

# Can social capital improve the consistency between farmers' willingness and behavior to reduce agricultural non-point source pollution?

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## Abstract

Farmers' participation in agricultural non-point source pollution (ANPSP) control is essential for rural eco-environment and food security. Based on 1299 questionnaires from 91 counties in 16 prefecture-level cities / autonomous prefectures in Yunnan Province, China, this paper empirically investigates and explores the effect of social capital on farmers' willingness, behavior, and consistency to reduce ANPSP. This study's findings indicate that most of respondents are willing to take or have taken action to reduce ANPSP. However, farmers whose willingness and behavior to reduce ANPSP are completely consistent account for 59.28% of the sample, indicating a high inconsistency between willingness and behavior. Social capital exerts a significantly positive influence on farmers' willingness, behavior, and consistency. Additionally, ecological capital cognition is introduced as an intermediary variable and shows an important role in the impact of social capital on farmers' behavior and consistency. Furthermore, heterogeneous impacts of social capital in different regions and ethnic groups are explored and show that social capital has more significant effects on consistency among Han farmers or farmers living in autonomous areas and large cities than that among other groups. This paper can provide references for the government to transform farmers' willingness into actual behavior and narrow the gap in the control of ANPSP.

**Keywords:** Agricultural non-point source pollution; Social capital; Willingness and behavior; Consistency; Farmers



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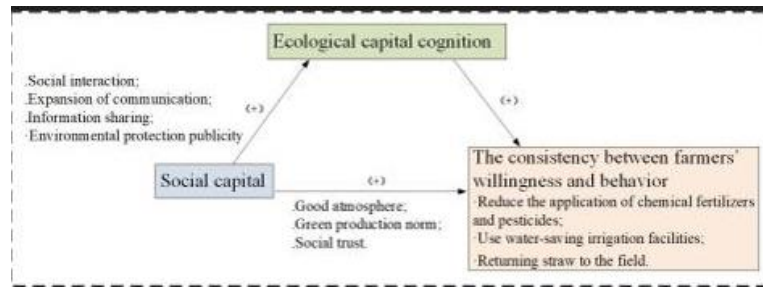
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## Graphical abstract



### 1. Introduction

Agricultural non-point source pollution (ANPSP) refers to ecological environment pollution resulting from some agricultural production activities, such as field irrigation, excessive application of pesticides and fertilizers, etc., (Zhang *et al.*, 2016), and has the characteristics of random occurrence, wide range of pollution sources, great harm, and wide range of influence (Yang *et al.*, 2017). Under the joint drive of rainfall and topography, pollutants accumulate excessively in the soil or enter underground runoff, which will cause serious harm to the ecological environment, food security, human health, and sustainable development (Li & Lei, 2025). The management of ANPSP plays a pivotal role in ecological environment protection and holds substantial significance for the construction of national food security, agricultural green development, and rural ecological civilization (Wang *et al.*, 2022). The deterioration of ANPSP is directly and inevitably related to farmers' unreasonable agricultural production behavior (Wang *et al.*, 2019), and promoting green production behavior among farmers is essential for enhancing the rural ecological environment (Price & Leviston, 2014). Therefore, the Chinese government has implemented numerous policies designed to encourage rural residents to change their production methods in agricultural activities and to reduce ANPSP. In March 2021, the "Implementation Plan for the Management, Supervision, and Guidance of Agricultural Surface Source Pollution (Trial Version)"<sup>1</sup> was released and emphasized the necessity to further promote the treatment of ANSP. However, the Civic Eco-environmental Behavior Survey (2020)<sup>2</sup> highlighted a phenomenon characterized by "high willingness and low behavior" in environmental protection. This indicates an inconsistency between the public's intentions and their actual behaviors in environmental protection. Willingness serves as the foundation of behavior and plays a crucial role in determining it. However, in practice, farmers often express a strong willingness to reduce ANPSP but may not actually engage in such behaviors (Ren *et al.*, 2022). Therefore, the government should improve the

consistency between rural residents' willingness and behavior to reduce ANPSP and clarify the influencing factors to take targeted measures to transform their willingness into action.

The study examines the effects of social capital in improving rural residents' consistency to reduce ANPSP and makes the following three contributions to the existing literature. Firstly, most scholars only pay attention to one certain type of ANPSP control measures, e.g., reducing the application of fertilizer (Zhang *et al.*, 2017), and improving the method of paddy field drainage (Jin *et al.*, 2022), but farmers can adopt a variety of green agricultural production methods to alleviate ANPSP. This paper concerns about the three types of reducing ANPSP: reducing the application of chemical fertilizers and pesticides, implementing water-efficient irrigation systems, and returning straw to the field, and investigates farmers' behavior and willingness of the above three measures, which can supplement the research on the management of ANPSP.

Secondly, most studies have investigated the factors influencing farmers' willingness or behavior to reduce ANPSP (Wang *et al.*, 2019; Wang *et al.*, 2018; Zhang *et al.*, 2019), but a paucity of research addressed the inconsistency between farmers' willingness and behavior, as well as strategies to enhance consistency. The existing research mainly explores the inconsistency between farmers' green production behavior and willingness from various aspects including socio-economic characteristics, planned behavior theory, farmers' perception and skills (Li *et al.*, 2021; Qiao *et al.*, 2022). However, to our knowledge, there has been no research to explore how to improve farmers' consistency to reduce ANPSP through social capital. Farmers view the countryside as an interconnected society and strongly identify with the agricultural lifestyle and human network in it (Atwell *et al.*, 2009), that is, social capital can be considered a crucial factor in farmers' willingness and behavior to reduce ANPSP (Hua, 2016). Thus, this study investigates the effects of social capital in improving farmers' willingness, behavior, and the consistency to reduce ANPSP, which is helpful to provide valuable insights for the government to reduce ANPSP.

Finally, different ethnic groups possess distinct national cultures (Xu, Meng, *et al.*, 2024), and the traditional taboos, beliefs, customs, and habits of ethnic minorities will promote environmental protection (Huang *et al.*, 2020; Mon *et al.*, 2020). However, limited research has noticed ethnic differences in farmers' ANPSP. Yunnan

<sup>1</sup> The Ministry of Ecology and Environment, Ministry of Agriculture and Rural Affairs. Implementation Plan for the Management, Supervision, and Guidance of Agricultural Surface Source Pollution (Trial Version). [https://www.mee.gov.cn/xxgk2018/xxgk/xxgk05/202103/t20210325\\_826163.html](https://www.mee.gov.cn/xxgk2018/xxgk/xxgk05/202103/t20210325_826163.html)

<sup>2</sup> Ministry of ecology and environment, People's Republic of China (2020). Civic Eco-environmental Behavior Survey. [https://www.mee.gov.cn/ywgz/xcyj/gzcy\\_27007/202007/t20200714\\_789277.shtml](https://www.mee.gov.cn/ywgz/xcyj/gzcy_27007/202007/t20200714_789277.shtml)

Province is an area inhabited by ethnic minorities, with the highest population of ethnic minorities in China, which makes it an ideal research area for this study. In addition, the size of cities in Yunnan Province is different; the economy of large cities is developed, the population is concentrated, but the economy of small cities is backward, and the population outflow is serious. Farmers living in different regions may have different willingness and behaviors to reduce ANPSP. Therefore, this paper explores the heterogeneity among different ethnic groups and groups living in different regions, which can provide references for implementing differentiated strategies to encourage farmers' involvement in the management of ANPSP according to local conditions.

The remainder of this paper is structured as follows: Section 2 gives research hypotheses. Section 3 provides a detailed overview of the data and methods. In Section 4, we summarize the results of this paper and discuss these results in Section 5. Finally, the research conclusions and policy implications are presented in Section 6.

## 2. Research hypotheses

### 2.1. Social capital theory

"Social capital" was initially introduced by Hanifan (1916), but it was widely concerned by the academic community in the 1980s. Bourdieu conducts a preliminary analysis of social capital and links it to the specific interests at the individual level, pointing out that a high level of social capital has brought great benefits to individuals (Jones, Sophoulis, *et al.*, 2009). Subsequently, the works of Coleman (1988) and Putnam (1992) make the concept of social capital widely known. Unlike other forms of capital, it exists neither in individuals, nor in material production tools, but in the structure of relations between individuals and individuals (Villalonga-Olives & Kawachi, 2015). Social capital is believed to have characteristics of coordination and organization, which can force public to bear the responsibility for environmental protection, promote their attitude and enthusiasm, and improve their efficiency in addressing environmental issues (Jones, Botetzagias, & Malesios, 2009; Macias & Williams, 2016). For example, Ostrom (2009) points out that members share moral and ethical standards, abide by reciprocal norms, and have sufficient trust in each other, which will contribute to the sustainability of social-ecological systems. Yildirim *et al.* (2021) show that a high level of social capital may positively influence individuals' natural resource management behavior, and environmental protection policies will be more effective if the level of social capital is improved. Farmers are also found to be easily influenced by the behavior of farmers around them when making decisions (Qiao *et al.*, 2022). While studying rural garbage sorting, Zhou *et al.* (2022) have found that social capital positively influences the transition from intention to action. Social capital can enhance farmers' access to information (Conley & Udry, 2010), and agricultural exchanges and learning can help improve farmers' environmental awareness and their understanding of green production concept (Aida, 2018), thus promoting

the transformation of intention into behavior. Based on this, the following research hypothesis is proposed:

H1: Social capital positively influences the willingness, behavior, and the consistency between willingness and behavior of rural residents to reduce ANPSP.

### 2.2. The role of ecological capital cognition

Social capital operates as an informal system, making it infeasible to directly change farmers' behavior like mandatory government directives (Xu *et al.*, 2024). Therefore, we seek to understand the indirect effects of social capital on farmers' willingness and behavior of reducing ANPSP. Social capital is helpful to foster closer ties among community members in environmental protection, and prompt residents to share environmental knowledge and information (Karahan & Roehrig, 2015), so as to have a clear understanding of natural resources and ecological environment. That is, the rural population can improve their understanding of agricultural ecological protection while formulating social rules, norms, and systems, which can promote ecological capital cognition (Pretty & Smith, 2004). Additionally, cognition serves as the foundation for intention and behavior, and ecological capital cognition has been believed as a direct motivation for farmers' intention and behavior to green production (Ren *et al.*, 2022). Farmers are usually limited by the level of ecological capital cognition when they are faced with willingness and behavior choices in environmental protection (Ren *et al.*, 2022). The improvement of farmers' ecological capital cognition can make them recognize the economic, social, and ecological benefits of green production, thus, make them actively learn and obtain technology and information about green production and protect the agricultural environment (Ren *et al.*, 2022; Wang *et al.*, 2021; Xu *et al.*, 2023). Furthermore, the research has shown that the difference of residents' ecological capital cognition significantly contributes to the deviation of their behaviors and intentions in agricultural production activities, and residents with high environmental awareness are more conscious and capable of putting their intention into practice (Ren *et al.*, 2022). Therefore, improving farmers' ecological capital cognition is critical to improve farmers' consistency to reduce ANPSP. Based on this, the following research hypothesis is proposed:

H2: Ecological capital cognition mediates the influence of social capital on rural residents' willingness, behavior, and the consistency between willingness and behavior to reduce ANPSP.

## 3. Data and method

### 3.1. Study area

Yunnan province is located in the southwestern border of China and borders Vietnam, Laos, and Burma, with a geographical location 97°31'–106°11' east longitude and 21°8'–29°15' north latitude. Yunnan province has 8 prefecture-level cities and 8 autonomous prefectures, and is known for the high ethnic diversity, with 25 of 55 ethnic minorities of China, and ethnic minorities account for

33.1% of province's total population<sup>3</sup>. It covers a total area of 394,100 square kilometers, with 52,867 square kilometers of cultivated land, accounting for 13.56%<sup>4</sup>. The total population of Yunnan province is about 470,000, of which rural population accounts for 49.95%<sup>3</sup>. In 2022, the grain output of Yunnan province was 19.58 million tons, ranking 14th among 31 provinces in China, and the agricultural output value was ¥401.218 billion, accounting for 13.86 % of the province's total GDP<sup>5</sup>. Yunnan province is rich in natural resources, including mineral deposits, biodiversity, water, etc., and farming, tobacco, mining, hydropower, and tourism are its pillar industries (Qian *et al.*, 2018). However, the implementation of ecological protection measures is inadequate, leading frequent environmental damage and vulnerable ecological environment (Wang & Ding, 2021). Therefore, in 2022, Yunnan province issued the "Implementation Plan of the 14th Five-Year Plan for Agricultural and Rural Pollution Control" to promote the prevention and control of ANPSP. Based on this, the rural areas of Yunnan province are taken as the research area to investigate the influencing factors of farmers' willingness, behavior, and the consistency to participate in ANPSP control. The results will provide data support and policy reference for the government to effectively implement measures and policies for the management of ANPSP, improve farmers' participation willingness and behavior, and improve rural ecological environment.

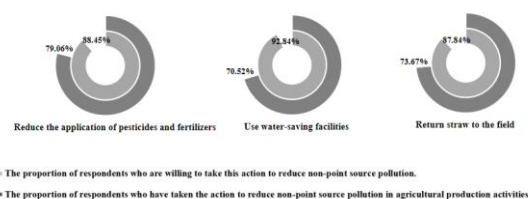
### 3.2. Survey design

The questionnaire is used to collect data and is structured into five sections. ① Introduction. This section introduces the background and purpose of the survey to ensure that respondents have a basic understanding of the policy background and research content. ② Basic assessment of rural environment status. This section explores respondents' satisfaction with their living environment as well as their evaluation of the necessity of improving the status quo. The two measurement questions are examined utilizing 5-point Likert scales ranged from "1 = very dissatisfied" to "5 = very satisfied", and "1 = very unnecessary" to "5 = very necessary". ③ Willingness and behavior of reducing ANPSP. Improper agricultural practices, including excessive use of fertilizers and pesticides, flood irrigation are the major factors that lead to agricultural pollution in China (Opoku-Kwanowaa *et al.*, 2020). Among them, excessive fertilizers and pesticides application, which is a problem with widely concerned, can cause soil hardening, soil acidification, and water eutrophication, and leave toxic residues in agricultural products, soil and water, causing environmental pollution and reducing the quality of agricultural products (Liu *et al.*, 2021; Wang *et al.*, 2021). Water-saving irrigation can

reduce pollutant emissions, alleviate ANPSP, and increase production (Zhuang *et al.*, 2019). Burning or discarding is a traditional way of straw utilization in China (Guo, 2021), but it will cause serious air and water pollution. Straw returning can effectively reduce pollution and form a healthier soil micro-ecological environment (Guan *et al.*, 2023; Su *et al.*, 2020). Therefore, the measures to reduce ANPSP are divided into three items: reducing the application of pesticides and fertilizers, using water-saving facilities, and returning straw to the field. Farmer's willingness and behavior of the three items are acquired, with "1 = yes" and "0 = no", as shown in **Table 1**. ④ Social capital and ecological capital cognition variables. Six measurement questions are designed and investigated using 5-point Likert scales ranged from "1 = strongly disagree" to "5 = strongly agree", which are shown in **Table 1**. ⑤ Socio-economic characteristics. Nation, gender, age, job, education level, and annual household agricultural income, etc. are acquired.

### 3.3. Sample Description

The initial design of the questionnaire was completed in December 2022, and numbers of pre-surveys were conducted in Yunnan province from January to May 2023. The final version was formed after several modifications according to the process of "pre-survey- modification-pre-survey- modification". 127 students from Yunnan Agricultural University were employed as investigators, and a formal sampling survey was conducted from May to August 2023 with farmers of 91 counties in Yunnan Province as the survey object. Additionally, the cognitive level of rural residents interviewed is limited, and their understanding of the questionnaire may be biased, which in turn affects the validity and authenticity of the questionnaire data. Therefore, we use the form of face-to-face question-and-answer to investigate, and the answers are filled in the questionnaire by the investigators. Finally, 1299 valid questionnaires are obtained.



**Figure 1.** Respondents' willingness and behavior to reduce ANPSP.

### 3.4. Estimation strategy

As previously discussed, social capital may exert both direct and indirect effects on farmers' willingness and behavior. A three-step mediating effect method is used to investigate the influence mechanism of social capital on farmers' willingness, behavior, and the consistency of reducing ANPSP. First, the basic model is constructed as follows:

$$Y_i = \beta_0 + \beta_1 CS_i + \beta_2 X_i + \delta_j + \varepsilon_i \quad (1)$$

Where  $Y_i$  refers to the willingness, behavior, and the consistency of respondent  $i$  to reduce ANPSP. Willingness

<sup>3</sup> Yunnan Bureau of Statistics, the seventh national census bulletin of Yunnan (2020). [http://stats.yn.gov.cn/tjsj/tjgb/202211/t20221102\\_1081454.html](http://stats.yn.gov.cn/tjsj/tjgb/202211/t20221102_1081454.html)

<sup>4</sup> National Bureau of Statistics, China Statistical Yearbook (2023). <https://www.stats.gov.cn/sj/ndsjsj/>

<sup>5</sup> Agricultural and Rural Department of Yunnan Province. Agricultural statistical yearbook of Yunnan Province (2023). <https://nync.yn.gov.cn/>

is coded as 1 only if the respondent answers "yes" to all three willingness questions; behavior is coded as 1 only if the respondent answers "yes" to all three behavior questions; and consistency is coded as 1 only if the respondent answers "yes" to all three willingness questions and simultaneously answers "yes" to all three corresponding behavior questions, and the remaining assignments are 0.  $CS_i$  is the social capital variable of respondent  $i$ .  $X_i$  is the control variable matrix, including gender, age, education, and per capita household agricultural income. The per capita household agricultural income variable is defined as the logarithm of the ratio of household agricultural income to the number of family members.  $\delta_j$  is the fixed effects of three ANPSP types.  $\epsilon_i$  is

a random error.  $\theta_0$  is a constant;  $\theta_1$  is the regression coefficient of social capital;  $\theta_2$  is regression coefficients matrix of control variables. Subsequently, the model of social capital and mediating variables is constructed:

$$M_i = \alpha_0 + \alpha_1 CS_i + \alpha_2 X_i + \mu_i \quad (2)$$

Where  $M_i$  stands for the mediating variable, is the ecological capital cognition.  $\mu_i$  is a random error.

Finally, social capital and mediating variable are introduced simultaneously. The final regression model is as follows:

$$Y_i = \gamma_0 + \gamma_1 CS_i + \gamma_2 M_i + \gamma_3 X_i + \delta_j + \eta_i \quad (3)$$

**Table 1.** Descriptive statistics of variables.

Latent variables	Measurement questions	Mean	S.D.
Satisfaction of living environment	Are you satisfied with your current living environment?	3.40	0.98
Necessity of improving living environment	Do you believe it is essential to further improve the rural environment of your current residence?	3.40	0.90
Willingness	Are you willing to reduce the use of pesticides and fertilizers?	0.88	0.32
	Are you willing to use water-saving equipment?	0.93	0.26
	Are you willing to return straw to the field?	0.88	0.33
Behavior	Have you reduced the use of pesticides and fertilizers in agricultural production?	0.79	0.41
	Have you used water-saving facilities in agricultural production?	0.71	0.46
	Have you returned straw to the field in agricultural production?	0.74	0.44
Social capital	SC1: My social circle can help me a lot.	3.71	0.95
	SC2: If I do not participate in village collective activities, I will be excluded or punished.	3.23	1.17
	SC3: Compared with other people in the village, I have a wide range of interpersonal relationships in society.	3.46	1.04
Ecological capital cognition	ECC1: Green hills are golden hills.	4.42	0.89
	ECC2: The natural environment of the village has potential ecological value (such as protecting biodiversity, protecting water sources, etc.).	4.26	0.95
	ECC3: The natural environment of the village has potential economic value (such as the developing agriculture, health tourism, etc.).	4.19	0.99

Note: SC2 was reverse-coded; higher scores indicate stronger perceived exclusion.

**Table 2.** Sample statistical analysis.

Variables	Definition	Mean	S.D.
Gender	Male=1, Female=0	0.48	0.50
Age	Below 18=1, 19-29=2, 30-39=3, 40-49=4, 50-59=5, Above 60=6	2.97	1.25
Education	Junior high school or below=1, Senior high school=2, Undergraduate=3, Higher degree=4	1.91	0.89
Household agricultural income(unit: 1000CNY/a)	Below 20=1, 20-40=2, 40-60=3, 60-80=4, 80-100=5, Above 100=6	1.70	1.08
Occupation	Farmer=1, Village cadres=2, Self-employed laborer =3, Nearby factory laborer=4, Migrant laborer =5, Part-time farmer=6, Freelance =7	4.12	2.59
Family member	From 1 to 8	4.40	1.19
Nation	Han Nationality =0, National minority =1	0.26	0.44

## 4. Results

### 4.1. Descriptive statistics

The respondents' satisfaction with their current living environment and their evaluation of the necessity to improve the current environment are investigated. 48.50% of respondents believe that the current living environment is general and below, 42.42% are satisfied, and only 9.08% are very satisfied. 78.06% of respondents

believe that the current living environment is necessary or very necessary to improve, and only 5.54% believe that it is not necessary. It shows that the rural residents' evaluation of their living environment is not very ideal, and it remains essential to enhance the governance and quality of rural living environment. Additionally, this paper emphasizes the importance of understanding farmers' social capital and ecological capital cognition. As shown in **Table 1**, the majority of respondents (57.04 %) believed

that their social circle could help them. Not many respondents (40.80%) think that they will be excluded or punished for not participating in village collective activities. A minority of respondents (17.94 %) believe that their interpersonal communication is not extensive. In addition, most respondents have a high ecological capital cognition, with average scores for the three measurement questions exceeding the general level. Finally, the proportion of respondents' willingness and behavior to reduce ANPSP are shown in **Figure 1**. The proportion of respondents who are willing to reduce the application of pesticides and fertilizers, use water-saving facilities, and return straw to the field is 88.45%, 92.84%, and 87.84%, respectively. However, the proportion of respondents who have implemented the above behaviors in agricultural production is 79.06%, 70.52%, and 73.67%, respectively. It shows that most farmers have strong intentions and behavior to reduce ANPSP. However, respondents' behavior of reducing ANPSP is less than their willingness, that is, there is an inconsistency. The inconsistency in the use of water-saving facilities is the largest, followed by return straw to the field, and reduce the application of pesticides and fertilizers, which are 22.32%, 14.17% and 9.39%, respectively. Additionally, according to this consistency coding rule, farmers whose willingness and behavior to reduce ANPSP are completely consistent account for 59.28% of the sample, which is much lower than the implied level of consistency derived by subtracting any single measure of behavior from willingness. This indicates that farmers exhibit low consistency in reducing ANPSP, highlighting the need to explore ways to further improve the alignment between their behavior and willingness.

#### 4.2. The effect of social capital on willingness, behavior, and the consistency between willingness and behavior

As shown in **Table 3**, the reliability and validity of social capital and ecological capital cognition variables are tested. The results indicate that Cronbach's alpha values exceed 0.745, Average Variance Extracted (AVE) values are greater than 0.669, Composite Reliability (CR) values are above 0.858, and Kaiser-Meyer-Olkin (KMO) values

are over 0.656. It indicates that the data of social capital and ecological capital cognition variables has passed the test of reliability and validity, confirming their suitability for factor analysis. Principal component analysis can be employed for dimensionality reduction, allowing for the extraction of principal components for subsequent analyses. Furthermore, the result of the Harman single-factor test shows that the first unrotated principal component explained 27.939% of the variance, which is below the 40% threshold, which alleviates concerns about homogeneity deviations.

Subsequently, econometric Model 1 is analyzed based on the Logit method, with the results presented in **Table 4**. As shown in **Table A1** of the Appendix, the VIF values for all variables are below 5, with an average model VIF of 2.54, suggesting that multicollinearity is within an acceptable range. Column (1), (3), and (5) only add the social capital variable, and social capital can significantly improve the willingness ( $\beta=0.118$ ,  $p<0.01$ ), behavior ( $\beta=0.127$ ,  $p<0.01$ ), and the consistency between willingness and behavior ( $\beta=0.142$ ,  $p<0.01$ ) of rural residents to reduce ANPSP. Columns (2), (4), and (6) add control variables, and the impact of social capital variables on willingness ( $\beta=0.123$ ,  $p<0.01$ ), behavior ( $\beta=0.134$ ,  $p<0.01$ ), and the consistency between willingness and behavior ( $\beta=0.149$ ,  $p<0.01$ ) is still significant, and the significance level and coefficient become higher. Marginal effect analysis shows that for each one-unit increase in social capital, the probability of respondents' willingness, behavior, and the consistency to reduce ANPSP will increase by 3.45%, 1.83%, and 3.03%, respectively. Additionally, increasing education level can significantly improve respondents' willingness, behavior, and consistency at the level of 1%. Age demonstrates a significant negative correlation with both consistency and behavior, while per capita household agricultural income shows a positive correlation with willingness and consistency. Gender does not exhibit a statistically significant effect in any of the models.

**Appendix Table A1** VIF

Variable	VIF
Social Capital	1.01
Gender	1.90
Age	4.01
Education	3.23
Ln(per capita household agricultural income)	3.79
Mean VIF	2.54

**Table 3.** Results of Reliability, Validity Test, and Factor Analysis.

Measurement questions	Standardization factor load	AVE	CR	Cronbach's $\alpha$	KMO	Bartlett Sphericity test
SC1	0.815	0.669	0.858	0.745	0.656	2959.921 (P=0.000)
SC2	0.764					
SC3	0.871					
ECC1	0.889	0.840	0.940	0.904	0.733	7877.85 (P=0.000)
ECC2	0.939					
ECC3	0.920					

Note: AVE is average variance extraction, CR is composite reliability, KMO is Kaiser-Meyer-Olkin.

**Table 4.** Estimation results.

Variables	Consistency		Willingness		Behavior	
	(1)	(2)	(3)	(4)	(5)	(6)
Social capital	0.142*** (6.07)	0.149*** (6.42)	0.118*** (4.04)	0.123*** (4.16)	0.127*** (5.40)	0.134*** (5.55)
Gender		0.018 (0.27)		-0.041 (-0.49)		0.046 (0.68)
Age		-0.057** (-1.75)		-0.058 (-1.45)		-0.059** (-1.80)
Education		0.363*** (7.75)		0.336*** (5.62)		0.376*** (7.92)
Ln(per capita household agricultural income)		0.109** (1.87)		0.221*** (2.95)		0.081 (1.38)
ANPSP type F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observation	3897	3897	3897	3897	3897	3897
Log likelihood	-2615.06	-2550.90	-1874.30	-1834.36	-2580.83	-2515.12

Note: Standard deviation in parentheses; \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.10$ .

#### 4.3. Mediating effect

Existing research has shown that social capital contributes to the dissemination of environmental knowledge and the enhancement of farmers' environmental awareness. Consequently, we first examine the impact of social capital on farmers' ecological capital cognition. The results of Formula 2 are shown in Column (1) of **Table 5**. Social capital has a positive effect on ecological capital cognition ( $\alpha = 0.318$ ,  $p < 0.01$ ). For every unit increase in social capital, the ecological capital cognition of rural residents will increase by 0.318. The regression results of Eq.3 are presented in Column (2), (3), and (4) of **Table 5**. Ecological capital cognition can significantly and positively affect respondents' consistency ( $\gamma = 0.155$ ,  $p < 0.01$ ). That is, ecological capital cognition will change the inconsistent behavior and willingness of respondents to the good result. Ecological capital cognition also has been found to affect respondents' willingness and behavior significantly and positively. Compared with behavior, ecological capital cognition plays a greater role in promoting willingness, in which the coefficient of the effect on willingness is 0.269 and of the effect on behavior is 0.114. In addition, after adding the ecological capital cognition variable, the effect

of social capital on respondents' behavior and consistency of reducing ANPSP is still significant, but the significance level and coefficient are reduced. That is, ecological capital cognition partially mediates the impact of social capital on behavior and consistency. The effect of social capital on respondents' willingness becomes insignificant after adding ecological capital cognition variable. That is, ecological capital cognition variable completely mediates the impact of social capital on respondents' willingness.

Additionally, a nonparametric test utilizing the bootstrap method can also assess the significance of these mediating effects (Preacher & Hayes, 2008). If the confidence interval between the lower and upper limits does not include 0, the result is significant. As shown in **Table 6**, the indirect effects of social capital on respondents' willingness, behavior, and the consistency in reducing ANPSP are significant, and the influence coefficients are 0.049, 0.086, and 0.036, accounting for 32.89%, 69.92%, and 26.87% of the total utility, respectively.

**Table 5.** Intermediary effect analysis and indirect impact of social capital.

Variables	Ecological capital cognition (1)	Consistency (2)	Willingness (3)	Behavior (4)
Social capital	0.318*** (18.51)	0.101*** (4.06)	0.033 (1.05)	0.098*** (3.90)
Ecological capital cognition	//	0.155*** (7.02)	0.269*** (10.40)	0.114*** (5.18)
Control variables	Yes	Yes	Yes	Yes
ANPSP type F.E.	/	Yes	Yes	Yes
Observation	3897	3897	3897	3897
Log likelihood	/	-2526.03	-1781.12	-2501.74

Note: Standard deviation in parentheses; control variables include gender, age, education, and per capita household agricultural income; \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.10$ .

**Table 6.** Bootstrap test for significance of mediating effect.

Effect	Consistency between willingness and behavior		Willingness		Behavior	
	Effect	Effect ratio	Effect	Effect ratio	Effect	Effect ratio
Total effect	0.149***	/	0.123***	/	0.134***	/
Direct effect	0.101***	67.79%	0.033	/	0.098***	73.13%
Indirect effect	0.049 (0.035, 0.065)	32.89%	0.086 (0.068, 0.105)	69.92%	0.036 (0.023, 0.051)	26.87%

Note: (Lower limit of confidence interval, Upper limit of confidence interval) in parentheses; \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.10$ .

**Table 7.** Heterogeneous effect of social capital on consistency between willingness and behavior.

Variables	Han Nationality (1)	National minority (2)	Non-Autonomous areas (3)	Autonomous areas (4)	Big city (5)	Small city (6)
Social capital	0.163*** (5.95)	0.101** (2.01)	0.133*** (4.27)	0.187*** (4.82)	0.162*** (4.98)	0.131*** (3.59)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
ANPSP type F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observation	2895	1002	2397	1500	2328	1569
Log likelihood	-1871.09	-673.39	-1532.23	-987.14	-1507.90	-1013.88

Note: Standard deviation in parentheses; control variables include gender, age, education, household agricultural income, and family member; \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.10$ .

#### 4.4. Heterogeneity test

Yunnan province has many ethnic minorities and strong ethnic cultures, and its autonomous areas are typical areas with intensive ethnic integration. In addition, the urban population of Yunnan province is not evenly distributed, and the size of cities is different. Therefore, it is essential to examine the heterogeneous effects of social capital on the consistency among farmers with different ethnic backgrounds or different regional characteristics, so as to provide references for the design of ANPSP control policies according to local conditions and people's conditions.

Firstly, this paper divides the respondents into Han and minority groups to study the heterogeneity, as shown in Column (1) and (2) of **Table 7**. Social capital significantly promotes farmers' consistency to reduce ANPSP among Han rural residents and ethnic minorities, but the promoting effect is greater, and the significance level is higher in Han nationality group than that in national ethnic minority group. With each one-unit increase in social capital, the average probability of consistency among Han respondents increases by 3.70%, while that among ethnic minority respondents increases by 2.43%. Secondly, there are 8 autonomous prefectures and 29 autonomous counties in Yunnan province, and the autonomous areas have high ethnic integration and are a gathering area of ethnic minorities. Therefore, this paper divides the respondents into non-autonomous areas and autonomous areas to explore heterogeneity, as shown in Column (3) and (4) of **Table 7**. Social capital significantly promotes farmers' consistency to reduce ANPSP in both autonomous and non-autonomous regions, but the promoting effect is greater in autonomous areas than in non-autonomous areas. With each one-unit increase in social capital, the average probability of consistency among respondents in non-autonomous regions increases by 2.98%, while that among respondents in autonomous regions increases by 4.35%. Finally, Yunnan province has 6 prefecture-level cities/ autonomous prefectures with a population of more than 3 million: Kunming, Qujing, Zhaotong, Honghe Hani and Yi Autonomous Prefecture, Wenshan Zhuang and Miao Autonomous Prefecture, and Dali Bai Autonomous Prefecture. Therefore, based on whether the population is equal to or exceeds 3 million, this paper divides 16 prefecture-level cities / autonomous prefectures into two groups, big cities and small cities, as shown in Column (5) and (6) of **Table 7**. Social capital can significantly improve the consistency among rural respondents in large cities and small cities at

1% level, but the promoting effect is greater in large cities than that in small cities. For each one-unit increase in social capital, the average probability of consistency among respondents in large cities increases by 3.70%, while that among respondents in small cities increases by 2.99%.

## 5. Discussion

Affected by natural geographical conditions, hydrological and climatic characteristics, and other factors, as well as the dispersion and diversity of sources, ANPSP presents randomness in time and uncertainty in space. The composition of pollutants in ANPSP is complex, often directly cause serious damage to humans and the environment, which has aroused widespread concern in society. However, compared with industrial and urban pollution control, the prevention and control of ANPSP starts late, characterized by a deficient policy, an inadequate institutional system, and insufficient capital investment, facing a severe situation and great pressure (Lu *et al.*, 2023). ANPSP control is crucial in the protection of ecological environments, as it is closely linked to the development of rural ecological civilization, national food security, and sustainable agricultural practices. In recent years, the government has placed significant emphasis on further promoting the control of ANPSP and has published a series of policy requirements. Guiding farmers' participation is an effective way for the government to control ANPSP, because farmers are not only the practitioners of agricultural activities, but also the direct beneficiaries of rural environmental improvement. Therefore, this paper concentrates on farmers' willingness and behaviors to reduce ANPSP. Our survey findings indicate that most of rural respondents are willing to take or have taken actions to reduce ANPSP. However, farmers whose willingness and behavior to reduce ANPSP are completely consistent account for 59.28% of the sample, indicating a high inconsistency between willingness and behavior. Therefore, the government should guide rural residents to change their agricultural production mode and clarify the factors that affect their adoption of pollution control measures to promote the willingness to turn to behavior.

Social capital serves as a significant complement to formal institutions in rural areas, thus influencing farmers' perceptions of environmental governance (Gao *et al.*, 2019). Therefore, this paper investigates the effect of social capital and finds that it is significantly and positively correlated with respondents' willingness, behavior, and

consistency to reduce ANPSP. From the perspective of social psychology, social capital will help rural residents gather and exchange information, transfer environmental knowledge, coordinate communication and cooperation, and produce "demonstration effect" (De Giorgi *et al.*, 2020). Therefore, social capital can not only improve farmers' willingness and behavior to reduce ANPSP but also narrow the gap and improve the consistency. It is worth noting that since 92.8% of farmers have already expressed their willingness to adopt water-saving facilities, the scope for social capital to further alter their willingness is very limited. For practices with already high baseline adoption willingness, mandatory regulatory enforcement combined with subsidies may be more effective than further investment in social capital. Additionally, ecological capital cognition is introduced to test the influence mechanism of social capital. The results show that social capital is conducive to the spread of environmental knowledge, so that farmers gain a profound understanding of the ecological and economic value of the rural environment. Ecological capital cognition is also found to significantly and positively affect willingness, behavior, and the consistency of rural residents to reduce ANPSP. Individuals with high awareness and attention to the environment tend to prioritize the harmful effects of environmental issues and exhibit a high level of pro-environmental behaviors (Trivedi *et al.*, 2018). Therefore, farmers with high ecological capital cognition recognize the value of ecological environment, have positive attitude towards environmental protection, and are willing to adopt behaviors of reducing ANPSP in agricultural production activities. In general, social capital can significantly and indirectly affect farmers' behavior and consistency to reduce ANPSP through ecological capital cognition.

In addition, our results show that social capital exerts significantly heterogeneous effects on the consistency among farmers with different ethnic backgrounds or regional characteristics. Social capital can significantly and positively affect the consistency of reducing ANPSP among Han rural residents but has smaller impact among ethnic minorities. Ethnic diversity may lead to social fragmentation and lack of trust among individuals (Barnes-Mauthe *et al.*, 2015). Yunnan province has many kinds of ethnic minorities, but the number of each single ethnic minority is small, and there is no minority with a dominant number. The barriers of ethnic minorities' complexity, dispersion, and language incompatibility will make it difficult for them to form strong social capital, so the promotion of consistency is smaller. Social capital can significantly and positively affect farmers' consistency in both autonomous areas and non-autonomous areas, but it has a greater promoting effect on rural residents in autonomous areas. Based on consanguinity and geography, China establishes a relational network centered around individuals, expanding outward layer by layer (Wang *et al.*, 2022), and residents with better community relations act more environmentally friendly (Hua *et al.*, 2021). Yunnan province implements a system of regional ethnic autonomy and guarantees the rights of

ethnic minorities to manage the affairs of their own ethnic areas, which helps to combine the country's policies and the specific characteristics of ethnic minority areas, and constantly consolidates and develops harmonious socialist ethnic relations. Autonomous areas have formed strong social atmosphere, and rural residents have frequent interpersonal interactions and a high level of trust, thus social capital can greatly promote the consistency of rural residents' behavior and willingness. Furthermore, social capital plays a significant role in enhancing the consistency among farmers living in large cities but has smaller effect among rural residents living in small cities. Residents in big cities have the opportunity to acquire more environmental protection knowledge and understand more about the value of ecological capital than those in small cities, so they have a stronger awareness of environmental protection (Xu *et al.*, 2023). In addition, the population density in large cities is greater than that of small cities, and the contact and interaction between individuals are close, which facilitate the dissemination and overflow of environmental protection knowledge, thereby further encourage environmental friendly behaviors among individuals (Li & Wu, 2020). Therefore, the role of social capital in enhancing the consistency among farmers in large cities is greater than that in small cities.

Finally, our results show that education level is positively correlated with respondents' willingness, behavior, and the consistency to reduce ANPSP. Age has a significantly negative impact on both consistency and behavior, indicating that younger farmers are more likely to maintain consistency between their willingness and actions and take practical steps. The decision-making of younger farmers may be more driven by positive evaluations of the outcomes of pro-environmental behaviors, whereas older farmers may place greater emphasis on the capacity, resources, and potential risks required to implement new practices, and heightened demand for a sense of control and certainty may form a critical constraint in bridging the gap from willingness to action (Phung & Dao, 2024). Education is crucial to enhance public awareness and knowledge of environmental protection (Eskandari-Damaneh *et al.*, 2020; Xu *et al.*, 2022), and higher educational attainment enables strategic rather than reactive approaches to environmental management (Lei & Zhang, 2026). With the enhancement of education level, rural residents are likely to develop a more profound understanding of the detrimental effects of ANPSP, so their willingness to reduce ANPSP will be increased, and they will be more able to turn their intention to actual behavior. Therefore, the consistency between willingness and behavior will be improved. Additionally, household agricultural income level is found to be closely correlated with respondents' willingness and consistency. Studies have shown that farmers are less motivated to replace chemical fertilizers with organic fertilizers and adopt environmentally sustainable prevention and control technologies (Niu *et al.*, 2022; Shi *et al.*, 2023), because the cost of transforming their agricultural production activities

exceeds the benefits of ANPSP (Psaltopoulos *et al.*, 2017). Therefore, the increase in agricultural income can compensate for part of the cost of agricultural production transformation and may enhance farmers' willingness and behavior to reduce ANPSP.

## 6. Conclusions, implications, and limitations

### 6.1. Conclusions

Farmers are the beneficiaries and important actors of ANPSP control. Encouraging farmers to engage in the management of ANPSP holds significant importance for enhancing the rural ecological environment, ensuring national food security, and advancing the development of rural ecological civilization in China. Based on 1299 valid questionnaires data from 91 counties in 16 prefecture-level cities/autonomous prefectures in Yunnan province, this paper empirically investigates the factors influencing farmers' participation in ANPSP control. The results show that about half of the respondents' evaluation of the current rural living environment is not ideal, and most respondents believe that improving the current rural environment is essential. This indicates a continued need to enhance the management of ANPSP and to elevate the quality of life for rural residents in the future. Furthermore, there exists an inconsistency in ANPSP control, and social capital can significantly enhance rural residents' willingness, behavior, and consistency. Additionally, social capital is found to indirectly promote behavior and consistency through ecological capital cognition. Furthermore, significant heterogeneities exist in the influence of social capital on the consistency of reducing ANPSP among farmers in cities with different scales and autonomy levels, and farmers with different ethnic backgrounds. Social capital can significantly improve farmers' consistency to reduce ANPSP among Han people and rural residents living in big cities, autonomous areas, and non-autonomous areas, but it has no significant impact among ethnic minorities and farmers living in small cities.

### 6.2. Policy implications

The findings hold substantial significance for the treatment of ANPSP in China. Firstly, improving the level of education and agricultural income can improve the consistency between farmers' behavior and willingness. In the control of ANPSP, the government should focus on farmers engaged in a certain scale of agricultural production and operation, implement educational and training programs, expand their knowledge and skills, and change their traditional ideas, habits and participation in agricultural production and environmental governance. In addition, the government should give certain subsidies to farmers who adopt green agricultural production behavior and technology, and moderately increase farmers' agricultural income.

Secondly, social capital can effectively improve farmers' willingness and behavior, and narrow the gap between the two, so that farmers can change from "intention" to "practice". However, intervention measures aimed at enhancing overall resilience can sometimes exclude impoverished groups due to factors such as cost, thereby exacerbating their vulnerability (Lei, 2025). The varying

effects of social capital across different groups may inadvertently widen participation disparities among them. Therefore, when leveraging social capital to promote agricultural environmental protection, policymakers must prioritize inclusivity to ensure that ethnic minorities and farmers in underdeveloped regions are not marginalized. Therefore, the government should address the issue that rural areas cannot gain information timely and effectively due to regional closure or lack of access to information, and make efforts to reduce farmers' information asymmetry, strengthen communication, and exchange among farmers. The government should strengthen environmental protection publicity, can regularly organize agriculture training sessions led by experts and face-to-face technical demonstration guidance. Newspapers, leaflets, television, radio, rural new media and other means should be used to publicize environmental knowledge to farmers, thus, increasing farmers' understanding of ANPSP control policies.

Finally, the government should promote farmers' participation in ANPSP control according to local conditions. The ethnic minorities in Yunnan province are relatively scattered, geographical dispersion and ethnic differences have led to a lack of communication and exchange between ethnic minorities. Therefore, social capital cannot effectively promote their effective participation in environmental governance. The government should strengthen communication and interaction among ethnic minorities and between ethnic minorities and the Han nationality, break the barriers of cooperation between different ethnic groups, and promote national unity. The implementation of regional ethnic autonomy system in autonomous areas has formed an internal ethnic culture, which makes the interpersonal interaction among residents frequent and the degree of trust high. It also once again emphasizes that the unity and harmony of ethnic relations is of great significance for farmers to participate in ANPSP control. Compared with large cities, the social capital stock of small cities is lower, poses challenges in promoting pro-environmental behavior through social capital. Although residents' behavior can be restrained and controlled through external supervision, the cost of supervision may be high and not sustainable. Therefore, it is necessary to consider taking effective measures to cultivate the social capital in small cities. County governments in small cities should establish "green-production cooperatives" that appoint one "environmental hub farmer" per village, financeable at RMB 2,000 per year from the existing "high-quality farmer training" budget line (Nongban-Ke [2022] No. 8). Training sessions should be scheduled during the winter slack season and prioritise minority villages, thereby seeking a visible demonstration network that can later spill over to neighbouring settlements.

### 6.3. Limitations

This study has three limitations that point to fruitful directions for future research. First, due to constraints in survey cost and feasibility, the sampling was conducted at the county level without collecting village-level identifiers

or detailed land-use data (e.g., cultivated land area). As a result, we are unable to control for unobserved village-level heterogeneity, identify community-level social interactions, or precisely account for the influence of operational scale. Future studies should incorporate village-level information and more granular land data to enable richer spatial and contextual analyses. Second, the ecological-cognition scale used in this study combines items that tap into both ecological and economic values. This mixing of constructs may obscure their distinct effects. Future work would benefit from developing and validating separate measures for ecological cognition and economic cognition to clarify their independent roles in shaping environmental behavior. Third, our analysis focuses largely on static factors such as social capital and cognition. However, agents' long-term behavioral strategies are often reshaped by dynamic external changes and shocks (Lei & Xu, 2024). Future research could adopt a more dynamic perspective by introducing time-varying external factors—such as policy shifts, climate events, or market fluctuations—to better understand how consistency between intention and behavior evolves over time.

#### Declarations

#### Availability of data and material

The datasets used or analyzed during the current study are available from the corresponding author upon reasonable request.

#### Competing interests

The authors have no relevant financial or non-financial interests to disclose.

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#### Authors' contributions

Zhihua Xu: Conceptualization, Writing - Review & Editing. Juan Xu: Writing - Original Draft, methodology, formal analysis. Li Shuqin: Visualization, investigation. Ji Chen: Questionnaire distribution and collection, data curation. Rui Chen: Questionnaire distribution and collection, funding acquisition.

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