International Journal of Agriculture and Food Science 2023; 5(2): 54-60

ISSN Print: 2664-844X
ISSN Online: 2664-8458
IJAFS 2023; 5(2): 54-60
www.agriculturaljournals.com
Received: 07-06-2023
Accepted: 20-08-2023

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Effects of paddy straw burning on soil quality of some selected villages of Attabira block of western Odisha, irrigated from Hirakud reservoir: A case study

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DOI: https://doi.org/10.33545/2664844X.2023.v5.i2a.148

Abstract
A large amount of paddy straw (Crop residue) is being generated with mechanized harvesting using combine harvesters in the irrigated paddy fields. This crop residue is burnt in the same field as a quick and easy method of removing it for the next crop, as the same fields are used for double cropping in a year. This practice damages micro-organisms present in the upper layers of the soil, including the soil's organic quality. The present investigation was conducted during January 2021 (rabi crop) and July 2021 (kharif crop) for the appraisal of the physicochemical parameters of soil samples collected from such agricultural fields of some selected villages in the Attabira block of Western Odisha that were irrigated by the Bargarh main canal, which flows from the Hirakud reservoir. The soil samples were analyzed by observing standard procedures, and the results revealed that the soil pH, electrical conductivity, and available potassium content increased due to crop residue burning. On the contrary, soil organic carbon content, available nitrogen, available phosphorous, and available sulphur were observed decreasing in the crop residue burnt fields. As crop residue burning helps in increasing the soil pH and EC levels, continuing this practice for a longer period may shoot up the soil pH and EC levels beyond the threshold levels, which may adversely affect the growth of the crop and the yield.

Keywords: Crop residue, straw burning, kharif crop, Rabi crop, soil pH, electrical conductivity

1. Introduction
Attabira Block is known as the rice bowl of Odisha because of its outstanding paddy production [1]. Almost all the crop fields in this area are being irrigated by the Bargarh main canal and its branch canals. Generally, double and triple cropping at the same place are typically viable due to adequate irrigation facilities. Traditional rice cultivation methods required a lot of labour. Commercial agriculture is now taking the place of traditional agricultural methods. Mechanised paddy harvesting, which uses tools like combine rice harvesters and paddy thresher machines, has begun as a response to rural workforce shortages and rising labour prices [2]. In the mechanized rice production system, large quantity of the paddy straw is generated. As the same fields are used for double and triple cropping, removal of this crop residue is necessary for next cropping. Hence, this crop residue is burnt in the same paddy fields as a quick and easy method of its removal. Since a long period, the intensive chemical fertilizer and pesticide-based agriculture has resulted in the deterioration of environmental quality and soil systems of this area. In addition to this, the crop residue burning is a new issue added to the list. Besides causing air pollution, burning paddy straw leads to the loss of soil organic matter and essential nutrients, reduces microbial activities and makes the land more vulnerable to soil erosion [3]. Straw carbon, nitrogen and sulphur are completely burnt and lost to the atmosphere in the process of burning. Finally, it leads to a number of physical and chemical processes that affects the sustainable functioning of soil.
Keeping the above facts in view a soil resource inventory work was carried out to assess the soil quality of five selected villages of Attabira Block in the Bargarh district of western Odisha namely Amastala, Bhoipura, Bugbuga, Dulampur and Larambha. These villages were selected on the basis of their agricultural importance regarding the development of the country.

Important physicochemical parameters analysed were soil pH, electrical conductivity, organic carbon content, available nitrogen, available phosphorus, available potassium and available sulphur.

2. Materials and Methods

The villages selected for the present study of soil quality were Amastala, Bhoipura, Bugbuga, Dulampur and Larambha of Attabira Block in the Bargarh district. In each village, soil samples from two types of crop fields were analysed. One where rice straw was burnt and the other with no rice straw burning. Again, the analyses were conducted for two different crops, one during the rabi crop (in the month of January) and the other during the kharif crop (in the month of July).

The soil samples were collected from the agricultural fields from a depth of about 10 centimeters using borer sampler and preserved in polythene bags for analysis in the laboratory [4]. All the soil samples were air dried under shade, processed and sieved to pass through 2 mm sieve and was analyzed for soil physical and chemical properties [5]. Soil pH and electrical conductivity (EC) were measured with 1: 2.5 soil: water ratio as per-method described by Richards (1954) [6]; organic carbon (OC) was determined by Walkley Black's wet digestion method [7]. The available N was determined by using alkaline potassium permanganate ($KMnO_4$) solution by determining the ammonia liberated [8]. The available P was determined by Olsen method by using 0.5 M $NaHCO_3$ extractant [9]. The available K was determined by using neutral ammonium acetate method by using flame photometer [5]. Soil available S was measured by turbidimetic method as described by Kumar *et al.* (2018) [10].

3. Results and Discussion

Seven physico-chemical parameters were determined for each soil sample collected from different crop (paddy) fields of five villages of Attabira block and were summarized in tables 2, 3, 4 and 5 with their statistical analysis represented in tables 6, 7, 8 and 9.

2.1 Soil pH

The amount of nutrient in the soil depends on the acidity or alkalinity. Soil having pH values less than 5.0 causes metallic toxicity on plants and due to high alkalinity the amount of bicarbonate increases which hampers the plant growth [11]. The optimum pH range for the cultivation of paddy is 5.5 to 7.5 [12]. Although it has observed pH values in some of the crop field of this area above 7.5, still paddy is the main crop of this area with other crop in different seasons.

Table 1: Parameters analysed

Parameters	Description	Unit
pH	Soil pH	Unit less
EC	Electrical conductivity	dSm^{-1}
OC	Organic carbon	$g\ kg^{-1}$
N	Available nitrogen	$kg\ ha^{-1}$
P	Available phosphorus	$kg\ ha^{-1}$
K	Available potassium	$kg\ ha^{-1}$
S	Available sulphur	$kg\ ha^{-1}$

Table 2: Physico-chemical properties of soil of rice straw unburnt fields during Kharif crop (July 2021)

Parameters	Name of the village					Mean
	Amastala	Bhoipura	Bugbuga	Dulampur	Larambha	
pH	7.04	7.36	7.32	7.33	7.27	7.26
EC	2.13	2.08	1.93	1.97	1.93	2.01
OC	3.21	2.87	3.17	2.68	2.99	2.98
N	321.84	305.27	324.57	278.64	324.19	310.90
P	28.84	26.34	26.55	29.37	28.72	27.96
K	376.42	385.31	385.04	376.61	404.67	385.61
S	87.64	92.47	73.58	88.47	79.68	84.37

Table 3: Physico-chemical properties of soil of rice straw burnt fields during Kharif crop (July 2021)

Parameters	Name of the village					Mean
	Amastala	Bhoipura	Bugbuga	Dulampur	Larambha	
pH	8.11	7.66	7.72	8.02	7.92	7.89
EC	2.19	2.28	2.08	2.39	2.11	2.21
OC	2.81	2.75	3.03	2.84	2.78	2.84
N	263.82	262.31	284.27	254.33	287.34	270.41
P	24.62	21.84	21.47	20.08	22.16	22.03
K	460.31	436.13	421.84	453.13	395.16	433.31
S	82.14	73.22	81.24	72.34	76.21	77.03

Table 4: Physico-chemical properties of soil of rice straw unburnt field during Rabi crop (January 2021)

Parameters	Name of the village					Mean
	Amastala	Bhoipura	Bugbuga	Dulampur	Larambha	
pH	7.18	7.62	7.84	7.43	7.25	7.46
EC	1.79	1.93	1.87	1.52	2.05	1.83
OC	3.23	2.81	1.82	2.75	2.46	2.61
N	335.72	327.54	257.64	298.86	318.24	307.60
P	24.34	19.24	27.29	23.51	23.92	23.66
K	341.57	306.15	355.64	298.34	334.27	327.19
S	88.13	82.54	77.42	82.44	80.22	82.15

Table 5: Physico-chemical properties of soil of rice straw burnt field during Rabi crop (January 2021)

Parameters	Name of the village					Mean
	Amastala	Bhoipura	Bugbuga	Dulampur	Larambha	
pH	8.05	8.15	7.51	7.96	7.94	7.92
EC	2.24	2.12	2.03	2.12	2.04	2.11
OC	2.35	2.71	2.64	2.51	2.56	2.55
N	245.24	256.37	262.14	238.37	274.88	255.40
P	21.47	21.85	20.84	17.44	22.68	20.86
K	410.31	385.44	305.78	338.64	332.16	354.47
S	71.04	70.38	74.31	72.55	71.47	71.95

The soil pH of soil samples collected (From crop fields with no straw burnt) during rabi crop have higher pH value (Average 7.46) compared to kharif crop (average 7.26). Also it has been observed that in both the crops the soil samples show higher pH values in rice straw burnt fields having values 7.92 during rabi and 7.89 during kharif crop as compared to the fields without straw burning (figure-1). The increase in pH in rice straw burnt fields can be attributed to the formation of hydroxides of potassium, calcium, and magnesium when rice straw ash gets mixed with water.

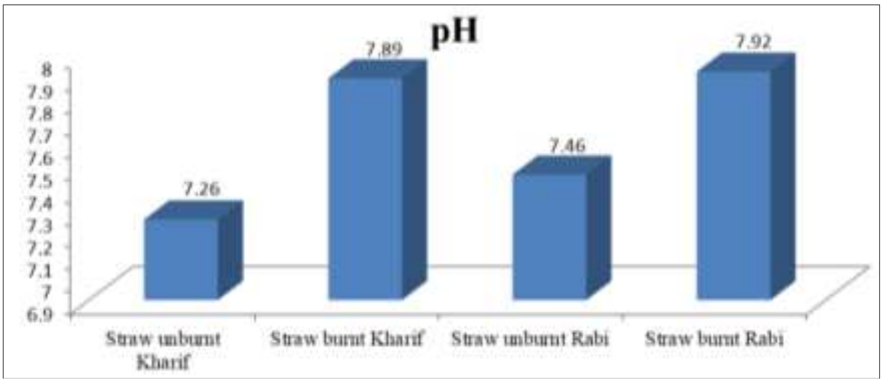

Fig 1: Variations in soil pH of different crop fields

2.2 Electrical Conductivity

Soil EC is a measure of the amount of salts in soil (salinity of soil). The predominant ions contributing to salinity and conductivity are sodium and chloride. Other ions responsible for conductivity are calcium, magnesium, potassium, sulphate, borate and bicarbonate. It affects crop yields, crop suitability, plant nutrient availability and activity of soil microorganisms which influence key soil processes including the emission of greenhouse gases such as nitrogen oxides, methane, and carbon dioxide. Excess salts hinder plant growth by affecting the soil-water balance. Salinity stress limits crop yield affecting plant growth and restricting the use of land [13]. The soil conductivity of soil samples (from crop fields without straw burning) collected in kharif crop has higher conductivity (2.01 dSm^{-1}) in average compared to rabi crop (1.83 dSm^{-1}). And it is noticed that in both the cases the soil samples shows increased electrical conductivity values in straw burnt crop fields with values 2.21 dSm-1 in kharif and 2.11 dSm^{-1} in rabi as compared to the straw unburnt fields (figure-2). The increase in electrical conductivity in rice straw burnt fields may be due to ions of potassium and calcium coming from straw ash.

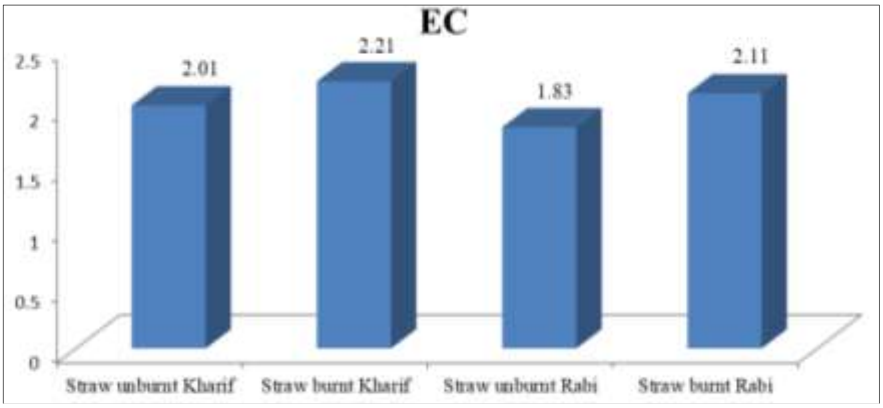

Fig 2: Variations in electrical conductivity (dSm^{-1}) of different crop fields

2.3 Organic carbon

Soil organic carbon is often considered as the largest contributor to soil quality [14, 15]. It is the most essential constituent of soil for maintaining its quality, sustaining biological activity, regulating water flow, buffering, storing, cycling of nutrients, and sustain soil productivity etc. [16].

The soil organic carbon of soil samples collected (From crop fields without straw burning) in Kharif crop have higher organic carbon content (2.98 g kg^{-1}) in average as compared to Rabi crop (2.61 g kg^{-1}). It is observed that in both the cases the soil samples shows a decreased in soil organic carbon values in straw burnt fields having values 2.84 g kg^{-1} during Kharif and 2.55 g kg^{-1} during Rabi crop as compared to the soil samples without straw burning (figure-3). Burning of organic matter and carbon during rice straw burning may be the cause of low organic carbon values in rice straw burnt fields.

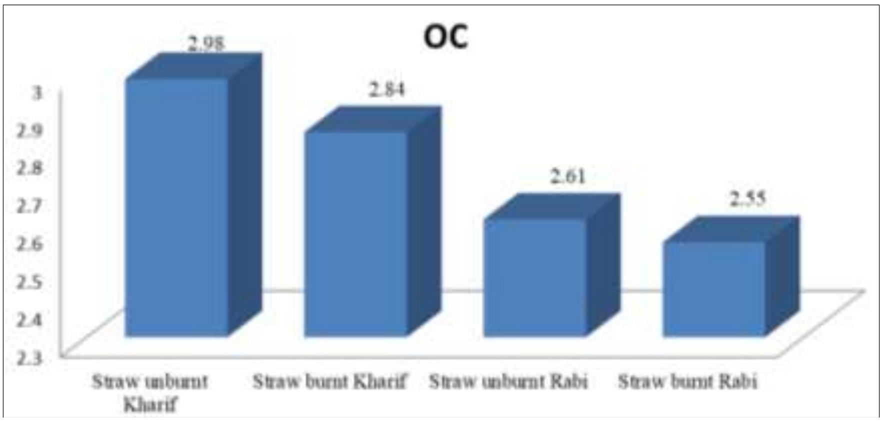

Fig 3: Variations in organic carbon (g kg^{-1}) of different crop fields

2.4 Available nitrogen (N)

Nitrogen (N) is a vitally important plant nutrient. Plants contain 1 to 5% nitrogen by weight. In soil, N that is present in organic form appears to be unavailable to plants. The available N in soil is that portion which is present in mineral forms usually in the form of ammonium and nitrate in the soil solution. It is an essential constituent of proteins having physiological importance in plant metabolism. It influences soil health primarily through changes inorganic matter content, microbial life, and acidity in the soil. The available nitrogen of soil samples collected (from crop fields without straw burning) in Kharif crop have higher available nitrogen content (310.90 kg ha^{-1}) in average as compared to Rabi crop (307.60 kg ha^{-1}). And it has been noticed that in both the cases the soil samples shows a decreased in available nitrogen content values in straw burnt field with values 270.41 kg ha^{-1} during Kharif and 255.40 kg ha^{-1} during Rabi crop as compared to the soil samples with no straw burning (figure-4). During straw burning, nitrogen gets burnt out as oxides of nitrogen, causing low available nitrogen values in rice straw burnt fields.

Fig 4: Variations in available nitrogen (kg ha^{-1}) of different crop fields

2.5 Available phosphorus (P)

Phosphorus (P) is an essential element classified as a macronutrient because of the relatively large amounts required by plants [17]. It is involved in several key plant functions, including energy transfer, photosynthesis, transformation of sugars and starches, nutrient movement within the plants [18]. The available phosphorus content of soil samples collected (from crop fields without straw burning) in Kharif crop have higher values in average (27.96 kg ha^{-1}) as compared to Rabi crop (23.66 kg ha^{-1}). And it has been noticed that in both the cases the soil samples show decreased available phosphorus content values in straw burnt fields with values 22.03 kg ha^{-1} during Kharif and 20.86 kg ha^{-1} during Rabi crop as compared to the crop fields with no straw burning. During burning of rice straw, phosphorus gets burnt out and this may the result of lower available phosphorus values in rice straw burnt fields.

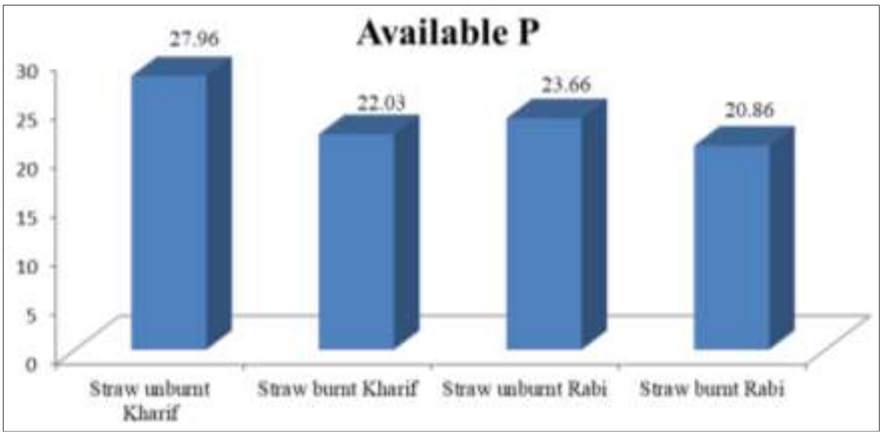

Fig 5: Variations in available phosphorus (kg ha^{-1}) of different crop fields

2.6 Available potassium (K)

Soil available K is the third most important nutrient for soil fertility and plant nutrition after nitrogen and phosphorus. Potassium is an essential plant nutrient and is required in large amounts for proper growth and reproduction of plants. It is important in photosynthesis, in the regulation of plants responses to light through opening and closing of stomata. The availability of potassium to the plant is highly variable, due to complex soil dynamics, which are strongly influenced by root–soil interactions. Many plant physiologists consider potassium second only to nitrogen in importance for plant growth. Potassium is second to nitrogen in plant tissue levels with ranges of 1 to 3% by weight [19]. Because of large differences in soil parent materials and the effect of weathering of these materials, only a little amount of soil K available to plant as soil solution and exchangeable form [20].

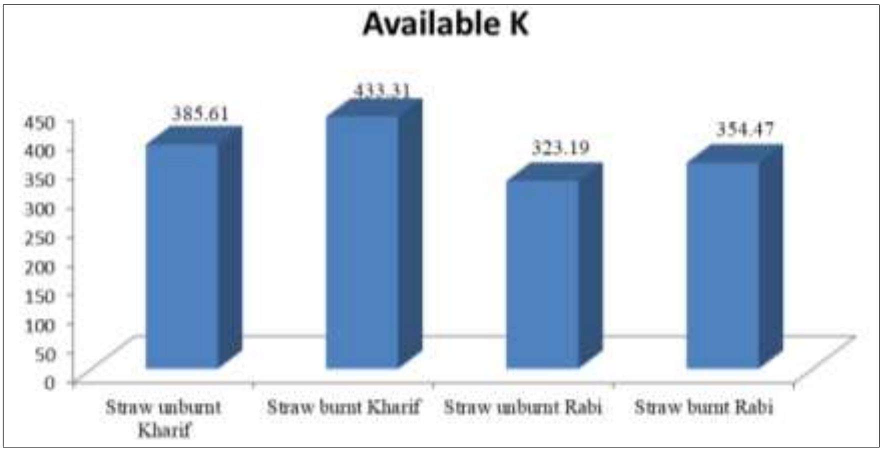

Fig 6: Variations in available potassium (kg ha^{-1}) of different crop fields

The available potassium content of soil samples collected (from crop fields without straw burning) in Kharif crop have higher available potassium content value (385.61 kg ha^{-1}) in average as compared to Rabi crop average available potassium content of soil (327.19 kg ha^{-1}). And it has been noticed that in both the cases the soil samples shows increased available potassium content values in straw burnt fields with values 433.31 kg ha^{-1} during Kharif and 354.47 kg ha^{-1} during Rabi crop as compared to the soil samples without straw burning. The potassium present in rice straw ash may be the reason behind higher value of potassium in rice straw burnt fields.

Fig 7: Variations in available sulphur (kg ha^{-1}) of different crop fields

2.7 Available sulphur (S)

Sulphur (S) is an essential secondary nutrient for sustainable crop production, is required by plants in approximately the same amount as P [21]. Approximately 95 percent of the total amount of S in soils is found in the organic matter. As the soil organic matter is decomposed the organic forms of the S is mineralized to sulphate-sulphur. This SO_4^{2-} sulphur is the only form of S that is absorbed by plant roots.

The available sulphur content of soil samples collected (from crop fields without straw burning) in Kharif crop has higher available sulphur content value (84.37 kg ha^{-1}) in average as compared to Rabi crop average available sulphur content of soil (82.15 kg ha^{-1}). And it has been noticed that in both the cases the soil samples show a decreased value of average available sulphur content in straw burnt fields with values 77.03 kg ha^{-1} during Kharif and 71.95 kg ha^{-1} during Rabi crop as compared to the soil samples without straw burning. Burning out of sulphur in rice straw ash may be the reason behind decreased available sulphur values in rice straw burnt fields.

3. Statistical analysis

Table 6: Correlation matrix of soil parameters of Straw unburnt kharif crop field

	pH	EC	OC	N	P	K	S
pH	1						
EC	-0.585	1					
OC	-0.629	0.199	1				
N	-0.419	0.007	0.901	1			
P	-0.458	-0.023	-0.246	-0.323	1		
K	0.239	-0.548	0.081	0.487	-0.052	1	
S	-0.080	0.728	-0.521	-0.586	0.167	-0.458	1

Table 7: Correlation matrix of soil parameters of Straw burnt kharif crop field

	pH	EC	OC	N	P	K	S
pH	1						
EC	0.225	1					
OC	-0.235	-0.435	1				
N	-0.315	-0.923	0.396	1			
P	0.362	-0.425	-0.240	0.107	1		
K	0.120	-0.029	0.549	0.282	-0.687	1	
S	0.188	-0.734	0.523	0.447	0.695	-0.137	1

Table 8: Correlation matrix of soil parameters of Straw unburnt rabi crop field

	pH	EC	OC	N	P	K	S
pH	1						
EC	0.025	1					
OC	-0.733	-0.272	1				
N	-0.760	0.158	0.893	1			
P	0.138	-0.096	-0.563	-0.686	1		
K	0.106	0.466	-0.452	-0.368	0.760	1	
S	-0.705	-0.289	0.954	0.793	-0.338	-0.207	1

Table 9: Correlation matrix of soil parameters of Straw burnt rabi field crop field

	pH	EC	OC	N	P	K	S
pH	1						
EC	0.618	1					
OC	-0.205	-0.707	1				
N	-0.296	-0.702	0.467	1			
P	0.108	-0.104	0.171	0.763	1		
K	0.801	0.900	-0.437	-0.424	0.231	1	
S	-0.951	-0.546	0.135	0.046	-0.409	-0.817	1

3.1 Correlation matrix interpretation

From the Correlation matrix tables, some observations may be done as follows. There are higher correlation between pH with available potassium in straw burnt fields (0.433 and 0.851) as compared to straw unburnt fields (0.255 and 0.107). Formation of hydroxides of potassium and other minerals from rice straw ash might be the reason behind this higher correlation in straw burnt fields. Again the ions of potassium and others present in rice straw ash such as sodium, calcium and magnesium might be another reason behind the strong correlation of electrical conductivity with potassium in straw burnt fields (0.644 and 0.902). On the other hand, in straw burnt fields, the correlations between organic carbon with nitrogen are reduced significantly. It might be due to the burning out of organic matters in those fields.

4. Conclusion

The main cause of burning rice straw is to clean up the ploughing land from the previous crop residues for the next crop. Based on the findings, it may be deduced that the physiochemical properties of the soil changes due to rice straw burning. Though it an simple and easy way of cleaning residue including weed and pest, it has some disadvantages like soil erosion, loss of organic matter and soil microorganisms in addition to air pollution. The rice straw burning also raised the pH and EC level. Continuing this practice for longer periods may raise the pH and EC level beyond the threshold levels which may adversely affect the growth of the crop and the yield [22]. Again as a reduction in soil organic carbon content, available nitrogen, phosphorus and sulphur is observed in the saw burnt fields, more organic and other manures are to be applied to compensate the above. People of this locality report that for increasing production of various crop, use of fertilizers, pesticides and herbicides have gone up to threefold during the last fifty years. This ultimately increases the cost of production of rice. Again, this extensive use of excess amount of agricultural chemicals, possibility of contamination of ground water sources for drinking purposes, cannot be ruled out [23]. This may be the reason behind increasing cases of serious health issues and cancer in this area. Hence there should be other methods of removal of these agricultural residues without hurting soil. The residues may be used for production of fuels, chemicals and power, as an alternative of fossil fuels. A general awareness of farmers is required by television, hording, posters, village seminars and instruction regarding the above, which will be effective.

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