Land-Use Intensification and Occupational Health Risk: An Ordinal Regression Analysis of Farming Households in Kuttanad, Kerala

Tony T Shaji[1], Dr S Chinnammai[2]

[1]Research Fellow, Agro Economic Research Centre, University of Madras, Chennai 600 005
[2]Professor and Director i/c, Agro Economic Research Centre, University of Madras, Chennai 600 005

Abstract
Agricultural Intensification Through Repeated Cropping Cycles Has Increased Farm Production and Farm Income in Land-Scarce Regions. However, Its Occupational Health Implications Remain Underexplored. This Study Explores the Association Between Cropping Intensity and Non-Chronic Health Symptoms Among Farming Households in the Kuttanad Region of Kerala. Primary Data Were Collected From 600 Farming Households Across the Alappuzha, Kottayam, and Pathanamthitta Districts. The Association Between Cropping Intensity and Symptom Burden Was Examined Using the Kruskal–Wallis H Test with Dunn–Bonferroni Post-Hoc Comparisons, Followed by an Ordinal Logistic Regression Model to Account for Occupational and Household Factors. The Analysis Revealed a Significant Association Between Cropping Intensity and Non-Chronic Health Symptom Burden. Even After Adjusting for Other Occupational and Household Variables, Cropping Intensity Remained the Only Significant Predictor of Symptom Burden, With Households Practising More Intensive Cropping Reporting a Greater Likelihood of Experiencing Higher Symptom Levels. The Findings Suggest That Repeated Cropping Cycles Are Independently Associated with Poorer Non-Chronic Health Outcomes, Implying the Importance of Incorporating Cropping Intensity into Occupational Health Assessments and Policy Interventions for Farming Communities.

Keywords: Cropping intensity, Agricultural intensification, Occupational health, non-chronic health symptoms, Ordinal logistic regression.

Introduction

As a means of expanding the output and the farm income from the reducing land base, agriculture in India. Cropping intensity refers to the number of times the same piece of land is cultivated with crops in a year. moved steadily towards higher cropping intensity over the successive decades. Cropping intensity implies at the number of times a land is used for cropping in a year. The expansion in irrigation, adoption of high-yielding variety of seeds, advancement in the fertilizer and pesticide manufacture and cropping Calander support under successive agricultural policies have been actively encouraged this intensification. Even though the production and income applications of cropping intensity are well documented, there lacks comparatively little direct attention to its health consequences.

The Kuttanad region of Kerala, which spans across three districts; Alappuzha, Kottayam and Pathanamthitta, provides a particularly relevant setting for examining this relationship. Kuttanad, often known as the "rice bowl of Kerala" is characterised by its unique below- sea- level paddy cultivation, increased adoption of high yielding varieties of seeds and intensive inputs use like chemical fertilizers and pesticides. The multiple cropping in a single year is associated with additional labour days, repeated cycles of land preparation, planting and transplanting, chemical application and harvesting which carries its own occupational exposures at each stage. It is found that the intensity of pesticide application in Kuttanad has substantially exceeded recommended limits set by the Kerala Agricultural University, which stimulated recurring pest pressure across cropping cycles (Devi,2009). The key research question is whether these repeated cropping cycles transforms into a measurably higher health burden to the farming households regardless of other major risk factors such as chemical handling practices or the landholding size.

This paper seeks to address this question empirically. Pesticide related health problems among agriculture workers among the low and middle- income countries report a consistent pattern of symptoms like eye and skin irritation, dizziness, headache and respiratory problem arising from the repeated occupational exposure (Kim et al., 20217). The study examines whether cropping intensity which is categorised as single, double and triple cropping per year reaches a statistically significant effect on the number of non-primary health symptoms reported by the farming households by employing the primary survey collected from the 600 farming households across the kuttanad region.

Materials and Methods

Data and Sampling Design

The study uses primary data from 600 farming households in the kuttanad region of Kerala comprising Alappuzha, Kottayam and Pathanamthitta districts. The sample size was determined using the Krejcie and Morgan (1970) formula and the data was collected through a structured questionnaire. The sample was allocated across these three districts using a district- stratified, multistage design with Probability Proportional to size at Gram Panchayat level followed by simple random sampling of the households. Among the sample districts, Alappuzha represents the highest segment (55.08 per cent) of agriculture worker population in the kuttanad region, Kottayam district constitutes 37.14 per cent and Pathanamthitta represents the remaining 11.90 per cent of the agricultural labourers and cultivators in the Kuttanad region (Census of India 2011, District Census Handbook: Alappuzha, Kottayam and Pathanamthitta). Accordingly, 330 samples were allotted to Alappuzha, 223 to Kottayam and 71 for Pathanamthitta. Within each district, four Gram Panchayats exhibiting the highest concentration of agricultural labourers and cultivators were identified as primary sampling units in accordance with the probability proportional to size. The Primary data was collected between September and November 2025. Before the finalisation, the interview schedule was translated into the regional language and pretested.

Analytical Methods

The bivariate association between the cropping intensity and health symptom burden is first tested using the Kruskal- Wallis H test (Kruskal & Wallis, 1952) with Dunn's (1964) post- hoc pairwise comparisons under Bonferroni correction (Bonferroni, 1936). Ordinal logistic (proportional odds) regression (McCullagh, 1980; Agresti, 2010) is employed as the primary multivariable analytical approach, with symptom count specified as the ordered outcome variable. As a robustness check, Poisson and Negative Binomial count regression models (Cameron & Trivedi, 2013; Hilbe, 2011) are also estimated.

Model Specification

An ordinal logistic (proportional odds) regression model is used for estimating the independent effect of cropping intensity while controlling the occupational and household- level cofounding variables since the dependent variable non- chronic health symptom count is measured as an ordered categorical variable (1-7). The model thus estimates the probability of a farming household belonging to progressively higher or lower categories of non-chronic health symptom burden.

Table 1 Dependent and Explanatory Variables used in the ordinal Logistic Regression Model

Variable	Type	Measurement Unit	Description
Dependent Variable			
Non- chronic health symptom count	Ordinal	Number of symptoms (1-7)	Ordered outcome variable ranging from 1-7, representing the number of non- chronic health symptoms reported by the farming household
Explanatory Variables			
Cropping Intensity	Categorical	Single/double/triple	Reference: Single cropping; Dummy variables created for Double cropping (1 = Double, 0 = Single) and Triple cropping (1 = Triple, 0 = Single).
Agrochemical use	Binary	Yea/ No	1= Households Using Chemical Fertilizers/ pesticides 0= Otherwise
Personal Protective Equipment (PPE) Use	Ordinal	Never/ Sometimes/ Always	Frequency of Using protective equipment during agrochemical application (Reference: Never)
Secondary Occupation	Binary	Yes/ No	1= Household head engaged in any secondary occupation 0= Agriculture only
Farmer Type (Landholding)	Categorical	Marginal/ Small/ Medium/ Large	Farm- size classification based on operational landholding (Reference: Marginal farmers
Type of Housing	Categorical	Kutcha/ Semi- Pucca/ Pucca	Type of residential house (Reference: Kutcha)
Toilet Facility	Binary	Yes/No	1= Household has access to toilet facility 0= No toilet facility
Source of Drinking water	Categorical	Own tap/ Own well/ shared/ Borewell/ Purchased	Primary source of drinking water used by the household (Reference: Own tap)
Education of Household Head	Ordinal	Education Level	Highest educational attainment of the household head (Reference: Illiterate)
Age of Respondent	Ordinal	Age groups	<30,30-39,40-49,50-59, 60 and above

			(Reference: 30 years)
Household size	Continuous	Number of members	Total number of members residing in the household

The following empirical Model is employed for estimating the independent effect of cropping intensity on non- chronic health symptom.

$$\log(P(Y_i \leq j)/P(Y_i > j)) = \kappa_j - (\beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \beta_6 X_{6i} + \beta_7 X_{7i} + \beta_8 X_{8i} + \beta_9 X_{9i} + \beta_{10} X_{10i} + \beta_{11} X_{11i} + \beta_{12} X_{12i}) \quad (1)$$

where,

Y = Number of non-chronic health symptoms experienced by the farming household (ordinal, 1–7)
$P(Y \leq j)$ = Cumulative probability that the household's symptom count falls in category j or below
X_1 = Cropping intensity: Double (1 = Double, 0 = Single)
X_2 = Cropping intensity: Triple (1 = Triple, 0 = Single)
X_3 = Agrochemical use (0 = No, 1 = Yes)
X_4= PPE use (0 = Never, 1 = Sometimes, 2 = Always)
X_5 = Secondary occupation (0 = No, 1 = Yes)
X_6 = Farmer type / landholding (Marginal/Small/Medium/Large)
X_7 = Type of house (Kutcha/Semi-pucca/Pucca)
X_8 = Toilet facility available (0 = No, 1 = Yes)
X_9 = Source of drinking water
X_{10} = Education level of household head
X_{11} = Age category of respondent
X_{12} = Household size (number of members)
κ_j = Threshold (cut-point) parameters separating adjacent symptom categories (j = 1, …, 6)
$\beta_1 \ldots\ldots \beta_{12}$ = Regression coefficients

Results and Discussion

Table 2. Distribution of Sample Households by Categorical Variables (N = 600)

Variable	Category	n	Percentage
Cropping intensity	Single	277	46.2
	Double	284	47.3
	Triple	39	6.5
Agrochemical use	Yes	549	91.5
	No	51	8.5
PPE use	Never	366	61.0
	Sometimes	161	26.8
	Always	73	12.2
Secondary occupation	Yes	348	58.0

	No	252	42.0
Farmer type (landholding)	Marginal (<1 acre)	444	74.0
	Small (1–2.5 acres)	126	21.0
	Medium (2.5–5 acres)	23	3.8
	Large (>5 acres)	7	1.2
Type of housing	Kutcha	56	9.3
	Semi-pucca	326	54.3
	Pucca	218	36.3
Toilet facility available	Yes	556	92.7
	No	44	7.3
Source of drinking water	Own tap	238	39.7
	Own well	131	21.8
	Shared tap/well	50	8.3
	Borewell	20	3.3
	Purchased water	161	26.8
Education of household head	Illiterate	55	9.2
	Primary	102	17.0
	Upper primary	141	23.5
	Secondary	173	28.8
	Higher secondary	82	13.7
	Diploma/Graduate	47	7.8
Age of respondent	<30 years	42	7.0
	30–39 years	96	16.0
	40–49 years	168	28.0
	50–59 years	174	29.0
	≥60 years	120	20.0

Source: Primary Data

Table 2 shows the descriptive statistics of the variables in the study. Of the 600 sample households, 46.2 per cent practised single cropping, 47.3 per cent double cropping, and 6.5 per cent triple cropping. Agrochemicals were used by the vast majority (91.5 per cent), though personal protective equipment was never used by 61.0 per cent of respondents, used sometimes by 26.8 per cent, and always by only 12.2 per cent. A little over half the households (58.0 per cent) reported a secondary source of income. Most households were marginal farmers (74.0 per cent), followed by small farmers (21.0 per cent), with medium and large farmers together accounting for only 5.0 per cent of the sample.

In terms of housing and amenities, 54.3 per cent of households lived in semi-pucca houses, 36.3 per cent in pucca houses, and 9.3 per cent in kutcha houses; 92.7 per cent had access to a toilet facility. Drinking water was drawn mainly from own taps (39.7 per cent) and own wells (21.8 per cent), with the remainder relying on shared sources, borewells, or purchased water.

The household head's education level was fairly evenly spread across categories, with the largest shares reporting secondary (28.8 per cent) and upper primary (23.5 per cent) education, while 9.2 per cent were illiterate. The age profile of respondents was concentrated in the 40–59 age range (57.0 per cent combined), with smaller shares below 30 years (7.0 per cent) and above 60 years (20.0 per cent).

Table 3 Descriptive Statistics of Continuous Variables

Variable	Mean	SD	Min–Max
Household size (members)	1.94	0.69	1–3
Non-chronic health symptom count	2.84	1.90	1–7

Source: Author’s Computation

Table 3 shows the distribution of the two continuous variables in the study. The average household size was 1.94 members (SD = 0.69), with a relatively narrow range of 1 to 3 members across the sample, indicating fairly small and homogeneous household sizes among the farming households surveyed. The non-chronic health symptom count averaged 2.84 symptoms per household (SD = 1.90), with values ranging from 1 to 7 out of the ten symptom types considered in the survey. The relatively high standard deviation relative to the mean suggests considerable variation in symptom burden across households, which is consistent with the subsequent finding that this variation is significantly associated with cropping intensity.

Bivariate Association: Cropping intensity and Symptoms Burden

Table 4. Non- Chronic Health Symptom Burden by Cropping Intensity

Cropping Intensity	n	Mean Symptom Count	SD	Mean Rank
Single	277	2.70	1.96	281.21
Double	284	2.96	1.95	309.97
Triple[a]	39	3.00	0.00	368.50
Total	**600**	**2.84**	**1.90**	—

Source: Author’s Computation

The Kruskal–Wallis test indicated a statistically significant difference in non-chronic symptom burden across the three cropping intensity groups ($H(2) = 10.85$, $p = 0.004$). Also, the mean rank scores increased in a gradual manner with cropping intensity, moving from 281.21 among single-cropping households to

309.97 among double-cropping households, and reaching 368.50 among triple-cropping households. This steady trend suggests a graded relationship between land-use intensity and self-reported morbidity, wherein households involved in more intensive cultivation practices are tend to report a comparatively greater burden of non-chronic health symptoms.

Table 4b. Dunn–Bonferroni Post Hoc Pairwise Comparisons of Cropping Intensity and Non-Chronic Health Symptoms

Cropping Intensity Pair	Test Statistic	Standard Error	Standardized Test Statistic	p-value	Adj. Sig.
Single vs Double	-28.757	14.248	-2.018	0.044	0.131
Single vs Triple	**-87.285**	**28.856**	**-3.025**	**0.002**	**0.007**
Double vs Triple	-58.528	28.812	-2.031	0.042	0.127

Source: Author's Computation

The pairwise comparisons shows that the significant Kruskal–Wallis result is mainly due to the difference between the single- and triple-cropping groups and remained significant after the Bonferroni adjustment (adjusted $p = 0.007$). Although the single-versus-double and double-versus-triple comparisons were significant before adjustment, they were not significant after correcting for multiple comparisons (adjusted $p = 0.131$ and 0.127, respectively). This pattern is consistent with the multivariate ordinal regression results, where both the double- and triple-cropping categories remained significant predictors after controlling for other factors, with the largest effect observed for the triple- cropping category

A supplementary Mann–Whitney U test between the single- and double-cropping groups also showed a modest but statistically significant difference (U = 35,610.5, $p = 0.045$), indicating that the observed association is not solely influenced by the limited variability in the triple- cropping subgroups.

Multivariate Analysis

An ordinal logistic regression was estimated with symptom count 1-7 as the ordered outcome for assessing whether the association between cropping intensity and non- chronic symptom burden remined after adjustment for other occupational and household characteristics. The model considered variables like cropping intensity, personal protective equipment use, agrochemical use, secondary occupation, farmer type, housing type, source of drinking water, sanitation , education of the household head, age and household size.

Table 3. Ordinal Logistic Regression Predicting Non- Chronic Symptoms Burden (N=600)

Predictor	OR	95% CI	p-value
Cropping intensity: Double (ref. Single)	**1.38**	**1.01–1.88**	**0.042****
Cropping intensity: Triple (ref. Single)	**1.95**	**1.15–3.31**	**0.013****
Agrochemical use: Yes (ref. No)	1.52	0.91–2.54	0.108
PPE use: Sometimes (ref. Never)	1.32	0.94–1.85	0.113

PPE use: Always (ref. Never)	1.20	0.76–1.89	0.445
Secondary occupation: Yes (ref. No)	1.05	0.76–1.44	0.777
Farmer type: Small (ref. Marginal)	0.96	0.67–1.37	0.810
Farmer type: Medium (ref. Marginal)	1.31	0.60–2.85	0.492
Farmer type: Large (ref. Marginal)	0.76	0.19–3.10	0.699
Housing: Semi-pucca (ref. Kutcha)	0.80	0.47–1.36	0.415
Housing: Pucca (ref. Kutcha)	0.85	0.48–1.49	0.562
Toilet facility: Yes (ref. No)	0.64	0.36–1.14	0.128
Water: Own well (ref. Own tap)	1.11	0.75–1.64	0.616
Water: Shared (ref. Own tap)	1.17	0.68–2.03	0.574
Water: Borewell (ref. Own tap)	1.15	0.52–2.55	0.722
Water: Purchased (ref. Own tap)	0.86	0.59–1.25	0.426
Education: Primary (ref. Illiterate)	1.35	0.76–2.41	0.309
Education: Upper primary (ref. Illiterate)	1.05	0.60–1.82	0.872
Education: Secondary (ref. Illiterate)	0.78	0.46–1.35	0.379
Education: Higher secondary (ref. Illiterate)	1.16	0.63–2.12	0.636
Education: Diploma/Graduate (ref. Illiterate)	1.17	0.58–2.34	0.657
Age: 30–39 (ref. <30)	1.46	0.78–2.74	0.238
Age: 40–49 (ref. <30)	1.12	0.62–2.00	0.710
Age: 50–59 (ref. <30)	1.32	0.74–2.38	0.350
Age: ≥60 (ref. <30)	1.23	0.67–2.27	0.509
Household size (continuous)	1.08	0.87–1.33	0.489

*Note. OR = odds ratio. Reference categories are indicated in parentheses. **p < .05.*

Cropping intensity persisted as the only statistically significant predictor of non-chronic symptom burden in the fully adjusted model. Compared with single-cropping households, the odds of reporting a higher symptom category were 38 per cent higher among double-cropping households (OR = 1.38, 95% CI: 1.01–1.88, $p = 0.042$) and 95 per cent higher among triple-cropping households (OR = 1.95, 95% CI: 1.15–3.31, $p = 0.013$). None of the other occupational or household variables, including agrochemical use, protective equipment use, landholding size, housing quality, sanitation, drinking water source, education, age, or household size, were statistically significant. These findings suggest that the association between cropping intensity and symptom burden is independent of these factors.

An approximate parallel-lines diagnostic showed a broadly consistent positive coefficient for the double-cropping category across successive symptom-count thresholds, supporting the proportional-odds assumption. The triple-cropping category could not be similarly assessed because of the absence of within-group variance.

Conclusion

This study assessed whether cropping intensity is independently associated with the burden of non-chronic health symptoms among farming households in Kuttanad, Kerala. The findings clearly states a clear and consistent relationship between cropping intensity and symptom burden. At the bivariate level, households engaged in more intensive cropping reported a greater number of non-chronic health symptoms. This relationship stayed significant in the fully adjusted ordinal regression model. Compared with single cropping households, those practising double and triple cropping had significantly higher odds of reporting greater symptom burden (OR = 1.38 and 1.95, respectively), even after adjusting for agrochemical use, protective equipment practices, landholding size, housing quality, sanitation, drinking water source, education, age, and household size. None of these other variables showed a statistically significant association with symptom burden, suggesting that cropping intensity acts as an independent occupational risk factor rather than simply reflecting differences in agrochemical exposure or socioeconomic conditions.

These findings indicate that the repeated cycles of land preparation, planting, chemical application, and harvesting associated with intensive cropping create a cumulative physical and occupational workload that is not fully captured by existing health frameworks, which primarily focus on agrochemical exposure. The results highlight the need to recognise cropping intensity as a distinct determinant of farmers' health within agricultural and occupational health research. In practical terms, district level agricultural health programmes should consider extending routine health screening to households practising double and triple cropping instead of limiting surveillance to farmers based solely on agrochemical use. Agricultural extension services can also broaden their focus beyond pesticide safety by incorporating guidance on reducing physical strain, improving work practices during peak agricultural seasons, and promoting measures that minimise occupational fatigue. Likewise, policies encouraging multiple cropping through irrigation support or cropping calendar interventions should be accompanied by appropriate occupational health safeguards to ensure that increased agricultural productivity is achieved without compromising farmers' health.

The cross-sectional design of the study limits the ability to establish causal relationships. Future research should adopt longitudinal or panel study designs, incorporate objective biomarkers of agrochemical exposure, and investigate whether the observed dose response relationship between cropping intensity and symptom burden is evident in other multiple cropping regions of India.

Despite these limitations, the study makes an important contribution to the emerging literature on agricultural occupational health by providing empirical evidence that cropping intensity is an independent determinant of non-chronic health symptoms among farming households. The findings underscore the importance of integrating cropping intensity into occupational health assessments, agricultural extension programmes, and policy interventions aimed at improving the health and well-being of farming communities.

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