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Farmers' Perspectives of Rodent Damage and Rodent Management in Smallholder Maize Cropping Systems of Southern Ethiopia

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Abstract

A survey was conducted in Chano area, Southern Ethiopia, to investigate farmers' viewpoints with regard to rodent pest problems. Farmers (n = 384) were interviewed using semi-structured questionnaire between October 2018 and January 2019. Pests were implied (51%) as the major constraints of cereal crop production followed by shifting to cash crops (20.6%), waterlogged farmlands (15.6%), infertile soils (8.6%) and insufficient rains (4.2%). Farmers experienced rodent outbreaks (83%) and identified maize (98%) as a crop most susceptible to rodent damage. Farmer suffered 23.5% average annual maize loss due to rodents. Being male (OR = 2.82, $P < 0.05$) and years spent in farming (OR = 1.13, $P < 0.001$) increased the likelihood of farmers' experience with rodent outbreaks. Seedling stage of maize was identified as the stage most susceptible to rodent damage (64.8%), followed by harvesting (19.3%) and maturity (15.9%) stages. When adjusted for other factors, a year increase in farming as an occupation decreased farmers' estimate of annual maize yield loss due to rodent damage by a coefficient of 0.04 ($P < 0.05$). An individual's experience (86.5%) was the major factor in deciding the type of rodent pest management. Application of rodenticides was the most frequently used (76%) rodent management method. We recommend awareness creation and extension support to the farmer community to reduce the reliance on toxic rodenticides and shift to community-based integrated rodent management approaches that would reduce the unacceptable damage levels.

Key words: Maize; farmers' perceptions; rodent pest management; socio-demographics; Ethiopia

1. Introduction

Rodent pests disproportionately affect the livelihood of smallholder farmers in the Afro-Malagasy region (Swanepoel et al., 2017). It is hypothesized that small-scale farming creates landscape mosaics that are generally suitable for rodent pests than mono-cultures (Makundi et al., 2009; Sluydts et al., 2009).

The southern Ethiopian Rift valley Lakes, Abaya and Chamo basin (Chano area included) has suffered severe anthropogenic land use and land cover changes in the past several decades (Ashebir et al., 2018). As a result, Lake Abaya experienced massive sediment load (Fassil et al., 2017; Fassil et al., 2018), with its sediment-displaced water inundating the nearby farm plots (Schütt and Wenclawiak, 2010). A number of farm plots at the eastern outskirts of Chano have been converted into swampy areas that are no longer suitable for growing food crops and are suspected of harboring rodent pests of field crops. Such newly developed swampy areas also have rendered corridors for crop raiding hippos from Lake Abaya. In Chano, farmers often protect their maize fields against hippos or leave their farms fallow in case of labor shortage to guard field crops against large-sized wildlife. The abandonment of farm plots for fear of crop raiding by large-sized wildlife exacerbates expansion of non-cropped biotopes that may act as refugia for small rodents. Moreover, increased use of Lake Abaya water for irrigation of banana plantations (including in the Lake's buffer zones) have caused development of saline soils (Tuma et al., 2014). Farm plots abandoned due to soil salinity also add to the size of the area with potential for rodent habitats. Furthermore, in Chano, individual farm plots are separated by hedges, which are used by the local farmers as access barriers to people and livestock. However, farmers and agricultural extension workers also report that the hedgerows create potential harborage for rodent pests.

Maize (*Zea mays L.*) is an important crop for food security in Ethiopia (Abate et al., 2015). However, the production of maize has significantly been threatened by rodent pests in East Africa including Ethiopia (Makundi et al., 2005; Mulungu, 2017). Maize is the staple food crop in Chano despite declining production due to a shift to cultivate fruits and vegetables. Therefore, we targeted maize to explore contextualized viewpoints of farmers with regard to rodent pest damage and management. Moreover, there is a lack of information regarding the relationship between production situations and farmer' perspectives of rodent outbreaks and crop damage in Africa. Analyzing the perceptions of farmers on the severity of pest damage across socio-demographic groups can provide better insights for instituting pest management strategies tailored to the problem areas identified (Singleton and Flor, 2015; Zhang et al., 2018). The results of this survey will be combined with the findings of an ongoing rodent ecology and crop damage study in the same area to help design ecologically based rodent pest management. The objectives of this study were to investigate (i) context-specific farmers' perspectives of rodent pest damage and management and (ii) how selected socio-demographics affect farmers' experiences with rodent outbreaks and estimations of maize yield loss due to rodent damage. We assumed (i) being male, seniority in farming, ≥ primary education, farms converted from non-cropped lands, increase in monetary expenditure for rodent management and annual maize yield would better predict the likelihood of farmers' experiences to rodent outbreaks; (ii) seniority in farming, increase in farm size, increase in stored maize loss due rodent damage and increase in monitory expenditure for rodent management would better predict farmers' estimate of annual maize yield loss to rodent damage. We also expected that estimates of maize losses due to rodent damage vary across socio-demographic groups.

2. Materials and Methods

2.1. Study area

Chano (N 6º4'0'', E 37º37'0'', ~1200 m above sea level, area = 2309 ha) is located 15 km north of Arba Minch town and 495 km South of Addis Ababa in Sothern Ethiopia (Fig.1). Chano is divided into three rural villages namely, Chano Chalba (CC hereafter), Chano Dorga (CD hereafter) and Chano Mile (CM hereafter). The rainfall is bimodal with short rains spanning September-November and the long rains covering March to May. It receives annual rainfall ranging from 800 to 1200 mm. The average annual maximum and minimum temperatures are 30˚C and 17˚C, respectively (Clark, 2010). The total population (projected for the year 2017) of Chano was about 19,660 people (Arba Minch Zuria District Socioeconomic and Geospatial Abstract, 2016/2017). Maize is cultivated rainfed twice a year: between April to July during the long rainy season and between August to December during the short rainy season (locally called Gaba and Sila seasons, respectively).

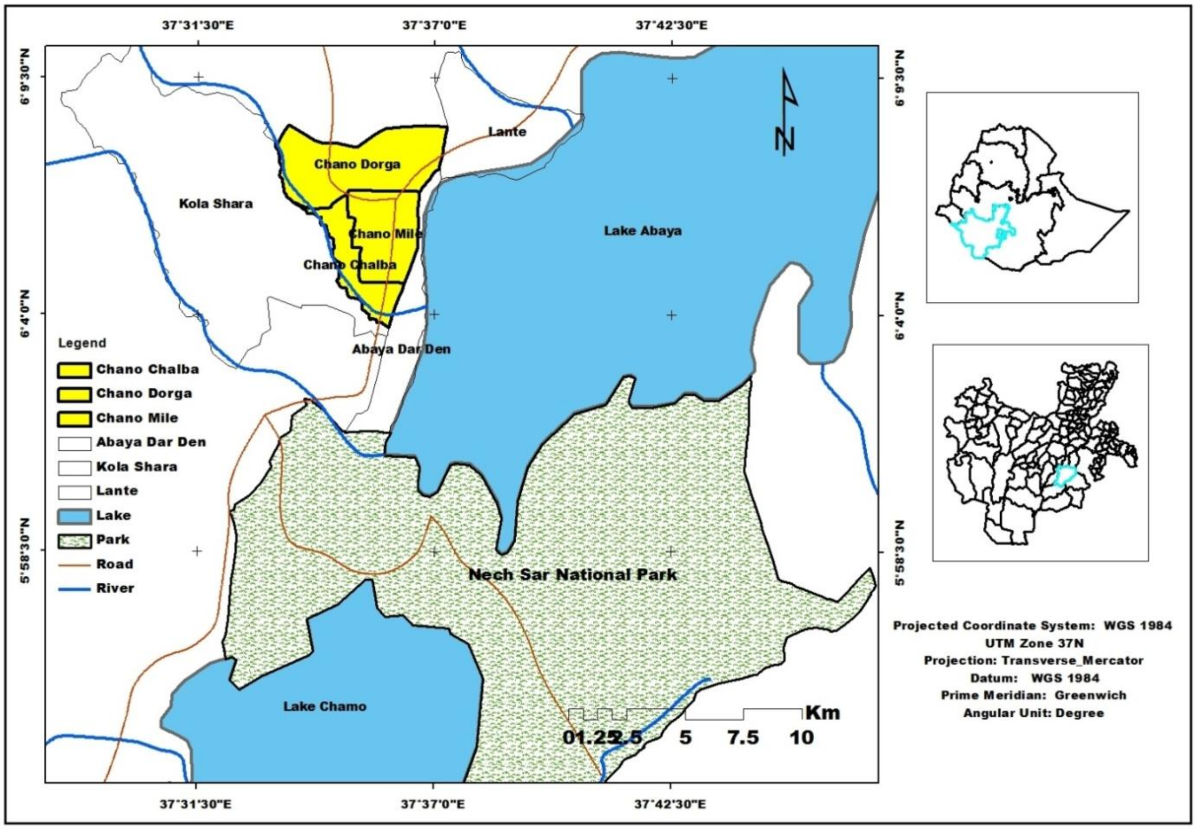

Figure 1. Map of the study area. The survey villages are located near the western shore of Lake Abaya within the Abaya-Chamo basin in southern Ethiopia

2.2. Sample size

Chano villages were purposively selected for the survey due to their location and their involvement in the ongoing rodent ecology and crop damage study. The sample size was calculated using the formula, $\boldsymbol{n} = \frac{\boldsymbol{z^2pq}}{\boldsymbol{e^2}}$, where '**n**' is the required sample size, '**z**' is the critical value (1.96) at 95% confidence level, '**p**' is an estimated proportion, "**q**" is 1-p and '**e**' is the margin of error which is fixed at 0.05 (Cochran, 1963). Since there were no earlier data on farmers' perspectives of rodent pest damage and management in the study area, a perception rate of 50% was assumed for "**p**" and hence, the calculated sample size was 384. The sample size was proportionally distributed to each of the three villages.

2.3. Sampling technique and interview

The list of farmer households in the villages were used as sampling frames. The total number of households in each village was divided by the proportionally allotted sample size and the quotient was used as a sampling interval until the required sample was obtained. Semi-structured questionnaire was prepared based on discussion with farmer representatives and village staff to contextualize the variables. The questionnaire was reviewed by an expert for completeness and was composed of three parts (socio-demographics, perceptions about rodent damage and rodent pest management). The questionnaire was pre-tested with a total of six farmers (2 from each of the villages) for further refinement. The questionnaire was translated to the official Amharic language and was administered by trained enumerators. The interview was administered to a farmer household head or spouse in the local Gamo language and lasted approximately an hour. The interviews were conducted between October 2018 and January 2019.

2.4. Data analysis

Data were entered into SPSS version 20 and descriptive statistics were generated. Chi-square tests were used to establish associations between farmers' demographics and their perceptions with regards to crop damage and rodent management. Independent sample t-test was used to compare farmers' estimates of maize annual yield loss, storage loss and monetary expenditure for rodent management between male and female respondents. One way analysis of variance (ANOVA) was used to compare estimates of maize annual yield and storage losses as well as monetary expenditure for rodent management between different age groups, education levels and villages. Binary-logistic and multiple regression models were used to identify socio-demographic predictors of farmers' experiences to rodent outbreaks and estimated maize yield loss due to rodent damage, respectively. The goodness-of-fit of the binary-logistic regression model was measured using Nagelkerke pseudo r^2, log likelihood function, Hosmer and Lemeshow Test, Omnibus Tests of Model Coefficients and Classification accuracy. Likewise, the goodness-of-fit of the multiple logistic regression model was checked using an adjusted coefficient of determination (adjusted R^2) and one-way ANOVA.

2.5. Ethical issues

The study was approved by the Arba Minch University, Ethiopia. Study permits were also obtained from the Gamo Zone and Chano Bureaus of Agriculture. Verbal consent was obtained from household heads or spouses prior to the interview.

3. Results

3.1. Socio-demographic profile

Of the 384 farmer household heads surveyed, 310 (80.73 %) were males and 74 (19.27%) were females (Table 1). The average age of the respondents was 62.46 years (range: 35-100). The average family size was 6.44 individuals (range: 1-16). The majority (58.85%) had no formal education. On average, the respondents spent 42.8 years (range: 10-80) in farming as an occupation.

Table 1. Socio-demographic profile of the respondents (n=384)

Socio-demographics	**CC**		**CM**		**CD**		Total	
	n=160		n=139		n=85		n=384	
	Mean ± SE	**Range**	**Mean ± SE**	**Range**	**Mean ± SE**	**Range**	**Mean ± SE**	**Range**
Age (in years)	57.02 ± 1.01	35-90	67.79 ± 1.23	36-100	64 ± 1.58	40-100	62.46 ± 0.74	35-100
Years spent in farming	40.40 ± 1.06	10-78	45.74 ± 1.11	13-80	42.51 ± 1.48	20-74	42.80 ± 0.69	10-80
Family size	6.08 ± 0.21	1-16	6.58 ± 0.24	1-15	6.92 ± 0.28	1-15	6.44 ± 0.14	1-16
Number of farm plots owned	1.50 ± 0.05	1-3	1.99 ± 0.03	1-3	2.78 ± 0.06	1-3	1.96 ± 0.04	1-3
Total farm size (ha)	0.79 ± 0.02	0.50-1.75	1.46 ± 0.02	0.50-1.75	1.28 ± 0.03	0.50-1.75	1.14 ± 0.02	0.50-1.75
Farm size (ha) for cash crops	0.51 ± 0.02	0.25-1.25	0.97 ± 0.02	0.25-1.25	0.71 ± 0.03	0.25-1.25	0.72 ± 0.02	0.25-1.25
Farm size (ha) for maize	0.28 ± 0.01	0.25-0.75	0.49 ± 0.01	0.25-0.75	0.57 ± 0.02	0.25-0.75	0.42 ± 0.01	0.25-0.75
Annual maize yield (kg ha^{-1})	1719 ± 33.38	1000-2500	1594 ± 40.06	1000-2500	1329 ± 45.49	1000-2500	1587 ± 23.66	1000-2500
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Gender								
Male	133	83.13	109	78.42	68	80.00	310	80.73
Female	27	16.88	30	21.58	17	20.00	74	19.27
Education								
NFE	73	45.63	96	69.06	57	67.06	226	58.85
Primary education	58	36.25	35	25.18	21	24.71	114	29.69
Secondary education	29	18.13	8	5.76	7	8.24	44	11.46

NFE = no formal education, SE = standard error

3.2. Farmers' perceptions about rodent damage and estimated maize losses

The perceived constraints for cereal crop production in the study area were pests (51%) followed by shifting towards cash crop cultivation (20.6%), waterlogging in farmlands (15.6%), reduced soil fertility (8.6%) and insufficient rains (4.2%) (Table 2). More males (85.7%) asserted pests as the major constraints for cereal crop production than females (14.3%). A majority (83%) experienced rodent outbreaks, with those lacking formal education (χ^2 = 16.28, df = 2, *P* < *0.001*) and the elderly (χ^2 = 61.68, df = 4, *P* < *0.001*) accounting for higher proportions. The seedling stage of maize was indicated as the most susceptible crop stage to rodent damage (64.8%) followed by harvesting (19.3%) and maturity (15.9%) stages. Over 50% of the farmers implicated the presence of non-cropped areas around farmlands to be more suitable for rodent pests. However, these claims varied with age groups (χ^2 = 31.47, df = 12, *P* < *0.01*) and villages (χ^2 =63.30, df = 6, *P* < *0.001*).

The farmers estimated an average annual maize yield loss of 206.3 kg ha^{-1} per household ($\pm$4.24 SE, range 100-300) due to rodents in farmlands. The average annual maize yield loss estimates varied significantly among villages F [(2,381) = 87.72, *P* < *0.001*], age groups F [(4,379) = 4.41, *P* < *0.01*] and education F [(2,381) = 3.53, *P* < *0.05*]. The pairwise comparison showed that CC had the lowest average annual maize yield loss estimate than the nearly equal estimates for CD and CM (Table 3). The younger (ages 35-64 years) farmers reported a lower average annual maize yield loss estimate than the older farmers (ages 65 to $\geq$75 years). The average annual maize yield loss estimate did not vary with education. Farmers estimated an average annual stored maize loss of 166.3 kg per household ($\pm$4.91 SE, range 50-300). The average annual stored maize loss estimate was significantly varied among the villages F [(2,381) = 30.13, *P* < *0.001*], age groups F [(4,379) = 3.84, *P* < *0.01*] and education F [(2,381) = 5.28, *P* < *0.01*]

(Table 3). The pairwise comparison revealed that the average annual stored maize loss was the lowest in CC than the nearly equal estimates for CD and CM. The younger (ages 35-54 years) farmers reported a lower storage loss estimate than the older farmers (ages 55 to ≥75 years). Moreover, farmers lacking formal education reported the highest average annual storage loss estimate of maize.

Table 2. Farmers' perceptions about rodent damage to maize

Variables (n = 384)		Proportion (%) with regards to respondents' profile												
Responses	Overall No. (%)	Sex		Age group					Education			Village		
		M	F	AG1	AG2	AG3	AG4	AG5	NFE	1^o	2^o	CC	CD	CM
Constraints of cereal crop production														
Pests	196(51.0)	54.2	37.8	30.8	53.2	53.8	51.8	54.3	53.5	49.1	43.2	36.2	80.0	50.4
Waterlogged farmlands	60(15.6)	13.5	24.3	35.9	19.0	9.9	12.0	13.0	14.2	18.4	15.9	19.4	4.7	18.0
Shifting to cash crops	79(20.6)	21.3	17.6	28.2	15.2	20.9	25.3	17.4	18.6	21.9	27.3	29.4	5.9	19.4
Insufficient rains	16(4.2)	2.9	9.5	0.0	3.8	5.5	2.4	6.5	4.9	2.6	4.5	2.5	9.4	2.9
Infertile soils	33(8.6)	8.1	10.8	5.1	8.9	9.9	8.4	8.7	8.8	7.9	9.1	12.5	0.0	9.4
Experience about rodent outbreaks														
Yes	317(82.6)	82.3	17.7	46.2	72.2	84.6	89.2	98.9	88.5	77.2	65.9	66.9	89.4	96.4
No	67 (17.4)	73.1	26.9	53.8	27.8	15.4	10.8	1.1	11.5	22.8	34.1	33.1	10.6	3.6
Place of biggest rodent problem														
Household compound	294(76.6)	79.6	20.4	82.1	73.4	78.0	77.1	75.0	76.5	76.3	77.3	83.1	76.5	69.1
Crop field	90(23.4)	84.4	15.6	17.9	26.6	22.0	22.9	25.0	23.5	23.7	22.7	16.9	23.5	30.9
Crop that most endure rodent damage in the field														
Maize	377(98.2)	80.6	19.4	100	98.7	97.8	98.8	96.7	97.8	98.2	100	100	97.6	96.4
Other	7(1.8)	85.7	14.3	0.0	1.3	2.2	1.2	3.3	2.2	1.8	0.0	0.0	2.4	3.6
Crop that most endure rodent damage in storage														
Maize	376(97.9)	98.1	97.3	100	100	100	96.4	94.6	96.9	99.1	100	100	100	94.2
Other	8(2.1)	1.9	2.7	0.0	0.0	0.0	3.6	5.4	3.1	0.9	0.0	0.0	0.0	5.8
Favor rodent occurrence in crop fields														
Infrequent weeding	149(38.80)	38.1	41.9	51.3	53.2	42.9	27.7	27.2	35.4	43.0	45.5	52.5	42.4	20.9
Non-crop areas near farmlands	193(50.26)	51.0	47.3	43.6	38.0	46.2	62.7	56.5	52.2	48.2	45.5	43.1	31.8	69.8
Soil mounds nearby	33(8.60)	9.0	6.8	5.1	7.6	9.9	3.6	14.1	9.3	7.9	6.8	4.4	18.8	7.2
Others	9(2.34)	1.9	4.1	0.0	1.3	1.1	6.0	2.2	3.1	0.9	2.3	0.0	7.1	2.2.
Maize stage most susceptible to rodent damage														
Seedling	249(64.8)	66.1	59.5	66.7	59.5	62.6	69.9	66.3	65.5	60.5	72.7	64.4	57.6	69.8
Maturity	61(15.9)	15.8	16.2	17.9	20.3	12.1	15.7	15.2	15.0	14.9	22.7	18.1	5.9	19.4
Harvesting	74(19.3)	18.1	24.3	15.4	20.3	25.3	14.5	18.5	19.5	24.6	4.5	17.7	36.5	10.8

AG = Age group; AG1 = 35-44 years, AG2 = 45-54 years, AG3 = 55-64 years, AG4 = 65-74 years AG5 = $\geq$ 75 years; NFE = no formal education, 1^o = primary 2^o = secondary

Table 3. Estimated losses of maize to rodent damages with respect to respondents' profile

Factors	Mean maize yield loss (kg ha^{-1} per household) ± SE	Mean stored maize loss (kg per household) ± SE
Village		
CC	151.25 ± 5.54^{b}	124.69 ± 6.83^{b}
CD	240.00 ± 7.71^{a}	204.12 ± 8.86^{a}
CM	248.92 ± 5.63^{a}	191.01 ± 8.27^{a}
Age group (in years)		
35-44	182.05 ± 13.68^{c}	135.90 ± 14.57^{c}
45-54	189.87 ± 9.46^{c}	144.94 ± 10.94^{c}
55-64	195.60 ± 8.83^{c}	163.74 ± 9.98^{cd}
65-74	219.28 ± 8.98^{d}	175.90 ± 10.61^{cd}
≥75	229.35 ± 7.81^{d}	191.30 ± 9.58^{d}
Education		
NFE	215.04 ± 5.34^{e}	179.43 ± 6.35^{e}
Primary education	197.37 ± 8.02^{e}	148.68 ± 8.71^{f}
Secondary education	184.09 ± 12.98^{e}	144.32 ± 14.83^{ef}

SE = standard error; means ± SE followed by different letters are significantly different at $P < 0.05$; NFE = no formal education

3.3. Farmers' practices of rodent management and estimated management cost

Rodenticides were the most frequently (76%) used rodent management method. The majority (86.5%) of the farmers adhered to personal experiences for information to decide on the type of rodent management practice and purchased rodenticide from village shops (83%) (Table 4). Rodent management was symptomatic, initiated after noticing rodent damage (53%) and nuisance (46%), but also carried out as part of the routine storage treatment (1.43%). However, the reasons for initiating rodent management varied significantly with age group (χ^2 = 20.79, df = 8, $P < 0.01$), education (χ^2 = 10.62, df = 4, $P < 0.05$) and Kebele (χ^2 = 105.91, df = 4, $P < 0.001$) (Table 4). Farmer estimate of average annual monetary expenditure for rodent management was US$ 1.49 per household (± 0.05 SE, Range 0.36-3.570).

Table 4. Farmers' perceptions about rodent management

Variables (n=384)		Proportion (%) with regards to respondents' profile												
Responses	Overall No. (%)	Sex		Age group					Education			Village		
		M	F	AG1	AG2	AG3	AG4	AG5	NFE	1^{o}	2^{o}	CC	CD	CM
Source of advice on how to manage rodents														
Personal experience	332(86.5)	85.2	91.9	97.4	86.1	85.7	83.1	85.9	87.6	82.5	90.9	93.1	82.4	81.3
Extension workers	9(2.3)	2.9	0.0	2.6	2.5	3.3	2.4	1.1	1.3	4.4	2.3	0.6	3.5	3.6
Informal pesticide traders	43 (11.2)	11.9	8.1	0.0	11.4	10.0	14.5	13.0	11.1	13.2	6.8	6.2	14.1	15.1
Source of input for rodent management														
Village shops	320(83.3)	84.2	79.7	89.7	79.7	80.2	81.9	88.0	83.6	83.3	81.8	85.0	83.5	81.3
Local markets	49(12.8)	11.6	17.6	7.7	16.5	15.4	13.5	8.7	13.3	12.3	11.4	13.1	14.1	11.5
Agrovets	15(3.9)	4.2	2.7	2.6	3.8	4.4	4.8	3.3	3.1	4.4	6.8	1.9	2.4	7.2
Initiation of rodent management														
After noticing nuisance	175(45.6)	44.8	48.6	66.7	51.9	51.6	37.3	32.6	38.9	54.4	56.8	75.0	34.1	18.7
After noticing damage	204 (53.1)	53.9	50.0	30.8	46.8	48.4	60.2	66.3	59.7	43.9	43.2	25.0	65.9	77.7
As part of preparing storage space for harvest	5(1.3)	1.3	1.4	2.6	1.3	0.0	2.4	1.1	1.3	1.8	0.0	0.0	0.0	3.6
Most frequently used rodent management method														
Environmental sanitation	8 (2.1)	2.3	1.4	0.0	1	1.1	3.6	3.3	2.2	2.6	0.0	0.0	1.2	5.0
Rodenticide	292 (76)	75.2	79.7	71.8	64	78.0	72.3	75.0	78.8	66.7	86.4	73.1	83.5	74.8
Trap	61 (15.9)	16.1	14.9	17.9	10	13.2	20.5	16.3	15.0	20.2	9.1	20.6	10.6	13.7
Cat	23 (6)	6.5	4.1	10.3	4	7.7	3.6	5.4	4.0	10.5	4.5	6.2	4.7	6.5
Employ indigenous practices of rodent management														
Yes	65(16.9)	19.7	5.4	15.4	19.0	14.3	15.7	19.6	13.7	22.8	18.2	21.9	9.4	15.8
No	319(83.1)	80.3	94.6	84.6	81.0	85.7	84.3	80.4	86.3	77.2	81.8	78.1	90.6	84.2
Cooperate with neighbor for rodent management														
Yes	33(8.6)	8.7	8.1	5.1	10.1	9.9	9.6	6.5	7.5	13.2	2.3	6.2	8.2	11.5
No	351(91.4)	91.3	91.9	94.9	89.9	90.1	90.4	93.5	92.5	86.8	97.7	93.8	91.8	88.5
Obtain governmental or non-governmental support in rodent management														
Yes	7(1.8)	2.3	0.0	2.6	0.0	3.3	2.4	1.1	0.9	3.5	2.3	0.6	3.5	2.2.
No	377(98.2)	97.7	100	97.4	100	96.7	97.6	98.9	99.1	96.5	97.7	99.4	96.5	97.8

AG = Age group; AG1 = 35-44 years, AG2 = 45-54 years, AG3 = 55-64 years, AG4 = 65-74 years AG5 = $\geq$ 75 years; NFE = no formal education, 1^{o} = primary 2^{o} = secondary

3.4. Determinants of farmers' experience with rodent outbreaks

The odds of experiencing with rodent outbreak significantly increased with increased years spent on farming (OR = 1.13, $P < 0.001$) and annual maize yield (OR = 1.00, $P < 0.01$), as well as being male (OR = 2.82, $P < 0.05$) and residence in CM (OR = 35.58, $P < 0.001$) and CD (OR = 16.70, $P < 0.001$) villages (Table 5). Conversely, the odds of experiencing rodent outbreak significantly decreased with increased annual monetary expenditure for rodent management (OR = 0.57, $P < 0.01$).

Table 5. Binary logistic regression model for farmers' experiences with rodent outbreaks

Independent variables	B Coefficient)	SE	Wald	OR (95%CI)	P-value
Constant	-5.98	1.40	18.35	0.003	<0.001
Gender					
Male	1.04	0.43	5.80	2.82(1.21- 6.56)	<0.05
Female-RC					
Years spent in farming	0.12	0.02	34.56	1.13(1.09-1.18)	<0.001
Education					
NFE	-0.59	0.57	1.07	0.55 (0.18-1.70)	>0.05
Primary	0.05	0.50	0.01	1.06 (0.40-2.81)	>0.05
Secondary-RC					
Village					
CM	3.57	0.64	30.86	35.58 (10.09-125.47)	<0.001
CD	2.82	0.69	16.91	16.70 (4.36-63.91)	<0.001
CC-RC					
Land use/cover at first acquirement					
Crop	-0.14	0.56	0.06	0.87 (0.29- 2.60)	>0.05
Non-crop-RC					
Annual monetary expenditure for rodent management	-0.57	0.01	9.19	0.57 (0.39-0.82)	<0.01
Annual maize yield (kg ha^{-1})	0.00	0.00	8.12	1.00 (1.00-1.00)	<0.01
Number of farm plots owned	-0.07	0.30	0.05	0.94 (0.52-1.69)	>0.05

RC = reference category; SE = standard error of the slope; OR = odds ratio; CI = confidence interval; NFE = no formal education

3.5. Determinants of farmers' estimate of maize yield loss to rodents

Total farm size, annual stored maize loss due to rodent damage and annual monetary expenditure for rodent management positively affected the average annual maize yield loss due to rodent damage (Table 6). Conversely, years spent on farming, percentage of farmland devoted to banana and other cash crops cultivation and sum total of annual maize yield negatively affected farmers' estimate of annual maize yield loss due to rodent damage. Adjusting for other factors, for every one-year increase in farming, the annual maize yield loss due to rodent damage decreased by a coefficient of 0.04 ($P < 0.05$). In addition, a US$ increase in annual monetary expenditure for rodent management increased farmers' estimate of annual maize yield loss to rodents by a coefficient of 0.60 ($P < 0.05$)

Table 6. Multiple regression for farmers' estimate of percent maize yield loss to rodent damage

Explanatory variables	Unstandardized Coefficients		Standardized Coefficients	t	P-value
	B	SE	Beta		
Constant	23.54	1.71		13.77	<0.01
Years spent in farming	-0.04	0.02	-0.08	-2.03	<0.05
Total farm size (ha)	6.10	0.82	0.31	7.41	<0.001
% farm size allotted for banana and other cash crops	-0.05	0.02	-0.08	-2.10	<0.05
Sum total of annual maize yield (kg ha^{-1} per household)	-0.01	0.00	-0.56	-15.45	<0.001
Stored maize loss due to rodent damage (kg per household)	0.02	0.00	0.20	5.55	<0.001
Annual monetary expenditure for rodent management	0.60	0.27	0.08	2.18	<0.05

SE=standard error

4. Discussion

4.1. Rodent damage

The farmers suffered average annual maize losses of 13% (206.3 kg ha^{-1} per household / 1,587 kg ha^{-1}) and 10.5% (166.3 kg per household / 1,587 kg ha^{-1}), in the field and in storage, respectively, due to rodent damage. Nevertheless, the losses estimated significantly varied across the socio-demographic groups. In economic terms, the farmers suffered a combined loss of US$ 118.43 annually which accounted for 53% of the average annual net income (US$ 225 per household) from maize. The combined annual loss was 372.53 kg per household. In Ethiopia, on average, adults consume 194 kg of cereals annually (CFSVA, 2019). Hence, the combined loss would have fed one-third of a member of a household for a year, considering the average family size of six persons.

However, farmers' estimate of maize loss due to rodent damage appeared to be concealed by the apparently severe maize raiding by other mammals, particularly hippos (*Hippopotamus amphibious*) and the invasive fall armyworm (*Spodoptera frugiperda*) in the study area. Farmers in Uganda also perceived baboons and wild pigs to cause most of the damage to field crops rather than small-sized mammals (Hill, 1997). Likewise, farmers in rice farming systems of Asia overlooked pests that are inconspicuous by size or the type of damage they cause (Litsinger et al., 2009). Moreover, farmers are often less aware of rodents as pests, as they are often secretive (Gross et al., 2019; Tola et al., 2017). Farmers' limited focus on rodent pests might also be attributed to their sense of apathy and tolerance (Palis et al., 2007). Farmers of different demographic groups equally recognized maize as a crop that most suffered rodent damage. This is substantiated by another study in Central Ethiopia and Tanzania by Makundi et al. (2005)

A majority of the farmers claimed that non-crop areas provided hiding places for rodent pests. This is in agreement with Mulungu et al. (2005) who reported farm fields close to land harboring rodents were more prone to damage. Majority of the farmers identified seedling stage of maize to be the most susceptible to rodent damage. Similar findings were reported by Makundi et al. (2005).

Farmers and extension workers reported that the practice of storing maize in outdoor granaries was being abandoned due to (1) the progressive decline in maize production and (2) theft of maize stored outdoors. Consequently, shelled maize was stored in bags indoors. These non-rodent-proof bags are easily damaged by rodents resulting in maize grain and nutrient loss, germination failure and contaminations (Mdangi et al., 2013; Ognakossan et al., 2016).

4.2. Rodent management

Generally, rodent management in the study area was initiated either by sighting of damaged crop or rodent movements in nearby fields and storage areas (Brown et al., 2008; Meheretu et al., 2010; Stuart et al., 2011). The most frequently used rodent management method was a toxic zinc phosphide rodenticide purchased from local shops. The rodenticide bait preparation was done at home by adult males. The perceived reasons for adult males handling the poison bait preparations were: children could easily be poisoned if allowed to prepare the bait, while women at reproductive age could purposively use the poison to induce abortions. This implies that female headed households with no access to male labor could be more vulnerable to rodent damage. Rodent management practices such as clearing the edges of farms and thinning the undergrowth of hedges was not reported. The leaf extract of *Datura stramonium* baited with maize flour was frequently mentioned as an indigenous practice of rodent management in the study area. Moreover, rodent management was carried out on an individual basis and not by the whole community. These practices are consistent with earlier reports from Ethiopia and elsewhere (Makundi et al., 2005; Meheretu et al., 2010; Stuart et al., 2011).

Farmers in the study area recalled the rodent pest control campaigns organized by the local crop protection sector during the 1983 and 1985 rodent outbreaks. In these campaigns, collective hunting and digging out rodents as well as clearance of potential rodent harborages were reported. According to the farmers, the community based rodent pest control campaigns have not since been repeated. The farmers also noted that the deterioration of social cohesion associated with urbanization is among the factors contributing to lack of community cooperation for pest management. It has been reported that farmers in Myanmar believed that rodents can only be controlled if they work together (Brown et al., 2008). In addition, farmer organizations in the

Philippines contributed to cooperative rodent management (Flor and Singleton, 2011; Stuart et al., 2011).

The estimated average annual monetary expenditure for rodent management, US$ 1.49 per household, was low compared to other developing nations. Subsistence rice farmers in Philippines were willing to invest an average of US$ 6.73 per person annually for rodent control (Stuart et al., 2011). In the present study, the monetary contribution was for expenditure on rodent control inputs particularly rodenticides and traps.

4.3. Determinants of farmers' experience to rodent outbreaks

In our study, male gender enhances experience to rodent outbreaks. The apparently higher responsibility of men for management of field crops (Gemechu et al., 2009) might have enhanced the likelihood of their experience with rodent outbreaks. Similarly, Zhang et al. (2018) reported that female household headship reduced the likelihood of perceived severity of pests possibly due to lower expenditure for control inputs. In our study, senior farmers tended to have more experience with rodent outbreaks. Zhang et al. (2018) also highlighted that the more years a farmer spent in farming, the more encounters he/she will have with pest outbreaks. Senior farmers often relied on their social capital and were found to be less receptive to new pest management technologies and hence their frequent encounters with pests (Palis et al., 2007). The experience of farmers with rodent outbreaks increased if their farms were originally obtained by conversion of a non-cropped land. A possible explanation for this could be that farms originally obtained through conversion of non-cropped land would still harbor relict rodent species in the remnant patches (Barnett et al., 2000). Moreover, increase in overall annual maize yield increased the likelihood of farmers' experience with rodent outbreaks. This might be attributed to the poor on-farm storage that causes maize grain spillage at times of surplus production which in turn can attract pest rodents (Ognakossan et al., 2016).

4.4. Determinants of farmers' estimate of maize yield loss due to rodent damage

Studies on crop production experience as a determinant factor of farmers' ability to estimate crop yield losses due to rodents are few. The number of years spent on farming significantly reduced the estimate of maize yield loss due to rodents made by farmers. Studies in Kenya indicated that experience in farming was significantly associated with lower estimate of storage losses of maize due to rodents (Ognakossan et al., 2016). The observed decrease in estimated maize yield loss due to rodents as seniority in farming increases might be attributed to the fact that younger farmers are more worried of rodent damage to the crops than older ones (Palis et al., 2007). The size of farm plots devoted to cultivation of banana and other cash crops significantly contributed to a decrease in estimated maize yield loss due to rodents. This is probably linked to the reduction in the size of available farmland for maize which is also the most vulnerable crop to rodent damage (Demeke et al., 2007; Makundi et al., 2005; Mulungu, 2017). Farmers with higher annual production estimated lower yield loss due to rodents. This is consistent with Zhang et al. (2018) who reported that the higher the annual crop production the lower will be the farmers' estimate of yield losses to pest attack. This might be attributed to the concealing effect of higher production on the amount lost due to rodent damage. Increase in stored maize loss due to rodent damage and monetary expenditure for rodent control enhanced farmers' estimate of maize yield loss due to rodent damage. This indicates that the overall economic loss caused by rodents can increase farmers' estimate of maize yield loss.

5. Conclusion

Maize losses to rodents and management costs appeared to be underestimated probably due to farmers' apathy and tendency to give more attention to crop raiding wildlife that are more conspicuous with regard to their size or the type of damage they cause. We have demonstrated a number of socio-demographic factors predicting farmers' experiences with rodent outbreaks and estimated maize yield loss due to rodent damage. Establishing the effect of wide-ranging production scenarios on farmers' perception of rodent damage and rodent management may allow targeted interventions against rodent pests. Rodent management was symptomatic and not community based. We recommend awareness creation and input support to the farmer community to reduce the reliance on toxic rodenticides and shift to community-based rodent management approaches.

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