2 and S_3 system both in L_1 and L_2.

Water use efficiency

Among the treatments T_3 recorded higher water use efficiency value of 25.3 kg ha-1 mm in L_1 and 19.0 in L_2 under S_3 sequence followed by S_1 and S_2 (Table 3 a). Among the locations, other better-

Table 5a. Effect of treatments on bio synthates production – CHO (kg ha-1)

T. No.	Location -1 system -1	system -2	system -3	Location -2 system -1	system -2	system -3
T_1	1686	1497	2465	1076	995	1755
T_2	1628	1434	2340	1059	974	1693
T_3	3707	3335	4800	2782	2505	3731
T_4	1169	1046	1971	599	459	1119
T_5	1949	1774	2800	931	735	1402
T_6	1173	1025	1992	452	369	1016
T_7	1911	1699	2848	1403	1192	2154
T_8	2101	1907	3172	1269	1096	2001
T_9	897	570	1215	324	225	704

Table 5b. Effect of treatments on bio synthates production - Protein (kg ha-1)

T. No.	Location -1 system -1	system -2	system -3	Location -2 system -1	system -2	system -3
T_1	328	204	277	213	175	196
T_2	317	195	264	212	171	188
T_3	651	444	558	486	397	429
T_4	234	145	215	139	92	120
T_5	354	240	318	196	132	154
T_6	248	143	216	124	84	105
T_7	363	230	320	280	209	240
T_8	383	258	357	259	196	221
T_9	147	80	131	83	57	72

Table 5c. Effect of treatments on bio synthates production – Fat (kg ha-1)

T. No.	Location -1 system -1	system -2	system -3	Location -2 system -1	system -2	system -3
T_1	334	77	61	222	52	43
T_2	325	74	58	325	51	41
T_3	560	145	126	414	111	96
T_4	261	61	46	176	29	26
T_5	324	86	71	221	39	33
T_6	282	60	46	182	28	22
T_7	359	84	70	297	62	53
T_8	354	93	79	282	58	48
T_9	168	35	28	114	20	15

performed treatments were T_8, T_7 in L_1 and T_7, T_8 in L_2 in all cropping systems tried. It is concluded that under sufficient water supply conditions, S_1 is the best option and under deficit water supply S_3 was the favourable alternate cropping sequence. Similar findings were reported by Ved Singh and Ram Deo (1998).

Harvest diversity index

Higher harvest diversity index was recorded in T_7 treatment in L_1 (Table 3b). With regard to L_2, the T_3 treatment under S_1 recorded high value. The lower HDI values recorded in T_6, T_9 and T_3 treatments in S_1, S_2 and S_3 in L_1 and under L_2 the T_9 recorded lower values of HDI in all the three cropping system tried.

Land use efficiency

The higher land use efficiency was recorded in S_1 (total crop duration 354 days) with 96.9 per cent followed by S_2 (total crop duration 350 days) having 95.8 per cent (Table 3c). It was concluded that there is a need to device strategies for its efficient utilization. The most efficiently used land is one, which does not remain ideal, but is occupied for some productive purposes throughout the year. Similar findings were reported by Singh and Sharma (2002).

Production efficiency

Among the cropping systems tried, S_3 sequence with T_3 treatment recorded higher production efficiency under both Rs. ha_{-1} day_{-1} and kg ha_{-1} day_{-1} parameters in both the locations (Table 4a & b). The crop production efficiency in terms of kg ha_{-1} day_{-1} and Rs. ha_{-1} day_{-1} was maximum under DSW treatment. The S_3 system both in L_1 and L_2 recorded higher values, followed by S_1 and lowest production efficiency was recorded in S_2 system in both the locations. It may be visualized that the economic yield and its price are important factor for influencing the production efficiency of a particular system and were the major reasons for higher production efficiency of S_3 system. This is in agreement with the findings of Singh and Sharma (2002).

Carbohydrate output

Since finger millet being the prominent millet crop it has been included in the S_3 cropping system and it removed more carbohydrate content of 4800 and 3731 kg ha^{-1} under DSW (T_3) treatment, in L_1 and L_2 locations respectively (Table 5a). Lower carbohydrate harvest was recorded in S_2 system at both the locations.

Protein output

Cotton seed contains a fair amount of protein, which has been included in the sequence S_1 (Table 5b). Protein harvest was higher (651, 486 kg ha_{-1} in L_1 and L_2 respectively) in S_1 system under DSW (T_3) followed by S_2. Lower protein harvest was recorded in S_2 cropping sequence at both the locations**.**

Fat output

The maximum fat output was recorded under DSW (T_3) treatment, with 560, 414 kg ha^{-1} at L_1 and L_2 respectively under S_1 cropping sequence, which was followed by S_2 and lower fat harvest recorded in S_3 cropping sequence both in L_1 and L_2 (Table 5c). The untreated control (T_9) plot recorded lower carbohydrate harvest in S_1 sequence with values of 168, 114 kg ha^{-1} under L_1 and L_2 respectively.

Focusing attention on the output of biosynthates by multiple cropping systems, there is a need to overcome the problem of malnutrition and under nutrition for the increasing population in developing countries. The protein is one of the most important food factors for the sustainable health of human population. Hence, cereal-dominating sequences provided better carbohydrate output. Similar findings were reported by Singh and Sharma (2002). From the results of the present study, it is concluded that the study area (North-Western zone) has a substantial area of sodic soils, which can be economically utilized by suitable reclamation. The soils can be reclaimed by using DSW, gypsum and ferrogypsum, alone or in combination with organics. There has been overall, improvement in soil physico-chemical properties by amendments application and rice based cropping system can be profitably adopted in these reclaimed soils.

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