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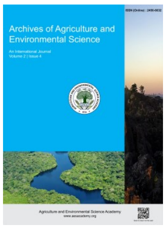

ORIGINAL RESEARCH ARTICLE

Pesticide use in agriculture and chronic health conditions: A survey-based cross-sectional study in Nepal

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ABSTRACT

The long-term (mis)use of chemical pesticides in agriculture may cause chronic health conditions. The study aimed to assess the relationship between pesticide use in agriculture and chronic health conditions of farmers. The study was done in two adjoining villages in Kavrepalanchok district of Nepal: Mahadevsthan having high application rates and long history of the use of pesticides in the agriculture; and Nayagaun - relatively low rates and a short history of the use of pesticides. Data was collected through household surveys, key informant interviews, focus group discussions, 'door-to-door' physical health examination, and free medical health camps. We performed an independent sample *t*-test and Poisson regression in data analysis. The findings showed higher prevalence rates of chronic health conditions in Mahadevsthan compared to Nayagaun. We also observed a significant positive association between pesticide use history and chronic health conditions. The incidence rate for multiple chronic conditions increased by a factor of 1.296 for an additional year of pesticide use. We, however, recommend in-depth longitudinal cohort studies for further examination of the relationship.

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INTRODUCTION

The relationships between agriculture and health are complex, but agriculture affects health and health affects agriculture (Hawkes and Ruel, 2006). This relationship is highly delicate for farmers, whose livelihoods solely depends upon agriculture. The application of synthetic pesticides in agriculture is a hot topic of discussion and debate because of its bidirectional effects (i) negative effects on human, environmental and ecosystem health (Uri, 1997; Wilson and Tisdell, 2001; Pethig, 2004; Pimentel, 2005; Sexton *et al.*, 2007; Atreya, 2008a; Atreya *et al.*, 2012) and (ii) positive effects on humankind (Cooper and Dobson, 2007; Aktar *et al.*, 2009). Use of synthetic pesticides in agriculture results in short-term (acute) and long-term (chronic) health problems. Pesticides induced acute symptoms include headache, skin irritation, eye irritation, and respiratory and throat discomfort (Murphy *et al.*, 2004; Mancini *et al.*, 2005; Atreya, 2008b; Neupane *et al.*, 2014; Kofod *et al.*, 2016). A significant number of evidences also exist elsewhere on long-term, low-dose exposure to pesticides and the development of chronic health conditions like reproductive abnormalities and cancer (Ecobichon, 2001; Safi, 2002; Stallones and Beseler, 2002; Acquavella *et al.*, 2003; Alavanja *et al.*, 2004; Mostafalou and Abdollahi, 2013). However, studies on the effect of pesticide use on chronic health conditions of farmers are limited in Nepal (Figure 1).

The country-level data in Nepal shows an increased importation of pesticides over years. This usage is nominal compared to other countries like Korea, Japan; however, an increased expansion and intensification of agriculture over the past few decades in many parts of Nepal has resulted in increased localised use of pesticides in agriculture, notably in vegetable farming (Jha et al., 2009; Sharma et al., 2012; Bhandari et al., 2018). As of 2018, Nepal has registered 170 technical ingredients of pesticides for agricultural use. Nepal Government has banned "Extremely Hazardous" chemical pesticides, particularly that of red coloured, for agricultural use; however, because of weak technical capacity of the concerned bodies to monitor and open border with India, prior studies have found these highly hazardous pesticides in the field. Farmers are, however, less aware of the potential long-term risk of pesticide use on their health and surround environments. Furthermore, farmers adopt inadequate safety protection equipment while applying chemical pesticides. The present situation in the agricultural commercialised area is that farmers use high rates of chemical pesticides for vegetable farming without adopting safety precautions; they are still unaware of the risk of low dose long-term pesticide exposure. Prior studies in Nepal have rarely considered the chronic health of farmers in relation to chemical pesticide use, their working conditions, and their interactions. There is also scanty empirical research on farmers' occupational health and safety in the country (Poudel et al., 2005; Carter, 2010; Joshi et al., 2011). Studies on pesticide use and its short-term human health effects are emerging in recent years in Nepal (Shrestha and Neupane, 2002; Atreya, 2007a, 2008a, 2008b; Atreya et al., 2012; Neupane et al., 2014; Khanal and Singh, 2016). However, those studies have not accounted for chronic health conditions of farmers and recent national data shows an escalated prevalence of chronic health problems in Nepal (Neupane and Kallestrup, 2013; Bhandari et al., 2014; Aryal et al., 2015; Mishra et al., 2015; Ghimire et al., 2019). Studies in Nepal have so far documented that farmers (i) face one or other kind of acute health problems from pesticide exposure; (ii) are unaware of the long-term pesticide effects on their health; and (iii) do not adopt sufficient safety measures. Because studies are insufficient on pesticide-induced chronic health conditions, this study aimed to assess the relationship between long-term pesticide use and chronic health conditions in an area where the use of chemical pesticides has a long history.

MATERIALS AND METHODS

Study area

We conducted this study from February to September 2015 in Kavrepalanchowk district of Nepal. Here, traditional cereal-based farming has been changed to the market-oriented vegetable-based farming system (Dahal et al., 2009). Vegetable farming is the major source of farm income in the district (Brown and Kennedy, 2005; Dahal et al., 2009). In the district, prior studies have informed us of the excessive use of chemical pesticides in vegetables (Atreya, 2008a, 2008b; Atreya et al., 2012); and pesticide residues in (i) vegetables (Rawal et al., 2012) and (ii) soil and river water samples (Dahal et al., 2007; Kafle et al., 2015) - henceforth the potential risk for chronic health conditions because of pesticide exposure could be high for farmers who have been living and applying chemical pesticides in the area for a long period. We picked two former village development committees (VDCs) of the district: (i) Mahadevsthan – with a long history of pesticide use, high rates of pesticide application, and highly intensified farming ('case' village); and (ii) Nayagaun - where the use of pesticides was comparatively less ('control' village) [for additional details on the agricultural intensification in the study area, refer to Dahal et al. (2009)]. These two adjoining VDCs are located about 45 km north of Kathmandu, the capital of Nepal, where 2,824 households inhabited during the study time. The elevation ranges from 800 to 2,000 meters above sea level. Farmers harvest three crops per year in the lower irrigated area (particularly the 'case' village), whereas the upper rain-fed area (particularly the 'control' village) supports maize and millet intercropped in the monsoon period, and potato or other vegetables or fallow during the winter season.

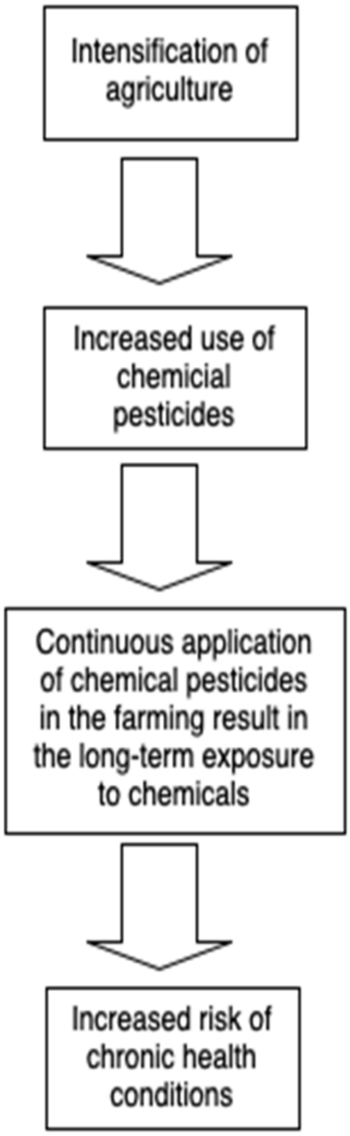

Figure 1. *Long-term exposure to chemical pesticides may increase chronic health conditions.*

Table 1. Ward wise sample size drawn for the study.

Ward	Mahadevsthan			Nayagaun	
	Total household	Commercial vegetable growing household (sampling frame) +	Sampled household	Total household	Sampled household
1	372	80	40	293	45
2	179	45	25	46	10
3	206	20	10	101	0*
4	191	60	30	70	0*
5	191	30	15	51	10
6	108	15	10	80	15
7	97	35	20	111	20
8	232	50	25	145	0*
9	297	50	25	54	0*
Total	1873	385	200 (+50)	951	100 (+25)

+Sampling frame was prepared through focus group discussion; *These Wards have a comparatively different environment and socio-economic conditions. For example, Tamang and Gurung ethnic communities dominated the wards, they are located at higher altitude, and commercial agriculture was less practiced; therefore, avoided in the sampling process.

Sample size and sampling process

The study adopted proportionate random sampling (Table 1), and the household sampling process slightly differs between VDCs. Each VDC contained nine wards (the smallest administrative unit). In the Mahadevsthan (the 'case' village), we conducted focus group discussions to identify vegetable growing pocket areas in each ward through VDC mapping. We prepared the sampling frame, enlisting vegetable growing households, especially for markets, in each ward, which resulted in 385 households. Ward-wise proportionate random sample of 200 households was drawn initially; and we further sampled 50 additional households from the 'case' village thinking probable absentee of the initially sampled households during the survey (people may be absent at home or unwilling to take part). We interviewed 226 households, which was about 12% of the total household, and about 60% of the commercial vegetable-growing households.

Likewise, in the Nayagaun ('control' village), we avoided four wards at a higher altitude and having dissimilar ethnic groups because we thought comparability is more important than representativeness. We adopted ward-wise proportionate random sampling for household selection. We sampled 100 households (additional 25 households), and 111 households were interviewed (12% of the total households).

Data collection tools

This study adopted household survey, key informant interviews, and focus group discussions for primary data collection. Moreover, physical health examination was performed to diagnose chronic health conditions. We developed a household survey questionnaire based on past studies, own experiences, and informal discussion with local key persons.

For primary data collection, the research team visited sampled households twice - originally for interviews (all the sampled households) and subsequently for physical health examination (partial households). The initial survey collected information on individuals' present health conditions, pesticide exposure, and self-reported health effects of pesticide use. We interviewed a family member who generally applied chemical pesticides on the farm. Before the survey, we took verbal consent from each respondent. We did 31 key informant interviews (KII), exclusively with agro-vet owners, lead farmers, government extension workers, and health workers. We visited local district and national level government and private institutions related to pesticide use, import, and regulation. Such institutions included were local level pesticide dealers, health care centres, farmers' associations, trade unions, and related community-based organisations; and District Agriculture Development Office (DADO), Department of Agriculture (DoA), and Pesticide Registrar Office. We also conducted two focus group discussions, one each in the VDCs. A focus group composed of about 20-25 local farmers, both males and females, and invited purposively in the discussion to understand pesticide use history, societal perceptions of pesticide usage, and its health impact.

Household selection for the physical health examination

After completing the initial household survey, the research team had screened the household with family members suffering from chronic health problems. We checked each filled-in initial survey questionnaire for possibility of long-term health problems and these households were preliminarily screened. The medical team visited each of the preliminarily screened households for chronic health examination. For this, we developed a two-page questionnaire, particularly aiming ten chronic health problems and pesticide use history. The medical team did confirmation of already self-reported (during initial household survey) chronic health conditions of the screened household members, including children if any. For this, the medical team observed their previous medical prescription, history of medication, relevant laboratory tests, and radiological investigations, if any. The team also measured height, weight, and blood pressure of the household members who had chronic health problems. The team also took the verbal consent of the household members before initiating health examination.

The study reports *the prevalence* (P) of chronic health conditions. It measures the existing cases of disease at the time of the study. It is a proportion of the total number of individuals who have a disease (C) to the population at risk (N) of having the disease. Here, population (N) was the total number of individuals (n) in the sampled households (s).

$$P = C/N$$

where, N = n*s

Besides, we organised a one-day free medical health camp in each village. The medical team screened the chronic health conditions of the attendee.

Data analysis

We entered data of the initial household survey, door-to-door medical examination, and medical health camp in the Excel program and cleaned. We transferred data to Stata/MP 14.1 for Mac (Revision 16, February 2016) and performed statistical analyses. We used Poisson regressions to observe the effects of pesticide exposure and age on chronic health conditions [both generalised and zero-inflated, and in terms of incidence rate ratio (IRR)]. The dependent variable is the number of chronic health conditions per individual confirmed by the medical team through door-to-door visits. The occurrence of a chronic health problem is rare and is a discrete count. In such a case, Poisson distribution fits well. The Poisson distribution is a discrete probability distribution that applies to occurrences of a rare event over a specified interval. The regression finds the probability of occurrence of chronic health conditions in the sampled population. Here, we assume that the occurrence of a chronic health problem is random, independent to each other, and uniformly distributed over the study area.

The prevalence of chronic health conditions increases with age and may be associated with the long-term use of chemical pesticides. Therefore, we modelled probability of chronic health problem per individual (λ) with the age of the individual, number of years of pesticide use and their interaction (Equation 1).

$$\log\lambda_{au} = \mu + \alpha_a + \beta_u + \delta_{au} \qquad (1)$$

where μ is the intercept, α_α represents age effect, β_μ represents exposure effect, and $\delta_{\alpha\mu}$ represents their interaction – all on the log scale.

It is more convenient to write equation (1) as

$$\log(\text{rate}) = \mu + \text{AGE} + \text{PUSE} + \text{AGE} * \text{PUSE} \qquad (2)$$

Here, the 'year of pesticide use' (PUSE) needs further explanation. It is the number of years of continuous pesticide application (which is a *proxy* for the duration of pesticide exposure) of an individual. These individuals have been applying chemical pesticides until the study time. These people have a long history of pesticide use and may have had sufficient exposure to pesticides, resulting in chronic health conditions. The study excluded those individuals who 'used to apply pesticides' and 'do not apply pesticides at present' in the regression. Because this approach excluded old-aged people and children and infants in the regression model if any.

RESULTS AND DISCUSSION

Respondent characteristics

We interviewed 337 households during the initial household survey. Table 2 provides the respondents characteristics. More than half of the respondents were female. The average age of the respondents was 44 years, and nearly 1/10th of them had completed Class 10 of education. The family size was similar between villages. Farmers believed that chemical pesticides quickly control pests (63% of the respondents), are effective in controlling pests (36% of the respondents), are easy to use (35% of the respondents) and are readily available (31% of the respondents) in the market. Moreover, they thought it minimizes the cost of production. For example, one respondent said that, "pesticides are compulsory to reduce labour costs because weeding rice manually costs rupees 1000 per Ropani [1 Ropani equals 508.7 m^2], but the use of pesticides lowered it around 150."

Farmers applied different types of chemical pesticides, mostly fungicides like mancozeb and metalaxyl. Insecticides such as dichlorvos, dimethoate, cypermethrin, fenvalerate, endosulfan, malathion were mixed with mancozeb. Farmers believed that they are applying less toxic chemicals, like mancozeb, which they perceived as a 'safe' pesticide – however other studies (Corsini *et al.*, 2005; Atreya and Sitaula, 2011; Runkle *et al.*, 2017) mentioned it is not. The use of pesticides was more than double in Mahadevsthan ('case' village) compared the Nayagaun ('control' village). For example, we aggregated hour of direct contact with pesticides while applying in the fields in a year at the present moment (Table 3). It was 11.8 h for Mahadevsthan and 5.3 h for Nayagaun. In general, more than one member in the household applied chemical pesticides on farm. Females were comparatively, however, less involved in pesticide-related work such as purchase, storage, and spraying. Nonetheless, females were responsible for such activities in 14% of the sampled households. A previous study in Nepal found significant gender differences in household decisions on pesticides used and warned of an increased risk of pesticide exposure for females (Atreya, 2007b). Other studies elsewhere also reported increased pesticide risk for females (Garcia, 2003; El-Zaemey *et al.*, 2013). We noticed that both males and females spray pesticides in Nepal. Women contributes more daily labour than male counterparts in the household. In addition, male member outmigration for household earnings has increased the responsibility of females in agriculture and forced left-behind women to apply chemical pesticides in their farms. During field observation, we observed pregnant women applying pesticides, carrying their infants to the field, and seeking help from children in the pesticide application process – without thinking the long-term consequences of pesticide application. During focus group discussions, many participants agreed that long-term application of pesticides may cause chronic diseases.

Table 2. Characteristics of the respondent.

Characteristics	Mahadevsthan (n=226)	Nayagaun (n=111)	Total (N=337)
Male respondent (%)	50%	46%	49%
Average age (years)	44	43	44
Education ≤ class 10 (%)	87%	87%	87%
Average family members	6	6	6
Household with at least one differently able member (%)	4.4%	10.8%	6.5%

Table 3. Estimation of exposure to pesticides.

Estimation	Mahadevsthan	Nayagaun
Number of pumps applied for vegetables by a household in a year. *	28.2 (Range: 2-123)	12.8 (Range: 2-100)
Hours of direct exposure to pesticides = Number of pumps applied X average time to finish a pump (hours/individual/year).	=28.2 x 25+ = 11.8 h	=12.8 x 25+ = 5.3 h

*Independent Sample *t*-test for equality of means: significantly different at the 95% confidence interval; + An average minute to spray a pump. It does not account for other pesticide-related activities such as mixing, preparation, travel to and from fields.

Table 4. Prevalence of chronic health conditions (1/10,000 individuals).

Chronic health problems	Door-to-door visit		Health camp	
	Mahadevsthan	Nayagaun	Mahadevsthan	Nayagaun
Hypertension	133	90	400	400
Diabetes	66	0	200	0
Thyroid	44	0	0	0
Chronic obstructive pulmonary disease (COPD)	37	60	600	400
Skin problems	29	15	300	600
Menstrual cycle abnormal	29	15	200	100
Neuropathic pain	29	0	0	0
Cancer	22	0	100	0
Birth defects	15	45	100	0
Asthma	7	0	0	0
Average	**41**	**23**	**190**	**150**

Prevalence of chronic health conditions

Medical team examined 164 individuals during door-to-door visit. Sixty-four percent were female. Nearly 15% were alcoholic, and 26% did smoke. Their average age was 47 years. Blood pressure measured was 120/78 mmHg. Body mass index (BMI) was 22.17 kg/m^2. Likewise, 320 individuals in the 'case' village and 326 individuals in the 'control' village attended the health camp. The medical team did physical health examination of 646 individuals. Sixty-two percent of them were female. Nearly 12% were alcoholics, and 18% did smoke. Their average age was 48 years. There were <3% infants (<5 years old), 10% children (5-17 years old), 62% adults (18-60 years old), and 26% seniors (>60 years old). Average blood pressure measured for adults and seniors was 113/73 mmHg.

The study reports 10 chronic diseases: chronic skin problems, chronic obstructive pulmonary disease (COPD), hypertension, menstrual cycle abnormalities, diabetes, birth defects, cancer, thyroid, neuropathic pain, and asthma. The prevalence of these health problems *confirmed* during door-to-door visits and *screened* during health camps are in Table 4. In the door-to-door checkup, the prevalence of chronic health problems was different between the 'case' and 'control' villages. Overall, the study found a higher prevalence of chronic health problems in the 'case' village (41/10,000) compared with the 'control' village (23/10,000). However, COPD (60/10,000) and birth defects (45/10,000) prevalence were higher in the 'control' village. Interestingly, in the 'control' village, there was no individual in our sampled population suffering from diabetes, thyroid, neuropathic pain, cancer, and asthma; however, we found individuals with such health problems in the 'case' village. During the door-to-door visit in the control village, there were no individuals in our sampled population with diabetes, cancer, thyroid, neuropathic pain, and asthma. Interestingly, individuals with these chronic medical conditions (and birth defects) were also absent in the 'control village' during free medical health camp.

We do not suggest comparing the prevalence of chronic medical conditions between door-to-door visits and medical health camps. Because the assessment methods were unique, 'sick' individuals are more likely to take part in the free medical check-up; and medically "confirmed" were the chronic health conditions in the door-to-door visit, whereas chronic diseases identified in the medical health camps were "probable". In addition, individuals with chronic medical conditions are more likely to attend the free medical camp, thinking that health camp may provide free medicines. Individuals with health problems in general attend the free health camp, therefore, we found a higher prevalence of chronic medical conditions in the health camps.

Chronic conditions and pesticide exposure – Poisson regression

We modeled age and pesticide exposure with multiple chronic health conditions confirmed at door-to-door visits following Equations 1 and 2. The regression considered only pesticide spraying individuals (n=85). We provide the summary statistics of the dependent variable and covariates in Table 5. 54% of individuals had no chronic health problems; 35% had one, and 11% had multiple chronic conditions. Age ranged from 17 to 74-year-old. These individuals have been applying pesticides for a long time (range: 2 to 40 years). The dependent variable, the number of chronic health problems, ranged from 0 to 2 with mean 0.56 and variance 0.46 (i.e., 0.680). The ratio of variance to mean is 0.82. A Poisson distribution assumes a ratio of 1 (the mean and variance are equal). Therefore, the study team saw that before adding explanatory variables, there is a small amount of under-dispersion. However, this needs to be checked after adding all covariates into regression. When regressed the *Goodness of Fit* under the Pearson Chi-Square, the dispersion has dropped to 0.784. This indicates that our data are heavily clumped together. Small sample size and 54% of them having zero value may be the reason for under-dispersion. Zero-inflated Poisson regression could be another option, however, generalized Poisson model is sufficient to use when faced with under-dispersed data (Hilbe, 2014).

Here we have provided both generalized (Table 6) and zero-inflated Poisson regression (Table 7) results. Both regressions model produced same results. The study found AGE nonsignificant ($p>0.05$). Although nonsignificant, AGE is positive for multiple chronic health conditions, meaning that chronic health conditions rate may increase at older age. PUSE and the interaction between AGE and PUSE are statistically significant ($p<0.05$). The exponentiated value for the years of pesticide use (PUSE - a proxy for 'exposure duration') is positive. It showed that higher the years of pesticide use, higher will be the rate of chronic health conditions. The IRR value is 1.296. This indicates that chronic health conditions rate increased by a factor of 1.296 for an additional year of pesticide use, holding all other variables constant. We also observed that the *interaction* between age (AGE) and years of pesticide use (PUSE) is negative and significant ($p<0.05$).

Worldwide, noncommunicable diseases accounted for 71% among all deaths (WHO, 2018) and predicted to increase approximately 76% by 2030 (Wang and Wang, 2020). Most of premature deaths, under the age of 60, occurred in low- and middle-income countries. Nepal is not an exception, study found an increased risk of noncommunicable diseases especially for older aged people (Ghimire *et al.*, 2019). There are multitude of conventional influencing factors for chronic health conditions, and studies also observed the association between the use of chemical pesticides and the risk of chronic health conditions elsewhere. For example, Mostafalou and Abdollahi (2013) and Gangemi *et al.* (2016) stated an increased risk of chronic conditions because of long-term exposure to pesticides. Our study showed higher prevalence of cancer, diabetes, thyroid disorder, neuropathic pain, and asthma in the 'case' village. We also observed positive and statistically significant relationship between higher exposure to chemical pesticides and chronic health conditions in the area where chemical pesticide use in agriculture has a long history.

Table 5. Summary statistics of variables used in Poisson regression.

Variable types and explanation		N	Minimum	Maximum	Mean	Std. Deviation
Dependent Variable	Number of chronic health conditions per individual	85	0	2	0.56	0.680
Covariate	Age of the individual (AGE)	85	17	74	48.3	12.632
	Years of pesticide use (PUSE)	85	2	40	15.5	7.832

Table 6. The effect of the age and the pesticide use history on chronic health conditions (Poisson regression).

Variables	IRR	Std. Err.	z	P>|z|	95% Confidence Interval	
AGE	1.0449	0.0359	1.28	0.200	0.9769	1.1178
PUSE	1.2962	0.1388	2.42	0.015	1.0507	1.5990
AGE x PUSE	0.9951	0.0022	-2.17	0.030	0.9908	0.9995
Constant	0.0353	0.0569	-2.08	0.038	0.0015	0.8291

Log likelihood = -63.8626; Likelihood ratio Chi-square test (3 df) = 8.13; Prob Chi-square = 0.0434; Pseudo R^2 = 0.0598; and N = 85.

Table 7. The effect of the age and the pesticide use history on chronic health conditions (zero-inflated Poisson regression).

Variables	IRR	Std. Err.	z	P>|z|	95% Confidence Interval	
AGE	1.0449	0.0359	1.28	0.200	0.9769	1.1178
PUSE	1.2962	0.1388	2.42	0.015	1.0507	1.5990
AGE x PUSE	0.9951	0.0022	-2.17	0.030	0.9908	0.9995
Constant	0.0353	0.0569	-2.08	0.038	0.0015	0.8291
Inflate constant	-22.3428	27626.7	-0.00	0.999	-54169.68	54124.99

Inflation model = logit; Log likelihood = -63.8626; Likelihood ration chi-square test (3 df) = 8.13; Prob Chi-square = 0.0434; N = 85 (nonzero observation 30, zero observation 55); Vuong test of zip vs. standard Poisson: z = -0.00; Probability z = 0.5009.

Exposure to pesticides can lead to dysfunction of bodily function and lead to chronic diseases, for example, adverse respiratory effects include development of asthma and chronic obstructive pulmonary disease (COPD), endocrine dysfunction leading to thyroid disorders and diabetes, cardiovascular dysfunction causing hypertension, skin diseases, neurological abnormality, abnormal birth defects and different types of cancers (Mostafalou and Abdollahi, 2013). Chronic exposures to pesticides can lead to different cancers involving lung, breast, prostate, skin, stomach, colon, blood, brain and lymphomas (Alavanja and Bonner, 2012; Pluth *et al.*, 2019). In addition to conventional risk factors for the development of diabetes, studies worldwide have showed an increasing prevalence of diabetes in pesticide exposed population (Saldana *et al.*, 2007; Everett and Matheson, 2010; Mostafalou and Abdollahi, 2012, 2013; Evangelou *et al.*, 2016). For example, meta-analysis studies (Jaacks and Staimez, 2015; Evangelou *et al.*, 2016) clearly observed an increased risk of diabetes for several organochlorine pesticides (DDT, DDE, heptachlor, hexachlorobenzene and chlordane). Likewise, similar to our findings, studies elsewhere have shown the association between hypothyroidism and the application of herbicides and insecticides in male pesticide applicators (Goldner *et al.*, 2013). A recent review of literature (Leemans *et al.*, 2019) clearly observed the association of the use of chemical pesticides such as organochlorine, organophosphate and carbamate pesticides with the thyroid axis disruption. Finally, we saw higher prevalence of asthma in the 'case' village. Chronic pesticide exposure could have induced asthma or aggravated previous asthma conditions and airway hyperresponsiveness. In the agricultural settings, numerous prior studies, for example, Hoppin *et al.* (2007), Hernández *et al.* (2011), Mamane *et al.* (2015), and Woldeamanuel *et al.* (2020) have found positive correlation between chronic pesticide exposure and chronic bronchitis.

It is, however, important to acknowledge that chronic health conditions, which are non-transferable between individuals, result from many factors (Miranda *et al.*, 2008; Aryal *et al.*, 2015; Allen *et al.*, 2020). Long-term exposure to pesticides is not only the cause. Person's background, lifestyle, and surrounding environment could affect the prevalence of chronic diseases. Tobacco use, physical inactivity, harmful use of alcohol, and unhealthy diets (WHO, 2018) - all increase the risk of chronic health problems. This study showed a positive association between the use of chemical pesticides in agriculture and the risk of chronic health conditions in Nepal. However, precaution must be taken while concluding the findings. Despite a clear relationship between long-term application of pesticides and chronic health conditions in the agricultural settings of the mountain areas of Nepal, this study was a preliminary, survey-based, assumed a simple causal relationship, and has a small sample size. In the regression analysis, we accounted only those households who had self-reported some kind of long-term illness during the initial survey and have been applying chemical pesticides. We recommend to initiate an in-depth longitudinal cohort study with clinical evidences on the issue to validate our results. Because of the small sample size, and refusal of a few respondents to talk to the physician on their health conditions, we found limited confirmation records of chronic health conditions.

Conclusion

We found farmers' routine exposure to different chemical pesticides in the study area. The results showed an increased risk of chronic health conditions because of the long-term application and exposure to chemical pesticides in an agricultural setting. The prevalence rate of chronic health conditions was higher in the area where agriculture has been highly intensified and the use of chemical pesticides was comparatively at higher rates for a long period. We observed that chronic health conditions rate increased by a factor of 1.296 for an additional year of pesticide use. As we said earlier, this study was survey-based and preliminary, we recommend further in-depth longitudinal cohort study to support our findings. Nonetheless, findings warrant that farmers should avoid the use of highly toxic pesticides, and the concerned body should implement public education and awareness activities, and promote alternative practices for chemical pesticide use in agriculture.

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Conflict of interest

The authors declare that they have no conflict of interest.

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