Acta Scientific AGRICULTURE (ISSN: 2581-365X)

Volume 8 Issue 11 November 2024

Research Article

Crop Residue management in Restoration of Ecological Resilience: Conservation Agriculture in Farm Reality

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Received: August 20, 2024

Published: October 07, 2024

Abstract

Open burning of surplus crop residue is common in the Asian countries which causes an array of deleterious outcomes from degrading soil ecological health to affecting human health and safety. The study was conducted to assess the farmers' understanding of the role of crop residues in sustaining soil and agronomic productivity, mitigating climate change, and restoring ecological resilience. Elucidating the factors, impacts, and perceptions of farmers, fifty respondents have been selected from Dalilpur and Kastodanga village of Nadia district by systematic random sampling for the study. The responses were collected through a structured interview schedule. The study envisaged that the communication variable and mean distance between two land fragments variables have been found to exert strong and determining contribution to the crop residue left in the field. To achieve agricultural sustainability and combat global climate change and vulnerability, it is imperative to explore the ecological role played by crop residue under the conservation agriculture systems and inculcate proper cognitive acceptance of retention of crop residue in fields among farmers to accomplish the core objectives of conservation agriculture at farm level.

Keywords: Conservation Agriculture; Crop Residue; Ecological Resilience; Residue Burning; Residue Retention

Introduction

The aftermath of green revolution has not only contributed to a 'quantum jump' of agricultural production and productivity, from 55 MT (1955) to 120 MT (1970), but has also generated surplus amount of crop residues from most of the Asian countries [10]. According to the Indian Ministry of New and Renewable Energy (MNRE), India generates on an average 500 Million tons (Mt here after) of crop residue per year (NPMCR), out of which over 25% of the total crop residues were burnt on farm [3]. A variety of gaseous pollutants, including SOx and NOx, volatile organic compounds, including polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs), and particulate matter, were released into the environment as a result of open crop residue burning globally [9]. Particulate emissions from crop residue burning have also been considered as a potential cause of Asian Brown Cloud formation over the Asian regions, in addition to several environmental and human health concerns [16]. Crop residue burning is estimated as the 4th largest type of biomass burning [1]. Burning crop residue has been shown to have a number of detrimental effects on both human and environmental health. Here are a few that have been briefly listed [2]

- **Loss of soil nutrient:** crop residue burning resulted in the fast release of photosynthetically accumulated plant nutrients in the atmosphere and nearby water bodies.
- **Impact on soil properties:** burning of crop residue leads to increase in soil temperature which causes detrimental effects on the beneficial soil biological communities involved in nutrient cycling and soil health management.
- **Emission of greenhouse gases (GHGs):** a substantial amount of GHGs such as CO2, CH4 and N-oxides are released during the crop residue burning.

- **Emission of other gases and aerosol:** crop residue burning also releases various other primary gaseous emissions and particulate matter which form aerosol and other secondary pollutants, and considered as detrimental to the environment.
- **Impact on human health:** crop residue burning causes various occupational and non-occupational diseases in humans.

Diverse resource-conserving technologies came into existence as a result of the requirement for proper management of the surplus crop residues.Conservation agriculture (CA) techniques (based on little to no tillage, residue recycling or mulching, and crop rotation) have been viewed as one of the most effective ways to simultaneously address the twin problems of managing excess crop residue and soil deterioration [20]. Retention of crop residue along with a no-tillage method has been found to preserve fresh organic matter in the topsoil, improving the health of the soil [25]. The benefits of it include improved water-use-efficiency, reduction in soil erosion [23], enhanced nutrient retention, soil enzyme activity [12], as well as soil heterotrophic respiration by improved microbial activities [18, 26]. Additionally, there have been reports of an increase in earthworm activity in soil [6]. The SOM pools are improved by residue retention policies used in conservation agriculture systems, but as the SOM degrades over time, GHGs (CO2, CH4, and N2O) are released [7]. Figure 1 provides a brief illustration of the advantages and drawbacks of retaining crop residue in a conservation agriculture system. The study was attempted to comprehend the role of crop residue in restoration of ecological resilience under conservation agriculture at farm level through farmers' perspectives, perceptions and interpretations.

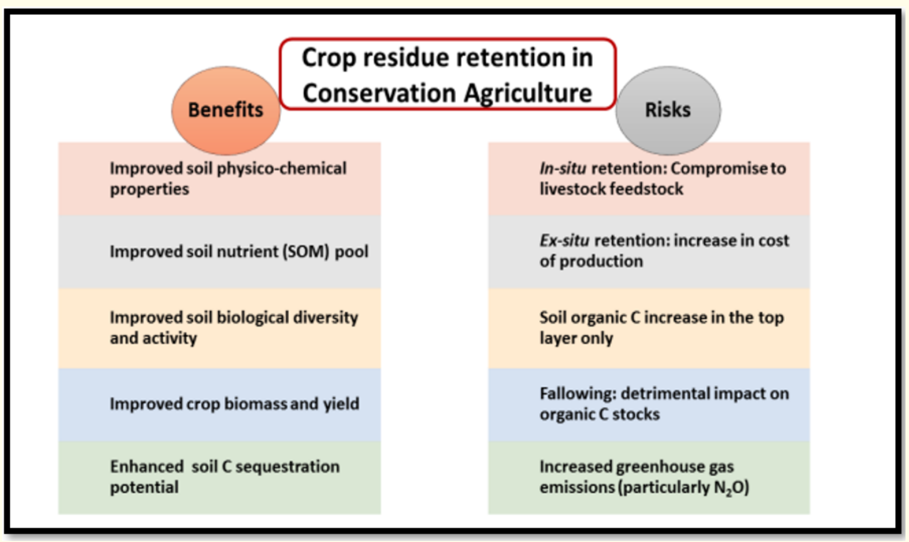

Figure 1: A brief account on the benefits and risks associated with crop residue retention in crop field under conservation agriculture practices [20].

Material and Methods

The study was carried out in Nadia district of West Bengal during the year 2020-21. The study used both purposeful and basic random sampling procedures [17]. Fifty farmers were chosen from the villages of Kastodanga and Dalilpur in the Haringhata block of the above mentioned district. The district, block, and villages were purposefully chosen for the study because they were under high-intensity agriculture, rice and vegetable-based farming, declining productivity, livestock count, and organic carbon. The number of respondent selection constraints was influenced by the COVID-19 situation, socio-political context, and level of farmer responsiveness. Although the study emphasizes on the Nadia district, the findings are anticipated to be applicable to a wide range of nearby places with similar climate and socioeconomic conditions. The study examined the farmers' perceptions and their interpretations of climate resilient technology in conservation agriculture using two sets of variables: (i) independent variables (x_1-x_{23}) and (ii) dependent variable (y). Crop residue left in the field (y) is collected using a pre-tested structured interview schedule, and relationships between selected twenty-three variables are analyzed using quantitative methods such as Coefficient of Correlation, Multiple Regression, Stepwise Regression, and Path Analysis using IBM SPSS v26.0 and the web-based application OPSTAT [19].

Results and Discussion

Relation between crop residue left in the field and selected socio-ecological variables

Table 1 presents the coefficient of correlation and multiple regression between crop residue left in the field (y) and 23 independent variables (x_1-x_{23}). It has been found that the variable age (x_1) has recorded significant but negative correlation with the dependent variable, crop residue left in the field (y). The relation depicts that the young farmers are more prone to crop residue management than the older one through different sensitization and training programmes. The young farmers might have been exposed to ecological education and perception, attained proficiency in restoring the ecological resilience. The communication variable (x_{21}) has recorded significant and positive correlation with the dependent variable, crop residue left in the field (y). The relation indicates that the role and contribution of different media, TV/radio, interpersonal opinion leader and cosmopolite source as fertilizer dealer, they have been sensitized about climate change or ecological resilience. Their responses have been recorded so that the yields of different rice variety over decade have been declined, this was their observation and perception. They have also observed and recorded during field survey, there has been a serious decline of biodiversity; decline of local cultivars is alarming and that is how and why through different educational programmes, exposure visits, training and sensitization programmes they have built up a favourable attitudes and perception about crop residue management. Beta coefficient of the causal variable total input cost has been negative but significant. It implies that input has been reduced in a response to better crop residue management. Whenever the crop residue is mix to the soil it will replace the need of application of chemical fertilizer then ecological resilience will be maintained and cost of input will be downsized and sustainability will be enhanced. Whereas beta coefficient of the variable savings/year (x_{16}) has been recorded positive and significant which implies that with the reduction of input cost, savings have been encouraged which is quite obvious. The beta coefficient of the causal variable average size of land fragment (x_7) has been negative but significant. It implies that the average size of land fragment has come up as one of the strongest determinant to decide on the nature, volume and type of crop residue management. The average size of land fragment is immensely important in deciding about all kinds of farm management. The less is the average size of land fragments, the higher would be the energy loses that is how with the number of land fragments the whole of the farm operations will turn energy prodigal and cost intensive. The R square value stands at 81.60 per cent can be inferred that the combination of 23 causal variables has been quite justified, effective, and able to explain 81.60 per cent of variance in the consequent variable crop residue left in the field.

Predicting application of crop residue left in field from selected variables

Table 2 presents the stepwise regression analysis which elicits that two causal variables, communication variable(x_{21}) and mean distance between two land fragments (m)(x_8) has come out with stronger determining character on the consequent variable, crop residue left in the field (y). These two causal variables together have contributed 37.60 per cent of variance in the consequent variable crop residue left in the field. The rest twenty variables have contributed only (81.60-37.60) per cent i.e., 44 per cent variance. The fact has elicited from this hard evidence speaks that the role and contribution of different media, TV/radio, interpersonal opinion leader and cosmopolite source as fertilizer dealer, they have been sensitized about climate change or ecological resilience. Their responses have been recorded so that the yields of different rice variety over decade have been declined, this was their observation and perception. They have also observed and recorded during field survey, there has been a serious decline of biodiversity; decline of local cultivars is alarming and that is how and why through different educational programmes, exposure visits, training and sensitization programmes. They have built up a favourable attitudes and perception about crop residue management. Mean distance between two land fragments(x_8) has come out as an important determinant for characterizing the crop residue management. It is expected that when distance will be reduced, the crop residue management would go better. On the other hand, it is also a fact that when land fragments are residing at higher distance most of the residues are not carried back in their home but it is mixed in the soil.

Independent Variables	'r' Value	Unstandardized Coefficients		Standardized Coefficients	t Value
		Reg. Coef. B	S.E. B	Beta	
Age (x_1)	-0.310*	-32.999	17.038	-0.714	-1.937
Education (x_2)	0.004	36.017	92.184	0.132	0.391
Functional education (x_3)	0.015	-171.682	139.386	-0.609	-1.232
Family size (x_4)	-0.089	-130.143	100.222	-0.388	-1.299
Size of land holding (bigha) (x_5)	0.157	52.108	73.959	0.207	0.705
No. of land fragments (x_6)	0.162	-1.858	7.979	-0.108	-0.233
Average size of land fragment (katha) (x_7)	0.062	-1.577	1.119	-0.831	-1.408
Mean distance between two land fragments (m) (x_8)	0.218	43.918	25.748	0.763	1.706
Size of homestead land (katha) (x_9)	0.078	54.540	134.983	0.182	0.404
No. of crops cultivated (x_{10})	0.149	-0.023	0.025	-0.412	-0.905
Total yield of crops cultivated (kg) (x_{11})	0.097	-0.008	0.012	-0.235	-0.686
Total marketed surplus of crops cultivated (kg) (x_{12})	-0.018	-0.003	0.002	-0.380	-1.413
Total input cost (Rs) (x_{13})	0.007	-0.002	0.001	-0.851	-2.193
On farm income (Rs) (x_{14})	-0.071	0.001	0.004	0.132	0.399
Family expenditure/year (x_{15})	0.156	-0.004	0.003	-0.363	-1.244
Savings/year (x_{16})	-0.078	137.116	72.766	1.044	1.884
Land under irrigation (bigha) (x_{17})	0.200	1.829	2.482	0.296	0.737
Cropping intensity (%) (x_{18})	-0.111	-0.786	0.576	-0.487	-1.365
Total hours of irrigation given (x_{19})	0.074	106.871	76.482	0.475	1.397
Livestock count (x_{20})	0.021	10.337	5.706	0.704	1.812
Communication variable (x_{21})	0.617**	0.090	0.163	0.136	0.552
Consumption of coal, firewood, fuelwood (kg/year) (x_{22})	-0.201	-0.108	0.108	-0.446	-1.002
Production of organic manure (kg/year) (x_{23})	-0.005	-32.999	17.038	-0.714	-1.937

Table 1: Coefficient of Correlation and Multiple Regression Analysis of Crop residue left in the field (y) vs. selected causal variables (x_1-x_{23}).

**Correlation is significant at the 0.01 level; *Correlation is significant at the 0.05 level; R square: 81.60%; The standard error of the estimate: 458.792.

Table 3 presents the path analysis wherein the total effect of exogenous variable on consequent variable has been decomposed into direct, indirect and residual effect.When the crop residue management is done properly, then the soil fertility status becomes better which ensures better yield as well as the economic status of the farmers. Therefore, the direct effect of savings has been found to exert highest positive effect on crop residue left in the field. The average size of land fragment is immensely important in all kinds of farm management. It becomes labour intensive, cost and energy prodigal that is why this variable has shown highest indirect effect on crop residue left in the field. It has been found that the exogenous variable land under irrigation has appeared as many as 21 out of 23 times in exerting the highest effect on the consequent variable crop residue left in the field, it implies that in an irrigated agro-based ecosystem the crop residue left in the field are higher. It is obvious that in a moist soil condition, sometimes it is muddy and therefore the general tendency is to leave higher proportion of crop residue left in the field. Two reasons are – i) In a wet condition, it is difficult to collect, ii) In a wet muddy condition, it is easy to admix with the soil which ultimately would add to the fertility of the soil. The residual value is 0.176 it infers that a little over 17.6 per cent cannot be explain with this combination of 23 variables. It has been supported by the R square value 81.60 per cent as well.

Independent Variables	Unstandardized coefficients	Standardized coefficients	Beta	t value
	Reg.coef. B	S.E. B		
Communication variable(x_{21})	7.455	2.231	0.508	3.341
Mean distance between two land fragments (m) (x_8)	0.629	0.288	0.332	2.183

Table 2: Stepwise Regression Analysis: Crop residue left in the field (y) Vs. 23 Causal Variables.

R square: 37.60%; The standard error of the estimate: 430.337.

Sl. No	Variables	Total Effect	Direct Effect	Indirect Effect	Highest Indirect Effect
1	Age (x_1)	-0.310	-0.714	0.404	-0.992(x_{17})
2	Education (x_2)	0.004	0.132	-0.128	0.397(x_{17})
3	Functional education (x_3)	0.015	-0.609	0.624	0.124(x_{17})
4	Family size (x_4)	-0.089	-0.388	0.299	0.507(x_{17})
5	Size of land holding (bigha) (x_5)	0.157	0.207	-0.050	0.348(x_{17})
6	No. of land fragments (x_6)	0.162	-0.108	0.270	0.383(x_{17})
7	Average size of land fragment (katha) (x_7)	0.062	-0.831	0.893	0.163(x_{17})
8	Mean distance between two land fragments (m) (x_8)	0.218	0.761	-0.543	0.512(x_{17})
9	Size of homestead land (katha) (x_9)	0.078	0.182	-0.104	0.716(x_{17})
10	No. of crops cultivated (x_{10})	0.149	-0.410	0.559	0.424(x_{17})
11	Total yield of crops cultivated (kg) (x_{11})	0.097	-0.235	0.332	-0.136(x_{17})
12	Total marketed surplus of crops cultivated (kg) (x_{12})	-0.018	-0.380	0.362	-0.666(x_{17})
13	Total input cost (Rs) (x_{13})	0.007	-0.851	0.858	-0.389(x_{17})
14	On farm income (Rs) (x_{14})	-0.071	0.132	-0.203	0.831(x_{17})
15	Family expenditure/year (x_{15})	0.156	-0.361	0.517	0.130(x_{17})
16	Savings/year (x_{16})	-0.078	1.044	-1.122	0.913(x_{17})
17	Land under irrigation (bigha) (x_{17})	0.200	0.296	-0.096	-0.428(x_5)
18	Cropping intensity (%) (x_{18})	-0.111	-0.487	0.376	-0.665(x_{17})
19	Total hours of irrigation given (x_{19})	0.074	0.475	-0.401	0.585(x_{17})
20	Livestock count (x_{20})	0.021	0.702	-0.681	-0.474(x_{17})
21	Communication variable (x_{21})	0.617	0.136	0.481	-1.033(x_5)
22	Consumption of coal, firewood, fuelwood (kg/year) (x_{22})	-0.201	-0.446	0.245	-0.837(x_{17})
23	Production of organic manure (kg/year) (x_{23})	-0.005	-0.713	0.708	-0.282(x_{17})

Table 3: Path Analysis: Decomposition of Total Effect into Direct, Indirect and Residual Effect: Crop residue left in the field (y).

Residual effect: 0.176.

Conclusion

The fast erosion of soil quality accompanied by huge depletion of ground water has driven Indian agriculture to a fragile ecological service delivery for attaining food security for millions. Almost 68 per cent of India's farmlands amounting to 142 million hectare are suffering from moderate to high level organic carbon deficiency. Exploitative agriculture, wrongly branded as modern agriculture, has been responsible for these ecological imbalances. Another problem is associated with teeming populace and fragmentation of holding. When small holdings further get fragmented due to population pressure, it will turn energy and resource prodigal. The present study executed in an alluvial agro ecosystem has focussed on the need for crop residue mixing with the soil of harvested landmass so the both carbon and nitrogen can be remixed. In doing this we need a community based resource recycling team and network communication. Stubble burning has become a pernicious habit amongst the farmers. We have to revert this trend, from resource prodigal to resource conserving practice amongst farmers. Conservation agriculture offers a splendid opportunity for a role reversal of our farmers. Simply because, when ecology giggles, human kind is secured.

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