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Impacts of wild boars on local livelihoods in rural communities: A case study of mountainous areas in southeast China

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Wild boar (*Sus scrofa*) seriously threatens agricultural production and rural livelihoods worldwide. Human-wild boar conflict has become an important research topic. We investigated the impact of wild boars on local livelihoods and rural community's responses to the impact, based on a case study in Fu'an City, Fujian Province, Southeast China. We conducted a questionnaire survey of 152 rural households in six villages of Fu'an City. Results demonstrated that the overall impact of wild boars on livelihoods was significant; however, there was impact heterogeneity depending on the mentioned factors. The impact lied on the scale of agricultural output value and the extent of livelihood dependency on susceptible crops. Different impacts resulted in discrepant countermeasures of rural households in dealing with wild boars. The magnitude of economic losses caused by wild boars to a great extent determined the selection of prevention measures. Rural households with more economic losses tend to adopt costly and effective prevention measures, such as fencing and human guarding. Recommendations were put forward to address the human-wild boar conflicts in China.

KEYWORDS

crop raiding, heterogeneity, human-wildlife conflict, wildlife management, China

1 Introductiion

Human–wildlife conflicts have been considered as one of the most challenging issues of wildlife conservation in the world (Holmern et al., 2007; Acharya et al., 2016; Huang et al., 2018; Bhatia et al., 2020; Stoldt et al., 2020; Zhang et al., 2020; Halley et al., 2021). The primary causes of conflicts are very complicated and vary in different regions. Human–wildlife conflicts could attribute to many reasons: 1) human population growth and habitat encroachment (Nyhus and Tilson 2004; Richard et al., 2004; Graham et al., 2005), 2) implementing nature conservation and increasing wildlife populations (Fall and Jackson, 1998; Palmeira et al., 2008), and 3) domestication (Herrero and De Luco, 2003). Conflicts between agricultural interests and wildlife conservation appear to be increasing globally (Redpath et al., 2013; Madden and McQuinn, 2014). These conflicts could result in significantly economic losses for related rural households, including crop raiding, forest damage, property damage, vehicle collisions, harming native vertebrates, and spread of zoonotic diseases to humans or livestock *etc.* (Karanth et al., 2013; Manral et al., 2016; Miller et al., 2017; Brown et al., 2018; Su et al., 2020; Wang C. et al., 2020; Zhang et al., 2020; McDonough et al., 2022). Such economic losses would bring about serious livelihood impacts, such as aggravating poverty and food deficiency,

especially for those whose livelihoods greatly depend on farming or forestry sections. Severe livelihood damages may urge farmers to adopt retaliatory wildlife killings, which, in turn, can lead to conflicts between farmers and environmentalists (Katel et al., 2014).

Wild boars (also known as wild pigs, *Sus scrofa*), native to Eurasia and Africa, are widely regarded as one of the most destructive species in the world. The wildlife would bring significant impacts on human interests, including crop raiding, spread of diseases, and vehicle collisions. In addition, wild boars could also cause reduction of biodiversity, especially reduction in plant and animal abundance and richness, where they are listed as invasive species (Massei et al., 2011; Taylor et al., 2011; McDonough et al., 2022). They have encroached upon all continents except Antarctica, and currently are among the most widely-distributed mammals in the world (Acevedo et al., 2014). The animal could survive in a wide spectrum of habitat types, ranging from taigas to tropical forests, mountains, and marshes (Massei et al., 2011). Human-wild boar conflicts have been reported as the most serious threats on farmers' livelihoods owing to its striking population growth and powerful destruction (Seward et al., 2004). The fast population growth and wide range of distribution of wild boars could be attributed to many factors, such as: the animal's high fertility, generalist feeding behaviour and lack of predators, translocation, insufficient population control by hunting and culling, land abandonment, reforestation and climate change (Geisser and Reyer 2005; Liu et al., 2019; Csókás et al., 2020). Wild boars have the highest reproductive rate among wild ungulates, with annual rise in population size that might exceed 100% (Bieber and Ruf, 2005). Wild boars can cause considerable damage to agricultural production of cereals, such as paddy (*Oryza sativa*), potato (*Solanum tuberosum*), wheat (*Triticum aestivum*), maize (*Zea mays*), oats (*Avena sativa*), and barley (*Hordeum vulgare*), fruits, such as bananas (*Musa paradisiaca*), watermelons (*Citrullus lanatus*) and sugarcane (*Saccharum officinarum*) through consumption and trampling, to animal production by disease transmission (Massei et al., 2011; Gentle et al., 2015; Miller et al., 2017; Brown et al., 2018; Bolds et al., 2022). Globally, substantial economic losses have resulted from wild boars, mainly through directly decreasing crop yields and livestock disease transmission. For example, only in the United States of America, the annual economic cost caused by wild boars including direct damages and control costs was estimated at least US$1.5 billion, which accounted for 3.26% of the total loss in damage and control costs per year caused by invasive mammals and birds in United States (Pimental, 2007).

Many management measures could be divided into two types: hunting and culling strategies to mitigate human-wild boar conflicts (Massei et al., 2011; Liu et al., 2019). Hunting is a lethal activity which strives to maintain the wildlife population to a suitable level. Culling strategies mean the selective removal of animals by many measures, including poisoning, trapping, snares, repulsion by light and sound, and exclusion fencing, whose primary objective is decreasing the wildlife populations (Herrero et al., 2006; Herrero et al., 2008). Some lethal techniques, such as power grids, trapping, and snares, aimed at reducing population densities are the most widely used means of managing the impacts of wild boars in many countries of Europe, America and Australia (Massei et al., 2011; Bengsen et al., 2014). But these lethal control techniques are criticized and even prohibited in many nations because of concerns of human safety, environmental impacts of toxicant substances, and animal welfare (McCann and Garcelon, 2008; Parkes et al., 2010; Massei et al., 2011). Non-lethal methods, such as electrical fencing, non-electrified fencing and repulsion, were generally adopted to lessen wildlife impacts by protecting valuable crops or preventing livestock disease transmission (Herrero and De Luco, 2003; Geisser and Reyer, 2004; Campbell and Long, 2009; Honda et al., 2011; Massei et al., 2011). Integrated management approaches have been widely recommended (Bengsen et al., 2014). It is worthy to notice that many variables, such as hunting permission, type of areas (urban or rural areas), land property, type of conflicts, may decide the selection of management measures.

Human-wild boar conflicts in China have substantially increased in recent decades, owing to effective environmental protection, natural recovery, wildlife conservation, rapid urbanization, shrinking rural population, and prevalent land abandonment (Cai et al., 2008; Hua et al., 2016). To promote wildlife conservation, the State Forestry Administration of China (SFA) listed wild boar as a protected species into the document: *State-Protected Terrestrial Species That Are Beneficial and of Important Economic and Scientific Research Value* in 2000. Consequently, the population of wild boars has increased substantially since the recent two decades, and nowadays is estimated at more than one million heads in China (Bing et al., 2021). Wild boars have wreaked havoc across the whole China through crop damage, and disease transmission (Hua et al., 2016). For example, in Sichuan Province of China, a total of 7,000–8,000 wild boar damage incidents are reported every year, and the economic losses caused by wild boars' crop raiding are about 215 million RMB (1 USD = 6.4515 RMB in 2021, the same below) (Yu, 2021). In addition, the predation of sheep and chickens are also reported in China (Cai et al., 2008), and transmission of African swine fever to domestic pigs in China are also reported (Vergne et al., 2017).

Besides a few studies focused on the livelihood impacts and responses of rural households who resided around nature reserves (Cai et al., 2008; Zhou et al., 2008; Li et al., 2013), less research has discussed such issues in other areas of China. To fill this gap, this study is to illuminate wild boars' livelihood impacts on rural households and farmers' countermeasures, which are fundamental for successful wildlife conservation and also for rural sustainable development.

Rural households' heterogeneity is highlighted in the study. The study would elucidate the differences in livelihood impacts and responses of different rural households. The results have policy implications for mitigating human-wild boar conflicts in China and other developing countries. Our objectives in this study are: 1) to evaluate the livelihood impacts on rural households caused by wild boars, and 2) to illustrate the responses of rural households and community countermeasures to mitigate the human-wild boar conflicts.

2 Method and data

2.1 Study area

Fu'an City is a county city, which located in northeastern Fujian Province, China (26°41′–27°24′N, 119°23′–119°52′E). The city is situated in a mountainous region where Jiufeng Mountains, Taimu Mountains and Donggong Mountains extend through. It covers an area of 1880 km^2 (including 333 km^2 water area), consisting of four townships in downtown, and 18 rural townships (Figure 1). In terms of land use, farmland and orchard accounted for 12.8%, and 12.3% of the total land, respectively (SBFC, 2020), which suggests that

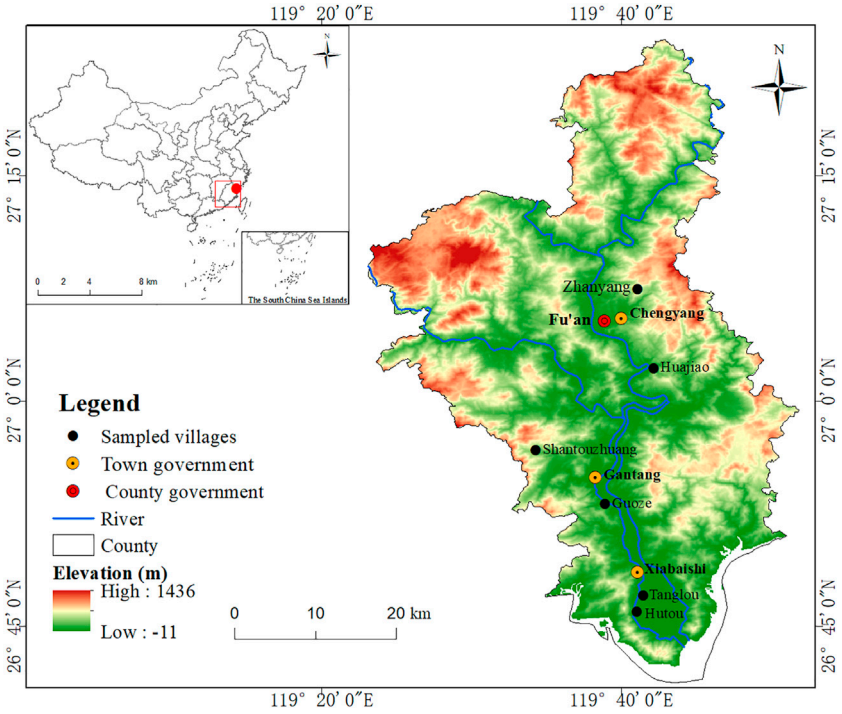

FIGURE 1
Location of study area.

availability of agricultural land is limited. Having a subtropical marine monsoon climate with mean precipitation of 1,350–2050 mm year^{-1} and warm annual temperatures, main natural vegetation types in Fu'an are *Pinus massoniana,* Chinese fir (*Cunninghamia lanceolata*), *Cupressus funebris, etc.* The luxuriant vegetation promotes the diversity of wildlife in this region, especially the wild boars and birds.

Farmland scarcity tremendously constrains crop farming, but urges rural households to extract mountainous resources in Fu'an City. Traditional farming has been restricted due to limited farmland (only 0.056 ha farmland per farmer in 2018), severe land fragmentation and poor accessibility (SBFC, 2020). Specialized agriculture, featured by intensification of cash crops, such as grape (*Vitis vinifera*), tea (*Camellia sinensis*), bamboo (*Bambusoideae*), and sugarcane (*Saccharum officinarum*), becomes a key component of rural economy in Fu'an City. On the other hand, the specialized agriculture also becomes the most severely afflicted sector in the human-wild boar conflict, because of its large scale, high value, susceptible crops and location. The farmland that is generally adjacent to mountains. In this region, local farmers' livelihood has been severely disturbed by wild boars for more than a decade. Primary crops in study area are paddy (*Oryza sativa L.*), sweet potato (*Ipomoea batatas*), grape (*Vitis vinifera*), bamboo (*Bambusoideae*), sugarcane (*Saccharum officinarum*), peach (*Prunus persica L.*), plum (*Prunus salicina lindl.*), longan (*Dimocarpus longan lour.*) and taro (*Colocasiaesculenta L. schott*), which are all favorite foods of wild boars.

Chinese mandarin has been greatly popularized as the only official language in China, but most rural households of Fu'an City prefer to speak local dialect in daily life. Apart from a small number of illiterate residents (especially the elder women), the majority of farmers could speak mandarin and local dialect simultaneously. The high popularization of Chinese mandarin would contribute to the field surveys.

Being one of the most successful counties in China in mitigating the human-wild boar conflicts, Fu'an City was designated in 2021 by National Forestry and Grassland Administration of China as one of 14 national pilot areas to manage wild boars. Early in 2006, a company named Shenlong Biology Company Limited set up a professional hunting team and gained the hunting permission of wild boars from Forestry Bureau of Fu'an City. At the end of 2017, the company acquired the gun license from local Public Security Bureau. This means that it was until 2017 when the company was fully authorized by local governments to cull wild boars. Moreover, local governments provided subsidy to the company for wild boar hunting. The company had hunted about 1,550 wild boars from November 2017 to the end of 2021.

2.2 Field survey and data collection

The survey data were collected from 15 November to 20 December 2021 by professional interviewers. Using typical sampling with spatial distribution and damage severity as primary selecting criteria, three towns with severe crop raiding by wild boars, Chengyang Town, Xiabaishi Town and Gantang Town, were selected as the study area. A two-stage random sampling technique was used to determine sampling households. Firstly, two sampling villages in each of these three towns were randomly chosen based on a village list, and then about 10% of total households in each village were selected randomly for survey after an inventory of households was enumerated. The

TABLE 1 Number of questionnaires in the sampling villages of Fu'an City, China.

Sampling village	Town	Survey household	Of total %
Zhangyang	Chengyang	30	11.3
Huajiao	Chengyang	28	8.5
Tanglou	Xiabaishi	20	9.1
Hutou	Xiabaishi	20	7.2
Shantouzhuang	Gantang	24	12.5
Guoze	Gantang	30	12.2
Total		152	

specific process of simple random sampling is as follows: 1) obtaining the directory of overall villages or rural households, 2) classifying and coding the villages for each town and rural households for each sampling village, and 3) selection of villages or rural households based on the random number tables. Meanwhile, two village leaders in each sampling village were selected to conduct in-depth interviews. Thus, in total 12 village leaders and 160 households were sampled as study participants.

Participatory rural appraisal (PRA) tools, including in-depth interviews and questionnaires were adopted in our study. First, we conducted about 2-h, face to face semi-structured interviews with village leaders. These in-depth interviews mainly focused on the overall livelihood impacts of wild boars in the village, the evolution of human-wild boar conflicts, primary manifestation of animal destruction, a crop damage, economic loss, governmental measures, farmers' responses and measures, *etc.* Some open questions could be raised during the interviews without subject to given questions. The obtained data of semi-structured interviews would promote the qualitative analysis in the next stage. Second, sampled households were interviewed with a questionnaire consisting of four sections (including 22 questions): perceptions of wild boar damages, livelihood impacts, responses and countermeasures, and demographics of households. The questionnaire survey was delivered face-to-face by investigators through question-and-answer to ensure the accuracy of the survey. The main respondents were the householders, other family members could join in to provide supplementary information. It is a tradition in rural areas of southern China that children (mainly sons) tend to live with their parents even after starting a family and having kids. The elder men are the householders for the majority of rural households, and the elder woman would became the householder if her husband died. Most of the respondents are the elder men with decades of farming experiences. Interview time for each household was about half an hour. Having excluded eight invalid ones due to logic errors, missing answers to key questions, and incomplete questionnaires, etc, totally 152 survey responses were analyzed. The distribution of surveyed households is shown in Table 1.

The households were classified into four categories based on their agricultural income level. Specialized agriculture households (SAH) were defined as the households with annual agricultural income per agricultural labour of more than 20, 000 RMB (1 USD = 6.4515 RMB in 2021, the same below), which was in line with the average annual disposable income per farmer (RMB 19, 851 *per capita*) in Fu'an City in 2020. For those households with lower annual agricultural income (i.e., less than 20,000 RMB per labour), we defined other three categories: pure farm households (PFH) (i.e. with non-farm income proportion less than 10%), mixed farm-business households (MFH) (i.e. with non-farm income proportion between 10% and 90%), and non-farm households (NH) (i.e. with non-farm income proportion more than 90%).

2.3 One-way ANOVA

One-way ANOVA was applied to clarify the different livelihood impacts among four categories of rural households. That is to say, classification of rural households (SAH, PFH, MFH, NH) is the dependent variable. Variables of wildlife induced livelihood impacts, including affected households in crop damages, economic loss per household, economic loss to total agro-income, economic loss to total income, and crop area damaged by wildlife, are the independent variables. The software of SPSS 20.0 has been utilized

TABLE 2 Descriptions of sampled rural households.

Sampling village	Age of interviewee	Number of farm labours per HH	Average age of farm labour	Subsistence agriculture (mu)	Cash crops (mu)	Farm income to total (%)	Total income (thousand RMB)
Zhangyang	53.5	1.9	57.9	0.76	5.47	70.73	82.0
Huajiao	58.4	1.8	58.8	0.28	2	26.93	55.7
Tanglou	49.5	2	57.6	0.15	4.8	43.66	60.7
Hutou	55	1.6	54.4	0.15	10	67.80	88.5
Shantouzhuang	51.8	2	54.4	2.13	1.25	49.78	45.8
Guoze	62.7	1.6	58.3	0.74	4	56.49	63.9
Average	55.6	1.8	57.1	0.72	4.4	59.22	61.3

***Note*:** HH, household; subsistence agriculture means the primary purpose of crop management, including paddy, sweet potato, and vegetables, is self consumption; 1 mu = 1/15 ha; cash crops including grape, sugarcane, tea, bamboo, longgan fruit, *etc.*; 1 USD, 6.4515 RMB, in 2021.
Source: Authors' survey, 2021.

TABLE 3 Results of One-Way ANOVA of livelihood impacts for different rural households.

Livelihood impacts	Mean value	F	Sig
Affected by wild boars in crop damages (%)	97.90	5.090	0.003
Economic loss per household (RMB)	4,368	6.237	0.01
Economic loss to total agro-income (%)	14.33	1.378	0.025
Economic loss to total income (%)	8.95	9.678	0.000
Average crop area damaged by wild boars (mu)	1.47	6.382	0.001

Note: **, * denote the significance at the 0.01, 0.05 level, respectively.

to carry out the One-way ANOVA to judge the household heterogenity of livelihood impacts.

3 Results

3.1 Socio-economic status of respondents

The respondents were mainly middle aged and elderly men. The average age of respondents was 55.6 years old, and there was some difference among villages. The average age of respondents in village Zhangyang, Huajiao, Tanglou, Hutou, Shantouzhuang, Guoze is 53.53, 58.43, 49.50, 55.00, 51.75, and 62.67 years of old, respectively. Results of One-way ANOVA also prove the respondents' age difference between sampling villages ($p < 0.05$). Only 23.7% of respondents were 45 years old or younger, comparing to 52.6% were 60 years old or above (Table 2). An average age of farm labours was 57.1 years old, with little difference among six surveyed villages (Table 2). The results indicate that generally elderly labours operate agriculture, which is one of important traits of Chinese agriculture, similar to that in Japan. There was a gender disparity in survey respondents. The majority of respondents (67.1%) were male. A low participation percentage of women can be attributed to various reasons, such as difficulty in communication due to illiteracy and lack of language skill of Chinese mandarin, being introverted and shy to strangers, *etc.* A household had an average of 1.8 agricultural labours, mainly the old couples. Constrained by low productivity of subsistence agriculture, most households were principally engaged in non-farm employment and commercial agriculture, such as growing sugarcane, tea, fruits, and bamboos. An average annual household income was 61,300 RMB, and the farm income to total is about 60% (Table 2).

3.2 Livelihood impacts of wild boar for different households

Before proceeding to One-way ANOVA of livelihood impacts, the normality test and test for equality of variances are necessary to be operated. Skewness and Kurtosis of all independent variables were calculated to judge if they were normal distribution. Results showed that all independent variables were all normally distributed. Levene's test for equality of variances was conducted to clarify if it was suitable for One-way ANOVA. The test results of variances showed that $p > 0.05$, which indicated that the variances were not significantly different at the level of $\alpha = 0.05$. That is to say, it is suitable to apply the One-way ANOVA. Results of One-way ANOVA further demonstrated that the heterogeneity of rural households exerted significant influence on

FIGURE 2
Crops damaged by wild boars: **(A)** Paddy **(B)** Sweet potato **(C)** Peach orchard **(D)** Litchi orchard.

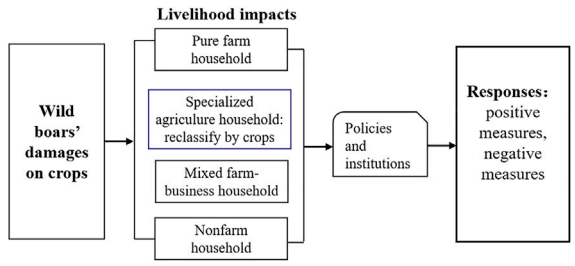

FIGURE 3
Livelihood impacts and farmers' responses to human-wild boar conflicts.

livelihood impacts induced by wild boars (Table 3). As shown in Table 3, all *P* of the five models of One-way ANOVA is less than 0.05. The results mean that the difference of the five variables between subgroups is significantly. The mean value of affected households in crop damages, economic loss per household, economic loss to total agro-income, economic loss to total income, and crop area damaged by wildlife is 97.90%, 4,368 RMB, 14.33%, 8.95%, and 1.47 mu household^{-1}, respectively (Table 3).

Crop damage is prevalent in human-wild boar conflicts in the study area. Direct crop raiding and subsequently production decline causes significant economic losses (Figure 2). An average annual economic loss for all surveyed households was 4,368 RMB per household. Severe economic losses could contribute to food insecurity and poverty, especially for those whose livelihoods that depend heavily on crops. However, livelihood impacts of wild boars' destruction were different among household categories (Figure 3; Table 4). As shown in Table 4, a majority of surveyed households reported that their crops had been damaged by wild boars over the past year. Except for NF (66.67%), more than 93.75% of SAH, PFH and MFH and 66.67% of NH households claimed that their livelihoods were affected by wild boars during the past year.

The heterogeneity of livelihood impacts caused by wild boars was prominent. The annual economic losses induced by wild boars were substantial for all livelihoods. In terms of the absolute value, SAHs suffered the greatest economic loss. The annual economic loss per household was 10,480 RMB. However, measured by the proportion of economic losses in the total annual household income, the loss of PFHs was the highest, which was 21.63%. For NHs, in either absolute or relative terms, the livelihood impact from wild boars was the lowest and negligible, this could be explained that their livelihoods hardly relied on agriculture. For MFHs, the livelihood impacts were intermediate (Table 3).

3.3 Responses of rural communities and governmental countermeasures

Many factors, including crops, farming scale, traits of plots (such as fragmentation, location, and slope of farmland), cost and effectiveness, jointly determine the implement of mitigation measures. Some non-lethal adaptation strategies are widely adopted by rural households to relieve the damages induced by wild boars. Many lethal and effective methods, including unauthorized hunting, poisoning, snares, electrical fencing, are not permitted in Fu'an City. There are five commonly utilized strategies for crop protection (Figure 4): 1) Fencing, namely building fences as physical barriers to prevent wildlife entering crop fields. The approach could be very effective when adopting solid fences (such as electrical fences and wire fences) and well-constructed around crops. Owing to forbidden use of electrical fences in China, fences are mainly made of wire mesh and plastic net. The recommended height of fences is 0.8–1.2 m, and all rounds of crops need to be closed. The fences made of wire mesh are more effective, but more costly. 2) Repulsion by light and sound, or called repellents, namely using artificially abrupt light and sound as visual and acoustic scares, such as scarecrow, firecrackers, lamp, loudspeakers, gongs and drums, and wind blowing iron boxes as deterrents to drive away wild boars. 3) Guarding, namely human guarding the crops at daytime and night to prevent wild boars' raiding. Some male farmers build tents in the centre of farms, and stay in these tents from dusk to the next morning. They need to patrol their farms every one or 2 hours to keep wild boars away. The night patrol continues two to 4 months a year in study area, especially in periods of approaching crop harvest and during harvest seasons. For example, the patrol period persists from head sprouting to harvest for paddy, from bearing fruits to harvest for fruits. Harvest seasons are diverse considering the variety of crops. Thus, the patrol periods are different for different crops and varieties. The longest

TABLE 4 Crop damages and economic losses caused by wild boars for different rural households.

HH type	HH number	Affected in crop damages (%)	Economic loss per household (RMB)	Economic loss to total agro-income (%)	Economic loss to total (%)	Crop area damaged (mu)	Primary damaged crops
SAH	50	96	10,480 (14,649)	14.04 (19.73)	10.27 (14.26)	2.43 (2.36)	Bamboo shoots, grape, longgan
PFH	32	93.75	2,162 (1860)	21.70 (17.96)	21.63 (17.94)	1.59 (0.90)	Paddy, sweet potato, bamboo shoots, fruits
MFH	40	100	1,630 (1748)	11.82 (16.43)	3.64 (4.69)	0.97 (0.866)	Sugarcane, grape, paddy
NH	30	66.67	183 (125)	9.95 (9.40)	0.29 (0.23)	0.42 (0.43)	Paddy, vegetables, sweet potato

Note: SAH, means specialized agriculture households; PFH, means pure farm households; MFH, means mixed farm-business households; NH, means non-farm households; HH, means household. 1 mu = 1/15 ha; 1 USD, 6.4515 RMB, in 2021; standard deviation is in parentheses.
Source: Authors' survey, 2021.

FIGURE 4
Protective measures adopted by rural households: **(A)** Human guarding **(B)** Repulsion by a loudspeaker **(C, D)** Wire mesh fence **(E)** Plastic net fence **(F)** Repulsion by a red banner.

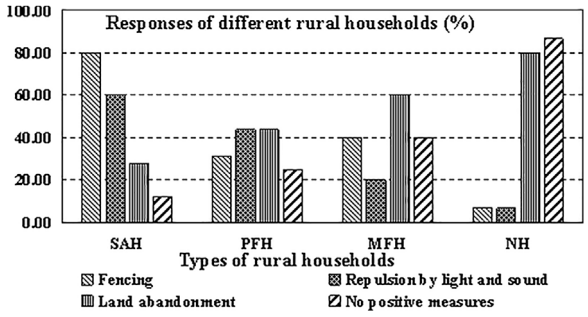

FIGURE 5
Mitigation measures practiced by different households in the study area. Note: SAH means specialized agriculture households, PFH means pure farm households, MFH means mixed farm-business households, NH means non-farm households.

patrol period is conducted by the owners of the longan (*dimocarpus longan lour.*) orchards in Hutou village starting from July to October. This strategy works, but human costs are very high. The approach was traditionally used to protect paddy crop when rural households were poor two decades ago. Nowadays, this approach is mainly adopted by some owners of large scale orchards because of high opportunity costs. 4) Land abandonment or transferring to non-susceptible crops, such as tea. Many cropland especially those closed to hills and mountains were partly or totally abandoned. The former three approaches are classified as positive measures because of their positive attitudes towards the conflicts, while the last one as negative measure owing to the negative attitudes with difficulties.

Results showed that different households preferred to distinct mitigation measures. SAH and PFH tended to adopt positive measures. The selection of fencing for SAH and PFH was 80% (i.e., 40 households) and 31.25% (i.e. 10 households), respectively. The utilization of repulsion method for SAH and PFH was 60% and 44%, respectively (Figure 5). A higher percentage of MFH and NH selected negative measures. There were 60% and 80% of rural households for MFH and NH, who chose land abandonment as their responses to wildlife conflicts respectively. And 87% of NH and 40% of MFH never adopted positive measures to respond wild boars' harassment (Figure 5). In addition, 6% of SAH adopted guarding method to protect their crops. In essence, cost-benefit ratio of management measures and the extent of livelihood dependency on agriculture are vital decisive factors, which determine the selection of measures for different rural households. High agricultural benefits of SAH promote farmers to use costly

FIGURE 6
Government dominated hunting: **(A)** Authorized only one professional corporation **(B)**Gun maintenance **(C)** Hunting dogs (Chinese rural dog, the colorful fur was inherited from the ancient wolf) **(D)** Returned from hunting.

measures, such as fencing, repulsion and guarding. Minimal economic losses (183RMB/household) and low livelihood dependency on agriculture (2.68% of total income) hindered NH to use any costly measures. High livelihood dependency (99.58%) and low agricultural income (17.10 thousand RMB/household) of PFH counteract each other and produce mixture measures (Figure 5).

Hunting is one of the primary governmental countermeasures to control wild boars. A company named Shenlong Biology Company Limited has been authorized and subsidized by local governments for hunting wild boars to mitigate human-wildlife conflicts (Figure 6). City governments subsided 300–1200 RMB per hunted wild boar to hunters. Carcasses of hunted wild boars have been treated by means of harmless disposal since the implement of new legislation banning on wildlife consumption in 2020. Local governments paid related treatment costs. About 1,550 wild boars were hunted in Fu'an City from November 2017 to the end of 2021.

4 Discussion

4.1 Decisive factors for magnitude of livelihood impacts

Research on wildlife livelihood impacts is critically essential to understanding the mechanisms underlying it and to frame harmonized development-conservation schemes. Results showed that agricultural scale and dependency on susceptible crops jointly determined the scale of economic losses and the severity of livelihood impacts, respectively. In detail, SAH had the highest economic losses (10,480 RMB per household) caused by wild boars, and PFH had the highest loss rates (21.63%) of total household income from wildlife destruction. The heterogeneity of wildlife livelihood impacts could attribute to remarkable differences in households and regions (Zhang et al., 2020; Mamo et al., 2021). In other words, at the household scale, the magnitude of wildlife livelihood impacts depends on farming scale of susceptible crops, and livelihood dependency on these crops. At the village scale, the severity of livelihood impacts lies on crop types, scale of agricultural output, and protection measures. Villages planting a great deal of crops easily raided by wild animals (such as cassava, paddy, maize, sweet potato, and fruits), would get more severe livelihood destruction than those mainly planting unpalatable crops, such as tea, sisal, chilli, etc (Parker and Osborn, 2006; Bukie et al., 2018; Raphela and Pillay, 2021). Moreover, villages with higher agricultural output value may well suffer great losses than those with less output. At the regional scale, the spatial heterogeneity of livelihood impacts largely depends on the distribution of wild boars, climate and terrain, population density, food availability, and crop varieties (Herrero and De Luco, 2003; Schley and Roper, 2003; Zhang et al., 2020).

4.2 Threats on China's poverty alleviation, food security and rural revitalization

Our findings prove that there are significant economic losses by wildlife negative effect in the study area. The annually direct economic losses in crops were estimated to be 434.90 million RMB (67.41 million US$) in Fu'an City, by extrapolation. The economic losses accounted for 8.14% of output value of primary industry. Great economic losses would pose great threats to rural revitalization. The prosperity of specialized agriculture and leisure agriculture is the kernel and priority of rural revitalization in China (Liu, 2019; Long et al., 2019; Zhou et al.,

2020). However, wild boars' substantial destruction could to some extent jeopardize the implement of rural revitalization in China. Moreover, wild boars' crop raiding has forced many farmers to abandon lots of farmland proximity to wildlife habitats (such as mountains, national parks, nature reserves) and to transfer superior farmland to grow non-susceptible crops (especially non-grain crops) (Hua et al., 2016; Acha et al., 2018). The prevalence of land abandonment and non-grain growing is detrimental to national food security (Salerno et al., 2016; Xu et al., 2019). Tremendous crop damages have also aggravated rural poverty, especially for the poorest rural households.

4.3 Countermeasures adopted by rural households

Countermeasures adopted by rural households are listed by effectiveness in descending order: guarding and patrolling, fencing, and repulsion. Guarding and patrolling is the most effective and non-lethal measure that rural households could use, however, it is also the most labour intensive and costly technique if opportunity costs of labours considered. It used to be widely employed by farmers to protect paddy, but nowadays is only utilized by some owners of large scale orchards to protect high value crops due to increasing labour cost. Guarding was less reported in most developed countries, but was still popular and adopted by many farmers in some poor developing countries, such as Nepal and India (Sekhar, 1998; Manral et al., 2016).

Respondents reported that only solid and firmly fixed wire mesh fences could effectively protect the crops, and other low-quality fences (such as plastic net fences) had low efficacy. Though high costs (including initial set-up cost and maintenance cost) of wire mesh fences limited its popular adoption, yet the method could be cost-effective when used to protect high value crops (Saito et al., 2011; Bengsen et al., 2014; Hua et al., 2016). Electrical fencing has been recommended as the most successful method of damage prevention in countries of Europe, America and Japan, where it is permitted (Massei et al., 2011). But electrical fences were illegal in China and violators could receive criminal punishment because it was thought to pose a high risk of wounding human. Other lethal management tools, including trapping and snares, are also forbidden to use in China owing to the same reason. Fencing was criticized that it only protected enclosed areas to a certain extent, and shifted the wildlife damages to less protected areas (Geisser and Reyer, 2004).

Several cost-saving ways of repulsion by light and sound have been widely used, such as scarecrow, automatic recording by loudspeakers, and wind driven drums in study area. However, the effectiveness has been the lowest because wild boars are very smart to adapt to these scaring devices quickly. In order to reduce crop damages, some owners of large-scale orchards had to adopt other costly and effective repulsion techniques, such as setting off firecrackers, campfires, beating gongs and drums, and shouting to repel wildlife during the night. These scaring measures are actually a combination of on-site guarding and repellents, and they are also widely used in South Asia and Africa (Manral et al., 2016; Naik et al., 2020).

4.4 Government countermeasures

Our field survey showed that hunting was the most effective measure to control wild boars, but the approach could only be authorized for one hunting team in the whole county. Hunting had been authorized and subsidized with 300–1200 RMB per hunted wild boar by local governments in study area since 2017. Previous studies showed that hunting could significantly reduce population density and damage frequency of wild boars (Geisser and Reyer, 2004). The establishment of incentive mechanism of hunting is the key factor for successful abatement of wild boars. However, this mechanism in Fu'an City has been destroyed since 2020. The incentive mechanism of hunting could be set up through three pathways: bounty systems, market of animal carcasses, and mixture of both methods. Bounty systems could effectively stimulate hunters to catch more wild pigs, if properly utilized and avoided the reported defects, such as cheating in bounty (Bengsen et al., 2014; Bevins et al., 2014). Moreover, commercial use of hunted boars is a more plausible way to motivate the hunters' initiative through market force. Past studies indicated only when wild boar meat derived from hunting provided a significant part of people's diet, hunting may substantially decrease the size of wild boars (Geisser and Reyer 2004). Hunting is a viable option for reducing wild boar populations only when the hunters get enough profits from either bounty mechanisms or commercial use of hunted boars.

However, China's National People's Congress enacted new legislation banning the consumption of terrestrial wildlife in an effort to protect public health in February 2020. The restriction has been adopted in response to the sudden outbreak of COVID-19, which has been considered to be linked to wildlife consumption (Wang H. et al., 2020). However, the one-size-fits-all legislation has directly caused sharp decrease of wildlife hunting. It is the unanticipated side product of the new legislation. Before the banning, the authorized hunters could consider the hunted wildlife as compensation to partly offset hunting costs. But the strict legislation has broken original cost-benefit balance and produced some newly expense (such as harmless disposal of animal carcasses). Local government provided subsides of 650 thousand RMB (about 100 thousand USD) to subsidize the company for hunting wild boars and harmless disposal of animal carcasses in 2021. But it was far not enough to cover the actual costs. And the encouragement is lacking. Increasing human-wildlife conflicts are the inevitable outcomes. The programs of only offering financial inducements for hunting as a means of controlling wild boars have been demonstrated as unsustainable in many countries (Bengsen et al., 2014). Governments at multiple levels (national, provincial or county) and land owners need to collaborate and take collective actions to control wild boars, owing to the mobile and prolific nature of wild boars (ShalekBriski et al., 2021).

Some experts recommend that local governments should boost the hunting of wild boars and promptly establish wildlife compensation/insurance institutions to mitigate human-wildlife conflicts (Chen et al., 2013; Hua et al., 2016). However, substantial financing gaps for most poor mountainous counties are the biggest challenge (Cai et al., 2008). The most viable measure may be eradication wild boars from the directory of protecting wildlife, and then loose hunting and consumption of wild boars, through top legislation revision. Differentiated wildlife management measures should be preferentially adopted based on the intensity of human-wild boar conflicts. Wild boars have been defined as pest animals in most countries of Europe, America and Australia, where there exists high destruction of wild boars (Bengsen et al., 2014). Along with increasingly severe human-wild boars conflicts in many areas of China, it is necessary to reconsider whether the species are strictly

protected as before. The prescription of universally effective, acceptable and unchangeable management approaches should be opposed. In addition, regional coordination of wildlife management should be highlighted to inhibit animal recovery owing to animals immigrating from adjacent areas (Cowled et al., 2006).

5 Conclusion and policy recommendations

Human-wild boar conflicts are increasingly occurring in many mountainous regions of China, threatening to agricultural development. Assessing wildlife livelihood impacts and illustrating community measures are fundamental to search for suitable solutions to human-wildlife conflicts. Our study demonstrated that there were tremendous livelihood impacts caused by wild boars, including severe crop damage, aggravating rural poverty, and imperiling food security. The livelihood impacts were different for different households, i.e. a household heterogeneity. The livelihood impacts of wildlife were determined by the farming scale of crops and livelihood dependency on susceptible crops. Specifically, the amount of economic losses was more for those households with larger farming scale of crops; the livelihood damage was more intensified for those with higher dependency on crops.

Our study reveals that professional hunting was the most effective control measure of wild boars, and the approach could quickly reduce the population of wild boars. Fencing and repulsion were two most prevalent preventive measures adopted by rural households. Heterogeneity of livelihood impacts led to heterogeneous countermeasures of rural households. Households with tremendous economic losses from wildlife preferred to adopt effective and costly prevention measures, such as fencing and guarding. Conversely, households with less livelihood impacts might preferentially choose negative responses, such as land abandonment, and growing non-susceptible crops.

Our study has some policy implications. First, the management of wild boars should highlight the heterogeneity, including farmers' heterogeneity, spatial heterogeneity and temporal heterogeneity. Governmental policies need to be more precisely to consider the claims of primary stakeholders, site-specific human-wild boar conflicts, and the dynamics of the conflicts. One size fits all policies should be discarded. Second, the establishment of incentive mechanism of professional hunting through bounty systems and market of animal carcasses should be placed into the priority of wildlife management. Supplemental institution innovation at multiple dimensions, such as collaboration among governments at all levels to raise funds for wildlife management, legislation adjustment in wildlife consumption, processing and export of wildlife products, is indispensable to building the mechanism. Third, widely collecting funds to compensate for rural households through various ways, such as tax, donation, and voluntary payment. This measure may be the least feasible one, given the substantial economic losses of wildlife destruction and current heavy tax burden in China.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Ethics statement

Written informed consent was obtained from the individual (s) for the publication of any identifiable images or data included in this article.

Author contributions

CW: investigation, writing original draft, writing–review and editing. BZ: project administration, conceptualization, writing–review and editing. XS: writing–review and editing. DL: writing–review and editing. TL: writing–review, formal analysis, and software validation. All authors contributed to the article and approved the final version for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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