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Adoption and multidimensional effects of socialized services for tea farmers

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KEYWORDS

Happiness mechanism, multidimensional effects, tea farmer, tea-related socialized services

HIGHLIGHTS

- Proposes a complete logical chain of socialized services → multidimensional effects → tea farmer well-being, enriching the theoretical understanding of agricultural socialized services.
- Broadens the perspective of the *happiness code* by moving beyond traditional economic performance analysis, adopting subjective well-being (SWB) as the ultimate evaluation index of socialized services for the first time.
- Provides targeted policy recommendations, contributing to the optimization of tea farmer adoption of socialized services and promoting the diversification of the forestry economy.

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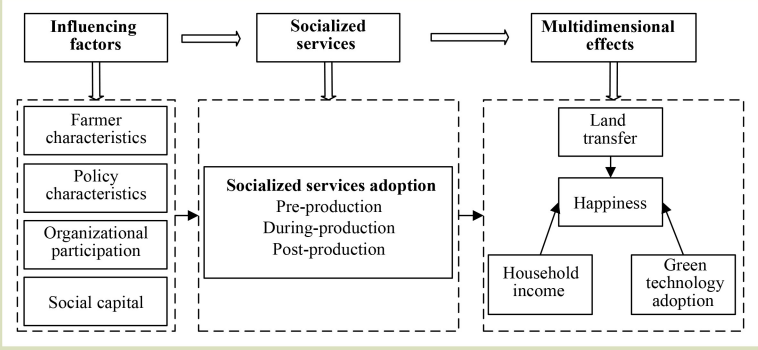
GRAPHICAL ABSTRACT



ABSTRACT

As a vital component of the forestry economy, the enhancement and development of tea-related socialized services contribute significantly to the diversification of forestry-based economic activities. This study established a theoretical framework to examine the multidimensional effects of tea farmer adoption of such services. These findings indicate that the household head age, health, number of family agricultural laborers, productive tea garden area, government technical training, green production demonstration zone and engagement in cooperatives have significant positive impacts on the adoption of socialized services, whereas factors such as tea garden slope, government penalties and family social status exert inhibitory effects. Also, the determinants influencing adoption vary across different service links. Adoption of socialized services by tea farmers also demonstrates multiple beneficial outcomes, including the inhibition of land outflow, increase the quantity of green technology adoption, higher income levels, and enhance subjective well-being (SWB), with the magnitude of these effects differing across various production links. Additionally, the impact of adopting socialized services varies between individual groups and village groups, particularly in terms of household income, land transfer and green technology adoption. Finally, the adoption of socialized services influences tea farmer SWB through pathways involving total income, tea income, green technology adoption, and leisure time.

1 Introduction

The rapid expansion of modern industries has triggered a substantial migration of young and middle-aged rural laborers, resulting in an increasingly aging agricultural workforce and a rising prevalence of part-time and sideline farming activities. Consequently, the questions, who will farm the land and who can farm it well, have emerged as a critical challenge for China's modern agricultural development. At present, China's agricultural sector remains dominated by smallholders, reflecting the characteristics of a large country with small-scale farmers. According to the Third National Agricultural Census, smallholders constitute over 98% of agricultural operators, 90% of agricultural workers and manage 70% of the total cultivated land. These smallholders face relative resource constraints in terms of land, capital, technology and information, while China's complex terrain, fragmented land distribution and regional diversity in cropping patterns further exacerbate the fragmentation of cultivated land[1]. These conditions position smallholders as pivotal yet challenging actors in agricultural modernization[2,3], making them a key factor in shaping its progress. Resolving the dilemma of who will farm the land and who can farm it well depends on the crucial role of agricultural socialized services. The Central Document No. 1 released by the Ministry of Agriculture and Rural Affairs of China in 2024, as the core policy document defining China's annual priorities for agricultural and rural work, it emphasizes the development of such services by promoting a modern agricultural management system, addressing the who-will-farm question, prioritizing smallholders, focusing on new-type agricultural business entities and leveraging socialized services as essential support, while simultaneously accelerating the cultivation of a high-quality agricultural workforce. The scale of agricultural socialized services had grown substantially, with service entities increasing from 227 thousand in 2017 to 1.09 million in 2023, and smallholder household served rising from 36.6 million to over 94 million. Nevertheless, adoption remains concentrated in grain-producing regions, with limited penetration in cash crops, and many farmers, particularly tea farmers, exhibit low adoption rates[4] and limited willingness[5,6]. Therefore, exploring the factors influencing tea farmer adoption of socialized services and assessing its effects is critical for promoting tea-related socialized services and enhancing the diversification of the forestry economy. In this study, agricultural socialized services refer to a suite of market-oriented provisions supplied by cooperatives, agribusinesses or specialized service households. These services are designed to either replace or supplement the production activities of smallholder households. They encompass a wide range of support across the entire tea production chain, including pre-production (e.g., technical training and land preparation), during-production (e.g., fertilizer application, pruning and weeding) and post-production (e.g., picking, marketing and logistics) stages.

Motivated by the practical demands of China's agricultural modernization, extensive research has been conducted on agricultural socialized services. For adoption factors, farmer decisions are shaped by personal, household and production characteristics. Personal traits include age[7], education and health[8]; household factors include labor force size[9] and aging[10]; and production characteristics include land scale[11] and specialization[9]. Additional influences include technical training[9], trust[12], cooperative membership[11], engagement with the digital economy[13] and access to information[14]. Research on the effects of socialized services has examined their impact on agricultural carbon emissions[15], green development[16], fertilizer reduction[17], total factor productivity[18], land scale management[19], cultivated land quality protection[20] and farmer welfare[21]. From an analytical perspective, Bai and Li[22] investigated decision-making mechanisms for agricultural socialized services in the digital era and Lu and Shen[23] explored government-led modern agricultural service systems. Jia et al.[24] analyzed pathways for integrating smallholders into modern agriculture through inclusive development and Li et al.[25] developed an evaluation system for Beidahuang's agricultural socialized service capacity from a food security perspective. Crop-specific studies include Chen et al.[26], who examined the influence of socialized services on succession intentions in grain-focused family farms, Zhang et al.[17], who analyzed pesticide use among rice farmers, and Zhang et al.[9], who found that socialized services facilitate green production in wheat farming.

Although existing research provides a foundational reference, several gaps persist. First, methodological limitations remain, as few studies systematically examine the factors influencing tea farmer adoption of socialized services from the perspectives of farmer characteristics, policy features, organizational participation and social capital, and research analyzing adoption factors across different production stages is scarce. Second, content fragmentation is evident, with most studies narrowly addressing the effects of socialized services on green production, land allocation or farmer welfare, lacking a

comprehensive multidimensional framework; in particular, there is insufficient attention to the multidimensional impacts of tea farmer adoption across production stages, especially regarding mechanisms affecting subjective well-being (SWB). Third, crop specificity presents another gap, as the majority of research focuses on staple crops, such as grain and rice, with minimal exploration of socialized services in tea production. The innovations of this study are threefold. First, it developed a theoretical framework capturing the multidimensional effects of tea farmer adoption of socialized services. Although existing studies largely focus on the singular impact of socialized services on agricultural income, this study systematically integrated their effects on income, land management, green technology adoption and SWB, proposing a complete logical chain of socialized services → multidimensional effects → tea farmer well-being, thereby enriching the theoretical understanding of agricultural socialized services. Second, it broadens the perspective of the *happiness code* by moving beyond traditional economic performance analysis, adopting SWB as the ultimate evaluation index of socialized services for the first time and revealing its transmission pathways, offering new insights into research on farmer well-being within the context of rural revitalization. Finally, based on empirical findings, the study provides targeted policy recommendations, contributing to the optimization of tea farmer adoption of socialized services and promoting the diversification of the forestry economy.

Therefore, from the perspective of farmers and based on household survey data from Anhui, Shaanxi and Sichuan Provinces, this study proceeded as follows. First, we constructed a multidimensional theoretical framework to analyze both the influencing factors, including farmer characteristics, policy features, organizational participation and social capital, and the effects, covering economic outcomes, land use, technological adoption and well-being, of tea farmer adoption of socialized services, using the propensity score matching (PSM) model. The theoretical framework is illustrated in Fig. 1. Second, we investigated group differences in adoption based on household head and village characteristics. Finally, we applied a mediation effect model to empirically examine the impact of socialized service adoption on tea farmer SWB. The findings are intended to enrich research on tea-related socialized services, optimize adoption pathways and promote the development of these services alongside the diversification of the forestry economy, thereby contributing to the construction of an agricultural powerhouse.

2 Theoretical analysis and research hypotheses

Tea is a vital cash crop within the forestry economy. As the world's largest tea producer and consumer, and the second-largest exporter, China's tea industry provides high added value, with global demand continuing to rise. This growing demand drives supply expansion, positioning tea production as essential for balancing global supply and demand. Tea-related socialized services are diverse and span the entire production chain: pre-production services include agricultural input procurement and technical training; during-production services cover cultivation, pest management and harvesting;

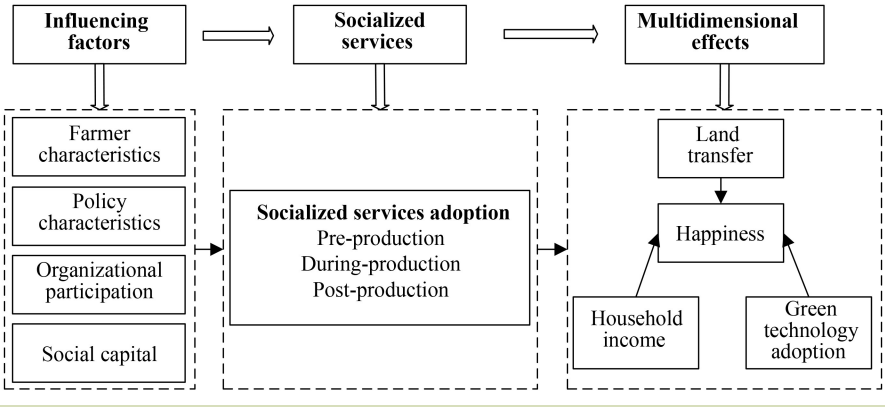


Fig. 1 Theoretical framework.

and post-production services involve processing, sales and distribution. These services profoundly influence tea farmer monetary income, land management, green production practices and overall well-being. By focusing on tea as a representative cash crop, this study seeks to advance the tea industry while promoting sustainable agricultural development.

Under the framework of rational smallholder theory[27], farmers, as grassroots operators, make production decisions guided by contextual rationality, flexibly adapting to market dynamics, technological advancements and resource allocation to maximize household benefits[17]. Labor scarcity encourages mechanization whereas the specificity of agricultural assets renders socialized services a cost-effective means of reducing marginal costs[17]. However, within the context of China's Three Rural Issues policy, the multidimensional mechanisms and effects of adopting agricultural socialized services remain insufficiently examined. As farmers expand their operations, they encounter constraints in labor, capital and technology, and face a choice: directly purchase inputs from factor markets, maximizing returns but incurring high costs; or adopt socialized services to achieve economies of scale, improve input efficiency and overcome resource limitations[28]. Compared to independent procurement, socialized services enhance bargaining power, significantly lower production costs and optimize overall profitability.

2.1 Factors influencing tea farmer adoption of socialized services

Based on Coleman's rational choice theory, actors seek resources that align with their interests. In this context, tea farmers adopt socialized services according to preferences shaped by their cognitive capacity, family labor availability, government policies and village endowments, with farmer characteristics having a particularly prominent role.

Farmer characteristics encompass household head traits, family characteristics and production attributes. Household head traits include age and health status: older tea farmers are less capable of labor-intensive agricultural tasks and are thus more inclined to adopt socialized services[29], while healthier farmers possess greater energy for large-scale operations, increasing their likelihood of adoption. Family characteristics involve the total number of family members and the number of agricultural laborers. As tea planting is labor-intensive, insufficient family labor reduces human input and production efficiency; conversely, a larger agricultural labor force can support a greater cultivated area and encourages adoption of socialized services to enhance output and efficiency[30]. Production attributes include the total scale of the tea garden, the productive tea gardens area, and the slope of the tea garden. Larger tea garden scales generally reduce land fragmentation and enhance contiguousness, lowering the cost of adopting socialized services[31], and steeper slopes can hinder operational feasibility. Based on these considerations, we proposed Hypothesis H1:

H1a: The household head age and health status, the number of agricultural laborers, and the productive tea gardens area all positively influence tea farmer adoption of socialized services.

H1b: The slope of the tea garden negatively affects tea farmer adoption of socialized services.

Policy characteristics include government penalties, technical training and green production demonstration zones. Although government penalties can enhance legal awareness and regulate behavior of farmers[32], excessive penalties can undermine trust in the government and hinder the adoption of socialized services. Government technical training expands tea farmer access to information, reduces information asymmetry and facilitates greater adoption of socialized services[33]. Green production demonstration zones, benefiting from favorable policy support and well-developed infrastructure, further encourage the adoption of these services. Based on these considerations, we proposed Hypothesis H2:

H2a: Government technical training and green production demonstration zones positively influence tea farmer adoption of socialized services.

H2b: Government penalties negatively affect tea farmer adoption of socialized services.

Organizational participation, particularly through cooperatives, plays a crucial role in tea farmer adoption of socialized services. Participation in cooperatives allows farmers to access key resources such as information and technology more quickly, reducing information search costs and technology trial-and-error costs. The integration of these resources further facilitates the adoption of socialized

services[34]. Additionally, training provided by cooperatives enhances the cognitive abilities of farmers, enabling them to adopt socialized services more effectively and rationally. Based on this rationale, we further proposed Hypothesis H3:

H3: Organizational participation positively influences tea farmer adoption of socialized services.

Social capital, as a non-physical resource, manifests across multiple dimensions, including social networks, behavioral norms, trust, leadership, consistency of action and social ethics. These elements facilitate interpersonal collaboration and enhance operational efficiency and social integration. Family social status, as part of the social network, influences family decision-making and development: higher family status confers greater authority, and larger families benefit from mutual assistance and labor sharing[35]. Consequently, even without adopting socialized services, such families can maintain production efficiency and tea quality. Therefore, higher family status can reduce the likelihood of adopting socialized services. Based on this, we proposed Hypothesis H4:

H4: Family status has a negative impact on the tea farmer adoption of socialized services

2.2 Multidimensional effects of tea farmer adoption of socialized services

Agricultural socialized services can lower operational costs while enhancing service quality, thereby reducing overall production expenses[36]. As rational actors, farmers voluntarily outsource land or agricultural operations to service organizations. The quality of these services is closely tied to the operational efficiency and income of the service providers. Driven by self-interest, socialized service organizations optimize resource allocation, enhance agricultural productivity, reduce operational costs and improve service quality through centralized procurement of inputs, large-scale operations and mechanized planting strategies. Collectively, these measures decrease comprehensive agricultural costs and increase the agricultural income of farmers. Also, higher efficiency and reduced labor intensity enable farmers to devote more time to non-agricultural activities, thereby boosting non-agricultural income and raising total household income. Based on these considerations, we proposed Hypothesis H5:

H5: The adoption of socialized services by tea farmers can increase their income.

The emergence of agricultural socialized services has markedly transformed tea farmer factor inputs and management practices. By alleviating constraints such as household labor shortages, technological limitations and financial barriers[25], these services relax resource endowment restrictions for tea farming households. This, in turn, facilitates more effective land scale management and enhances the benefits of agricultural operations. Compared to leasing out land, tea farmers increasingly prefer self-management or even expanding their land holdings, thereby promoting the development of land scale management. Based on this, we proposed Hypothesis H6:

H6: The adoption of socialized services by tea farmers can inhibit land outflow.

Agricultural socialized service organizations reduce chemical input usage to secure policy incentives[37] and introduce modern technologies, advanced agricultural machinery, and expert guidance to establish standardized technical protocols. These measures enable precise application of chemical inputs and improve traditional extensive farming practices[38]. Also, tea farmers who participate in pre-production technical training services gain greater awareness of green production technologies, partially mitigating information asymmetry that can lead to excessive input use and low efficiency. This process facilitates the transition toward green production. Based on these considerations, we proposed Hypothesis H7:

H7: The adoption of socialized services by tea farmers can increase the green technology adoption quantity.

Addressing rural challenges requires not only material improvements but also efforts to enhance the spiritual well-being and overall happiness of farmers. Agricultural socialized services help bridge the gap between modern agriculture and smallholders. By providing access to modern production inputs and advanced technologies, these services increase household agricultural output efficiency[39]. Simultaneously, mechanized services reduce manual labor demands, freeing tea farmers to engage in non-agricultural work or pursue personal interests, thereby improving overall household welfare. Based on these considerations, we proposed Hypothesis H8:

H8: The adoption of socialized services by tea farmers can enhance their SWB.

2.3 Happiness mechanism of tea farmer adoption of socialized services

The happiness mechanism of tea farmer adoption of socialized services refers to the process whereby the adoption of such services acts as a starting point, influencing tea farmer SWB through total income, tea income, the extent of green technology adoption and leisure time. For tea farmers, SWB is defined as the comprehensive cognitive and affective evaluation of their quality of life based on their internal standards[40]. Existing research on SWB has predominantly examined factors such as income, education, equality of opportunity, and individual effort[41], while comparatively little attention has been given to the impact of socialized services on tea farmer SWB.

With the continuous evolution and expansion of agricultural socialized services, their scope now encompasses production, technical support, information sharing, financial services, insurance and multiple service segments, including packaging, transportation, processing and marketing of agricultural products. As an emerging factor of agricultural production, these services are deeply integrated into modern agriculture and are key to transforming and upgrading traditional farming practices[25]. By improving production efficiency and reducing operational costs, socialized services contribute directly to higher household monetary income for farmers and enhance tea farmer SWB by alleviating their economic and labor burdens. Simultaneously, tea-oriented socialized services promote the reduction and efficient use of chemical inputs, facilitating a transition toward green production[6]. This shift improves ecological conditions, elevates tea farmer quality of life and positively influences their overall happiness. Through the adoption of these services, professional organizations and mechanized operations reduce individual labor demands in tea production, transfer part of the workload, free up personal time, and shorten production cycles, thereby increasing leisure time and enhancing tea farmer SWB. Therefore, we finally proposed Hypothesis H9:

H9: The adoption of socialized services by tea farmers can enhance their happiness through income, technology and leisure time.

3 Materials and methods

3.1 Data and variables

3.1.1 Data

The data for this study were collected through household surveys conducted by the research team in key tea-producing regions of Anhui, Shaanxi and Sichuan Provinces between July and August 2020. To ensure scientific rigor in sample selection, we used a combination of stratified and simple random sampling, aiming for approximately equal sample sizes across strata. Specifically, the selected counties and districts were Huangshan, Jinzhai and Qimen in Anhui, Emeishan, Tongjiang and Wangcang in Sichuan, and Baihe, Hanbin, Xixiang and Ziyang in Shaanxi. Within each county or district, three townships were randomly chosen, followed by two villages per township, and 10–15 tea-growing households per village. One village-level questionnaire was administered per village, while tea farmer questionnaires were completed through face-to-face household interviews, capturing information on household head characteristics, family demographics, production practices, policy engagement and participation in socialized services. The research team, composed of doctoral and master's students, began the study by conducting an extensive literature review and consulting with experts during the questionnaire design phase. Following this, a one-week preliminary survey was conducted to ensure the structural integrity and clarity of the questionnaire before launching the formal survey. Ultimately, the study collected 895 valid responses from tea farmers. It should be noted, however, that the use of cross-sectional data might limit the ability to capture dynamic changes over time. The survey area and sample distribution are given in Table 1.

3.1.2 Dependent variable

Given the multifaceted impacts of tea-related socialized services on farmers, this study used four dependent variables: household income, land transfer, green technology adoption and SWB. Household income comprised total household income and tea income. Land transfer captured the area of tea garden inflow and outflow. Green technology adoption was measured by both the quantity of green technologies adopted and the timing of their adoption. SWB was assessed using three Likert-scale questions: does your household enjoy a high quality of life, is your household highly satisfied with its current situation, and does your household feel optimistic

Table 1 Research area and sample distribution

Province	County (City/District)	Township	Sample size (households)	Percentage (%)
Anhui	Huangshan	Sankou, Xinming	98	11.0
	Jinzhai	Mabu, Qingshan	97	10.8
	Qimen	Likou, Ruokeng	94	10.5
Shaanxi	Baihe	Kazi, Maoping, Songjia	102	11.4
	Hanbin	Shuanglong, Yanba, Yinghu	80	8.9
	Xixiang	Liushu, Xiakou	37	4.1
	Ziyang	Chengguan, Huangu, Xiangyang	107	12.0
Sichuan	Emeishan	Guihuaqiao, Jiajiang, Puxing, Shuangfu	103	11.6
	Tongjiang	Xinglong, Yanxi, Yong'an	98	11.0
	Wangcang	Gaoyang, Mumeng	79	8.8

about the future. Responses are recorded on a five-point Likert scale, where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree.

3.1.3 Explanatory variables

The core explanatory variables cover tea farmers' adoption of socialized services, as well as if this is as pre-, during- and post-production socialized services. To address potential selection bias, a counterfactual approach based on PSM was used. Adoption was coded as a dummy variable, with 1 representing farmers who adopted socialized services (treatment group) and 0 representing those who did not (control group). For socialized services (covering pre-, during- and post-production stages), a value of 1 was assigned if any one of these services was adopted, and 0 if none were adopted. This coding was likewise used for pre-, during- and post-production socialized services including technical training and land tillage services as pre-production, fertilizing, pruning and weeding as during-production, and harvesting, trading and logistics as post-production.

3.1.4 Control variables

To isolate the factors influencing socialized service adoption and quantify its multidimensional effects, control variables were selected based on existing literature and data availability. Household characteristics included the age and health status of the household head, total family size, number of family agricultural laborers, total tea garden area, productive tea garden area, and tea garden slope. Policy characteristics comprise government penalties, government technical training, and the presence of green production demonstration zones. Organizational participation was measured by cooperative membership (yes/no) and social capital was captured through the perceived social status of the household.

3.1.5 Mediating variables

To examine the indirect effects of socialized service adoption on SWB, three mediating variables were included total income, tea income, the quantity of green technology adopted and leisure time. These mediators helped clarify the mechanisms through which socialized services influence farmer happiness. The definitions, coding and descriptive statistics of all variables are summarized in Table 2.

3.2 Model setting

3.2.1 Propensity score matching model

This study used PSM to examine the multidimensional effects of socialized service adoption by tea farmers for several reasons. First, socialized service adoption is primarily voluntary, with farmers making autonomous decisions, resulting in non-random samples and potential self-selection bias. Second, adopters and non-adopters often differ in their characteristics, creating selection bias when estimating the effects of adoption on multidimensional outcomes. PSM addresses these issues by comparing observed outcomes with counterfactual scenarios, allowing for more accurate estimation of the effects of socialized service adoption. Third, because data on adopter outcomes under non-adoption are unavailable,

Table 2 Descriptive statistics of variables

Variable		Variable definition and assignment	Mean	Std
Household income	Total income	Total household income (10,000 yuan, log-transformed)	2.03	0.801
	Tea income	Income from tea production (10,000 yuan, log-transformed)	0.833	0.725
Land transfer	Inflow area of tea gardens	Actual area of leased-in tea gardens (m^2)	38.2	217
	Outflow area of tea gardens	Actual area of leased-out tea gardens (m^2)	37.7	188
Green technology adoption	Quantity of green technology adoption	Count of adopted green technologies: sticky traps, insecticidal lamps, IPM, deep tillage, commercial organic fertilizer, or waste recycling (1 point per technology)	2.78	1.49
	Time of green technology adoption	1 = Leading other farmers in adoption; 2 = Following large farmers/enterprises; 3 = Adoption due to peer influence; 4 = No-adoption	3.60	0.751
Happiness	subjective well-being (SWB)	Average score of three Likert-scale questions: high quality of life, high family happiness, and optimism about the future (1 = Strongly disagree to 5 = Strongly agree)	10.8	1.68
Socialized service adoption		Assign a value of 1 if any of the following three links is used; otherwise, assign a value of 0	0.630	0.483
Pre-production socialized service adoption		Assign a value of 1 if either the land-plowing service or the agricultural technology training is used; otherwise, assign a value of 0	0.356	0.479
During-production socialized service adoption		Assign a value of 1 if any of the outsourcing services such as fertilizing, pruning, or weeding is used; otherwise, assign a value of 0	0.143	0.350
Post-production socialized service adoption		Assign a value of 1 if any of the picking, market trading, or logistics services is used; otherwise, assign a value of 0	0.378	0.485
Household characteristics	Household head age	Actual age (years, log-transformed)	4.05	0.182
	Household head health	1 = Unable to self-care; 2 = Chronic disease with self-care; 3 = Frail with minor illness; 4 = Healthy; 5 = Very healthy	3.93	0.871
	Total family size	Number of family members	3.80	1.70
	Number of family agricultural laborers	Number of agricultural laborers in the household	2.00	0.788
	Total tea garden area	Total tea garden area (hectares)	1.75	0.637
	Productive tea garden area	Area of high-yield tea gardens (hectares)	1.51	0.776
	Tea garden slope	1 = Extremely steep; 2 = Moderately steep; 3 = Flat; 4 = Moderately flat; 5 = Very flat	2.86	0.815
Policy characteristics	Government penalties	Frequency of penalties imposed on the village: 1 = Never; 2 = Rarely; 3 = Occasionally; 4 = Often; 5 = Very often	1.72	0.731
	Government technical training	Relevance of green technology training: 0 = No; 1 = Yes	3.51	1.06
	Green production demonstration zone	1 = Located in a demonstration zone; 0 = Otherwise	0.521	0.500
Organizational participation	Participation of cooperative	Membership in agricultural cooperatives 1 = Yes; 0 = No	0.107	0.310
Social capital	Family social status	1 = Household surname is dominant in the village; 0 = Otherwise	0.454	0.527
Instrumental variable (IV)	GI count	Number of geographical indications	0.247	0.476
Mechanism variable	Leisure time	Number of close contacts (log-transformed)	3.86	0.815

direct comparisons between adopters and non-adopters can introduce endogeneity. PSM mitigates this issue by constructing counterfactual scenarios, reducing multidimensional farmer characteristics into a single propensity score and matching adopters with non-adopters across multiple dimensions.

This study matched treatment groups (socialized service adopters) and control groups (non-adopters) under identical external conditions to analyze the outcomes of different adoption states. First, a logit model was used in Stata software to estimate the factors influencing tea farmer adoption of socialized services, expressed as, in Eq. (1).

$$PS = P(C = 1|X_i) = \exp(\beta X_i)/(1 + \exp(\beta X_i)) \quad (1)$$

where, PS is the propensity score, $C = 1$ indicates if adoption of agricultural socialized services, $C = 0$ indicates non-adoption, the subscript i denotes the i-th tea farmer and X_i represents the observable characteristics of the farmer, including individual traits, family attributes and production features.

After estimating the propensity scores, it is essential to assess the common support region and the balance of propensity scores between the treatment and control groups. A large common support range and a significant reduction in bias after matching indicate a satisfactory matching effect. During the analysis, considering that different matching methods affect the relationship between balancing bias and estimated effects, this study used four matching methods: K-nearest neighbor matching, K-nearest neighbor matching within a caliper, radius matching and kernel matching to estimate the multidimensional effects of socialized service adoption. Using multiple methods enhances the robustness and reliability of the results. In practice, if the outcomes are consistent across different matching methods, it indicates that the results are robust and not dependent on a specific matching approach[42].

Finally, tea farmers who have adopted socialized services are treated as the treatment group, while those who have not are the control group. The multidimensional effect is then calculated as the difference between the treatment and control groups, represented by the average treatment effect (ATT) on the treated, to quantify the impacts of adopting socialized services. The ATT is expressed as, in Eq. (2).

$$ATT = E(Y_1|C = 1) - E(Y_0|C = 1) \quad (2)$$

where, Y_1 is the multidimensional effect of tea farmers who have adopted socialized services and Y_0 is the outcome these farmers would have experienced if they had not adopted such services. Since $E(Y_1|C = 1)$ can be directly observed, but $E(Y_0|C = 1)$ is unobservable representing a counterfactual outcome, the PSM method is used to construct appropriate substitute variables for $E(Y_0|C = 1)$.

This approach ensures rigorous causal inference by balancing observed covariates between treatment and control groups.

3.2.2 Mediation effect model

Following Wen and Ye[43], a mediation model tests how socialized service adoption affects happiness through mediators:

$$H = \alpha_1 X + \varepsilon_i \quad (3)$$

$$M_i = \beta_1 X + \varepsilon_i \quad (4)$$

$$H = \gamma_0 + \gamma_1 X + \gamma_2 M_i + \varepsilon_i \quad (5)$$

where, X is the explanatory variable, indicating whether the tea farmer adopted socialized services, M_i is the mediating variables, including total income, tea income, the quantity of green technology adoption and leisure time, and H is the outcome variable, representing tea farmer SWB. In Eq. (3), α_1 is the total effect of socialized service adoption (X) on farmer happiness (H). In Eq. (4), the coefficient β_1 is the effect of X on the mediating variable (M_i). In Eq. (5), the coefficient is the effect of M_i on H after controlling for X, and another coefficient captures the direct effect of X on H after accounting for M_i. The residual term represents unexplained variation in the regression. The mediating effect is calculated as the product of the relevant coefficients $\beta_1 \times \gamma_2$.

4 Results and discussion

4.1 Analysis of factors influencing tea farmer adoption of socialized services

Before conducting the empirical analysis using the PSM regression model, variance inflation factors were calculated to assess multicollinearity among the explanatory variables. The results showed that the maximum value of these factors was well below commonly accepted thresholds, indicating no severe multicollinearity and confirming the appropriateness of the model for analysis. To match adopters and non-adopters of socialized services, the conditional probability of adoption was estimated. Given the binary nature of adoption status, a logit model was used for empirical estimation and the results are presented in Table 3.

For the characteristics of household heads, both age and health status significantly and positively influenced tea farmer

Table 3 Logit estimation results of tea farmer adoption of socialized services

Variable	Socialized service adoption			Pre-production socialized service adoption			During-production socialized service adoption			Post-production socialized service adoption		
	Coe	SE	z	Coe	SE	z	Coe	SE	z	Coe	SE	z
Household head age	1.05**	0.454	2.31	1.05**	0.46	2.28	−0.059	0.593	−0.1	0.04	0.445	0.09
Household head health	0.388***	0.095	4.1	0.423***	0.102	4.15	0.038	0.124	0.3	0.025	0.095	0.27
Total family size	−0.01	0.051	−0.2	0.067	0.052	1.3	0.044	0.066	0.66	−0.043	0.051	−0.85
Number of agricultural laborers	0.260**	0.116	2.24	−0.242**	0.110	−2.20	−0.006	0.138	−0.04	0.527***	0.114	4.62
Total tea garden area	−0.15	0.121	−1.24	−0.131	0.121	−1.08	1.1***	0.153	7.17	−0.054	0.12	−0.45
Productive tea garden area	0.574***	0.109	5.29	0.333***	0.108	3.09	0.001	0.138	0.01	0.923***	0.116	7.95
Tea garden slope	−0.230**	0.099	−2.33	0.011	0.098	0.11	0.127	0.127	1	−0.336***	0.0990	−3.41
Government penalties	−0.219**	0.104	−2.1	0.019	0.105	0.18	0.134	0.135	0.99	−0.332***	0.107	−3.10
Government technical training	0.426***	0.075	5.65	0.719***	0.088	8.21	0.104	0.101	1.03	0.025	0.076	0.32
Green production demonstration zone	0.737***	0.16	4.6	0.24	0.159	1.5	0.009	0.211	0.04	0.534***	0.159	3.36
Cooperative membership	0.568**	0.276	2.06	1.05***	0.248	4.23	0.385	0.296	1.30	−0.496*	0.255	−1.95
Family social status	−0.3**	0.145	−2.07	−0.234	0.146	−1.6	-0.312	0.202	−1.54	−0.056	0.144	−0.39
Constant term	−6.97	2.06	−3.38	−9.4	2.12	−4.43	-4.84	2.66	−1.82	−1.81	2.02	−0.89
Likelihood ratio (LR)		174***			164***			66.1***			165***	
Pseudo R^2		0.148			0.141			0.0900			0.139	
Sample		895			895			895			895	

Note: ***, ** and * indicate the significance at 1%, 5% and 10% levels, respectively.

adoption of socialized services. Older farmers and those in better health were more likely to adopt such services. This might have been because younger farmers often had alternative sources of income and manage smaller tea garden areas, reducing the likelihood of adopting socialized services. In contrast, older farmers; adopting socialized services helped mitigate their dependence on physical strength, increasing adoption probability. Additionally, age and health status significantly affected the adoption of pre-production socialized services. Older farmers might have had more available time to participate in pre-production technical training, while healthier farmers had the physical capacity to engage in activities such as plowing and other preparatory agricultural work.

For family characteristics, total family size does not have a significant impact on tea farmer adoption of socialized services, whereas the number of family agricultural laborers has a significant positive effect. A greater number of agricultural laborers allows for broader participation in tea planting and enhances the agricultural human capital of the family. Adoption of socialized services enables the family to maximize the value of this labor, thereby promoting increased household income. Also, a larger agricultural labor force facilitates the adoption of socialized services across both pre-production and post-production stages.

For production characteristics, the total tea garden area did not significantly affect overall adoption of socialized services, but it had a significant positive impact on the adoption of during-production services. This is likely because during-production activities, such as fertilizing, pruning and weeding, can benefit from mechanization and larger areas facilitate more efficient use of machinery. The area of productive tea gardens also had a significant positive effect on the adoption of socialized services. Larger and more contiguous productive areas make mechanized and other service operations more convenient and efficient, thereby increasing adoption likelihood. Additionally, productive tea garden area positively influenced adoption across pre-production and post-production stages. In contrast,

the slope of tea gardens had a significant negative impact on adoption rates. Steeper slopes increase terrain complexity and hinder the effective implementation of socialized services; in some cases, services can raise costs without improving production efficiency. Consequently, tea farmers with steeper tea garden slopes were less likely to adopt socialized services, particularly in post-production stages. Overall, Hypotheses H1a and H1b are supported.

For policy characteristics, government technical training had a significant positive effect on tea farmer adoption of socialized services. Such training enhanced the theoretical knowledge and cognitive skills of farmers, helping them address challenges encountered during tea production. Technical training also significantly promoted the adoption of pre-production socialized services. Similarly, green production demonstration zones positively influenced adoption, as the prestige associated with these zones fosters pride and enthusiasm among farmers, encouraging them to engage with socialized services. These zones also significantly boosted adoption in post-production stages. In contrast, government penalties negatively affected adoption; frequent punitive measures at the village level can deepen farmer dissatisfaction with higher authorities and decrease willingness to adopt socialized services, particularly in post-production. Overall, Hypothesis H2 is supported.

Participation in cooperatives had a significant positive impact on tea farmer adoption of socialized services. This could be because cooperative membership enhanced organizational capacity and improves production efficiency. Additionally, production and management training provided by cooperatives could have influenced farmer behavior, encouraging active adoption across various stages of socialized services. Consequently, cooperative participation increased the likelihood of tea farmers adopting these services, supporting Hypothesis H3. Cooperative membership also significantly promoted the adoption of pre-production socialized services; however, it did not facilitate adoption in post-production stages. This limitation might have arisen because many cooperatives lacked fully developed mechanisms for post-production activities such as tea picking, sales and transportation, and were unable to effectively link small-scale farmers with larger markets. In contrast, family social status had a significant negative effect on adoption. High-status families often had strong clan networks and internal support, ensuring production quality without reliance on socialized services, thereby validating Hypothesis H4.

4.2 Common support hypothesis test

The application of PSM requires substantial common support in propensity scores between the treatment and control groups. A limited common support domain can result in sample loss, as unmatched observations outside this range are excluded, whereas a broader common support reduces sample attrition during matching[44]. To validate the common support assumption, the conditional probability of tea farmers adopting socialized services was first estimated using a logit model. Kernel density plots were then generated to compare propensity score distributions before and after matching (Fig. 2), with solid and dashed lines representing adopters and non-adopters, respectively; the vertical axis denotes probability density, and the horizontal axis indicates propensity scores. As shown in Fig. 2, significant differences in propensity score distributions existed between the two groups prior to matching, with substantial overlap observed after matching,

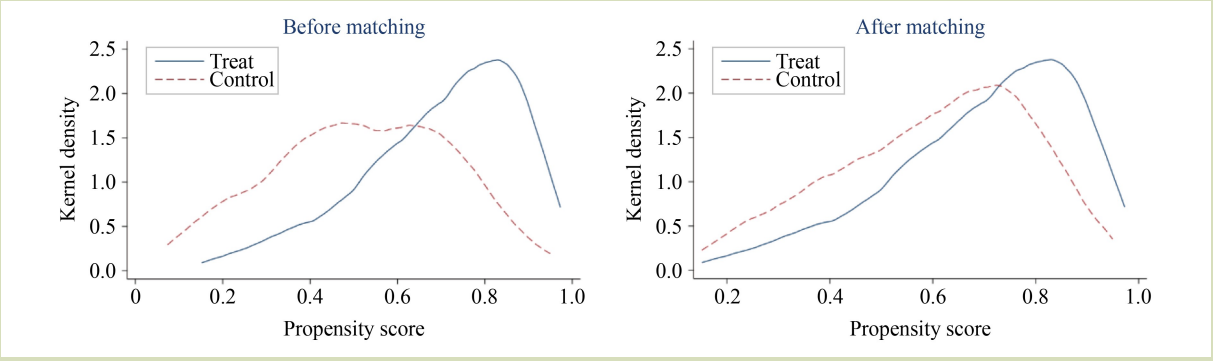


Fig. 2 Common support domain before and after matching.

confirming that the common support assumption was satisfied and that the matching effect was adequate.

4.3 Balance test

A core objective of PSM is to achieve balanced distributions of explanatory variables between treatment and control groups. After matching tea farmer samples, the significance of differences in explanatory variables between the two groups was rigorously tested (Table 4). The results indicated that post-matching, the mean bias in explanatory variables was substantially reduced, and the overall bias declined markedly. According to Rosenbaum and Rubin[45], a standardized bias exceeding 20% after matching indicates a failed match, rendering the data unsuitable for PSM. In this study, the standardized bias of all matched samples remained below 20%. Figure 3 further illustrates that the standardized biases of explanatory variables were significantly reduced after matching, confirming that the matching quality was satisfactory.

4.4 Multidimensional effects of socialized service adoption

Table 5 presents the multidimensional effects of tea farmer adoption of socialized services, estimated using four different

Table 4 Results of balance test

Matching method	Pseudo R^2	LR	p-value	Mean bias	Med bias
Before matching	0.148	175	0.000	25.7	18.7
K-nearest neighbor matching	0.012	18.4	0.105	6.60	6.30
K-nearest neighbor matching within a caliper	0.011	17.5	0.134	6.40	6.10
Radius matching	0.008	11.7	0.469	5.10	4.70
Kernel matching	0.008	11.8	0.459	5.10	4.70

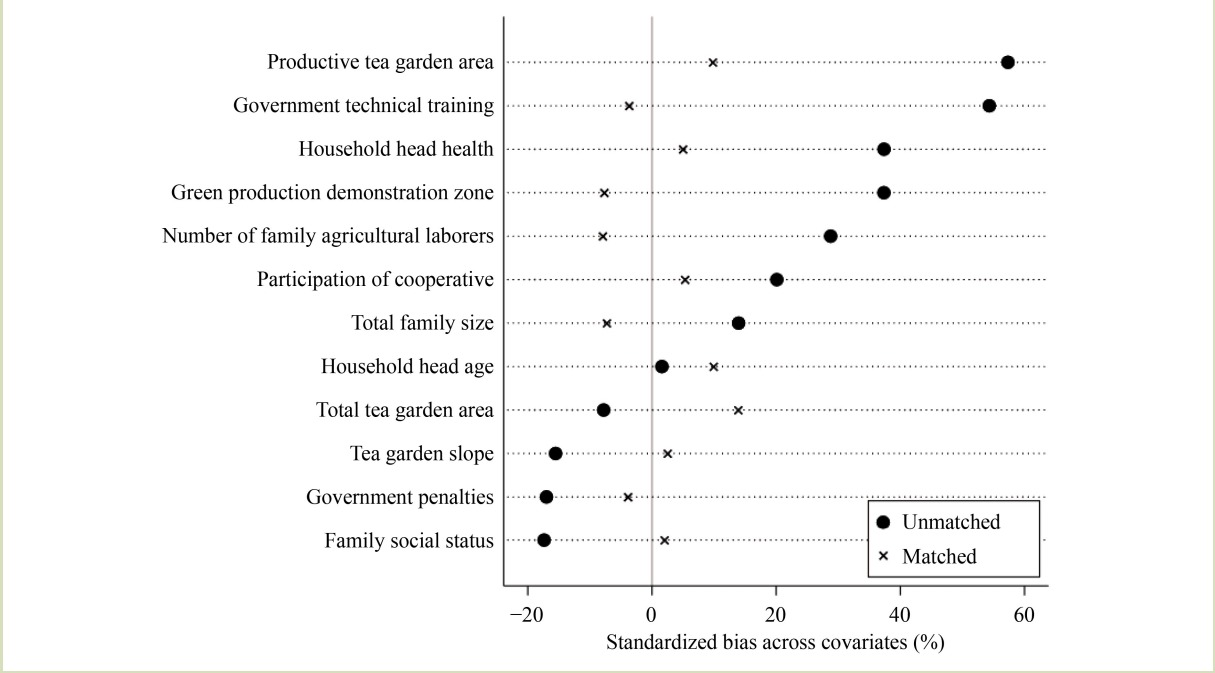


Fig. 3 Standardized bias of explanatory variables after matching.

Table 5 Multidimensional effects of socialized service adoption on tea farmers

Variable	Matching method	Mean of treatment	Mean of control	ATT	*t*-value
Total income	K-nearest neighbor matching	2.12	1.93	0.189	2.49**
	K-nearest neighbor matching within a caliper	2.12	1.93	0.189	2.51**
	Radius matching	2.12	1.95	0.174	2.42**
	Kernel matching	2.12	1.95	0.174	2.42**
Tea income	K-nearest neighbor matching	0.995	0.675	0.319	5.55***
	K-nearest neighbor matching within a caliper	0.995	0.677	0.317	5.53***
	Radius matching	0.995	0.674	0.321	5.93***
	Kernel matching	0.995	0.673	0.322	5.95***
Inflow area of tea gardens	K-nearest neighbor matching	0.0646	0.0281	0.0364	1.14
	K-nearest neighbor matching within a caliper	0.0646	0.0281	0.0364	1.14
	Radius matching	0.0646	0.0322	0.0324	1.10
	Kernel matching	0.0646	0.0323	0.0322	1.09
Outflow area of tea gardens	K-nearest neighbor matching	0.0532	0.112	−0.0585	−1.83*
	K-nearest neighbor matching within a caliper	0.0532	0.116	−0.0626	−1.97*
	Radius matching	0.0532	0.102	−0.0490	−1.68*
	Kernel matching	0.0532	0.102	−0.0487	−1.66*
Quantity of green technology adoption	K-nearest neighbor matching	3.07	2.75	0.321	2.46**
	K-nearest neighbor matching within a caliper	3.07	2.74	0.324	2.49**
	Radius matching	3.07	2.74	0.329	2.66***
	Kernel matching	3.07	2.74	0.327	2.65***
Time of green technology adoption	K-nearest neighbor matching	3.55	3.56	−0.0117	−0.18
	K-nearest neighbor matching within a caliper	3.55	3.56	−0.0168	−0.26
	Radius matching	3.55	3.58	−0.0357	−0.56
	Kernel matching	3.55	3.58	−0.0338	−0.53
SWB	K-nearest neighbor matching	11	10.7	0.311	1.95*
	K-nearest neighbor matching within a caliper	11	10.7	0.309	1.94*
	Radius matching	11	10.7	0.263	1.74*
	Kernel matching	11	10.7	0.263	1.74*

Note: ***, ** and * indicate the significance at 1%, 5% and 10% levels, respectively.

matching methods across economic, technical, land and happiness dimensions. Given that different matching algorithms produce varying common support intervals, sample loss differs between methods, creating slight variations in matching between treatment and control groups. Nevertheless, as given in Table 5, after controlling for observable variable differences, the results from all four matching methods were largely consistent, with the *ATT* significant at least at the 10% level. These findings indicate that the matching results are robust and reliable.

From a counterfactual perspective, regarding economic effects, the *ATT* for the total income of tea farmers ranged from 0.174 to 0.189, significant at the 5% level. This indicates that, after controlling for other factors, adoption of socialized services increased total income by 17.4%–18.9% compared to non-adopters. The *ATT* for tea income ranged from 0.317 to 0.322, significant at the 1% level, indicating that socialized service adoption raised tea income by 31.7%–32.2%. These effects are likely to have arisen because socialized services enhanced factor allocation efficiency, reduced production costs, and increased revenue. Additionally, support from socialized service organizations allows farmers to expand operations and achieve economies of scale, leveraging professional and organizational advantages. Since tea income constituted a substantial portion of total household income, these improvements directly elevated overall income. Hypothesis H5 is thus confirmed.

For land allocation, the adoption of socialized services by tea farmers did not significantly affect the inflow area of tea gardens but had a significant negative impact on land outflow, reducing it by 4.87%–6.26% at the 10% significance level. This effect most likely arose because socialized services alleviated capital and labor constraints in farmland management, enabling farmers to achieve higher returns through self-operation compared to leasing land to others. Consequently, tea farmers were incentivized to retain their land, confirming Hypothesis H6.

For technical adoption, the *ATT* for the quantity of green technology adoption ranged from 0.321 to 0.329, significant at the 5% level, indicating that adopters of socialized services used 32.1%–32.9% more green production technologies than non-adopters. This effect most likely arose from socialized services promoting environmentally friendly practices and facilitating greater frequency and diversity in the use of green technologies. In contrast, socialized service adoption did not have a significant impact on the timing of green technology implementation. Hypothesis H7 is thus confirmed.

For SWB, the *ATT* ranged from 0.263 to 0.311, significant at the 10% level, indicating that adoption of socialized services increased tea farmer SWB by 26.3%–1.1%. Mechanized and organized socialized services reduce labor dependence in tea production, freeing up time for farmers to engage in leisure activities or personal pursuits, which in turn enhances overall well-being. Hypothesis H8 is therefore confirmed.

4.5 Multidimensional effects of different socialized service stages

Building on the analysis of the overall multidimensional effects of socialized service adoption, this section further examines the specific impacts of pre-, during- and post-production services using K-nearest neighbor matching (K = 4). As presented in Table 6, the effects varied across different service stages, with each link demonstrating distinct multidimensional effects.

Adoption of pre-production socialized services had significant positive effects on total income, significant at the 10% level, and on SWB, significant at the 1% level. This effect most likely arose because pre-production agricultural technology training

Table 6 Multidimensional effects of different socialized service stages

Variable	Pre			During			Post		
	Treatment	Control	ATT	Treatment	Control	ATT	Treatment	Control	ATT
Total income	2.12	1.99	0.126*	2.21	2.08	0.127	2.31	1.95	0.361***
Tea income	0.912	0.893	0.0185	1.06	1.03	0.0229	1.29	0.757	0.529***
Inflow area of tea gardens	0.0456	0.0354	0.0102	0.0819	0.0791	0.0028	0.0602	0.0575	0.0028
Outflow area of tea gardens	0.0546	0.0528	0.00190	0.0186	0.0683	−0.0497**	0.0553	0.0482	0.0070
Quantity of green technology adoption	2.90	2.97	−0.0653	3.25	3.04	0.210	3.28	2.73	0.550***
Time of green technology adoption	3.49	3.60	−0.101	3.48	3.60	−0.123	3.62	3.56	0.0571
SWB	11.1	10.7	0.413***	11.2	10.9	0.280	11.1	10.8	0.291*

Note: ***, ** and * indicate the significance at 1%, 5% and 10% levels, respectively.

gave tea farmers greater theoretical knowledge, enhancing their understanding of the benefits of socialized services. Such training broadens access to information and promotes more scientific and efficient tea cultivation, thereby increasing household income. Also, acquiring new knowledge during training boosts the cognitive skills and confidence of farmers in tea planting, and because less physical labor is required at this stage, their SWB was correspondingly enhanced.

Adoption of during-production socialized services have a significant negative impact on tea garden outflow area, significant at the 5% level. This effect most likely arose because during-production activities, such as fertilizing, pruning and weeding, require considerable labor and time. Prior to adopting socialized services, tea farmers with limited labor and time resources were more inclined to lease their land to large-scale operators. The introduction of organized, professional and mechanized services streamlines these tasks, reducing labor dependence and production costs. Consequently, tea farmers were more likely to retain their land, decreasing land outflow and reducing the propensity to transfer land.

Adoption of post-production socialized services had significant positive effects on total income, tea income, the quantity of green technology adoption and SWB, with significance at the 1% and 10% levels. Professional market services reduce search costs, while stable buyer relationships secure consistent transaction profits and minimize intermediary markups, thereby increasing both tea and total household income. Specialized post-production picking services used professional tools to prevent tea contamination and tree damage, maintaining quality and yield without compromising green processing practices. Additionally, logistics services reduced transportation costs and preserve tea quality through professional handling, enabling higher sales prices. Collectively, these post-production services saved farmers time, labor and costs across picking, transportation and trading processes, thereby enhancing their overall SWB. Compared to during-production services, post-production socialized services are more significant for enhancing both income and SWB. This greater impact most likely arose from the market-empowerment nature of post-production services, which not only reduce transaction costs but also generate dual benefits by increasing income and improving happiness through value-added distribution, risk mitigation, and the reconstruction of social identity.

4.6 Group difference analysis

The PSM analysis evaluated the multidimensional effects of tea farmer adoption of socialized service but did not capture structural differences between treatment and control groups as reflected by the *ATT*. Since the household head served as the family decision-maker, their characteristics are pivotal for shaping livelihood strategies and influencing the adoption of socialized services. Also, variations in village infrastructure endowments might have resulted in differential multidimensional effects, which could depend on both individual and village-level factors. Accordingly, this study grouped samples based on household head education (an individual characteristic) and road infrastructure (a village characteristic), using K-nearest neighbor matching (K = 4) to examine between-group differences in the multidimensional effects of socialized service adoption.

4.6.1 Group difference analysis based on individual characteristics

The data in Table 7 indicates that for tea income, socialized service adoption produced significant positive effects for both household heads with primary school education or lower and those with junior high school education or higher, with significance at the 1% level. The *ATT* values were 0.390 and 0.370, respectively, indicating that adoption increased tea income by 39.0% and 37.0% compared to non-adopters. This larger income gain for primary-educated farmers might have resulted from their greater dependence on tea planting as their primary livelihood, whereas those with junior high education or higher had higher human capital and often participated in non-farm labor, leading to relatively lower engagement in tea production.

For land transfer, socialized service adoption by primary-educated tea farmers significantly reduced land outflow, with an *ATT* of −0.0945, representing a 9.45% decrease. In contrast, for household heads with junior high education or higher, adoption significantly increased land outflow, with an *ATT* of 0.0326, or a 3.26% rise. This divergence can be attributed to differences in resource reliance and labor allocation: lower-educated farmers leverage socialized services to overcome resource constraints, improve planting efficiency and enhance profitability, thereby reducing their willingness to lease out tea gardens. Conversely, higher-educated farmers, often engaged in off-farm work, prefer transferring land to large-scale growers due to limited time for agricultural management.

Table 7 Group differences in the multidimensional effects of socialized service adoption

Variable	Primary school and below			Junior high school and above			Better road infrastructure			Poorer road infrastructure		
	Treatment	Control	ATT	Treatment	Control	ATT	Treatment	Control	ATT	Treatment	Control	ATT
Total income	2.18	2.01	0.172	2.07	1.80	0.272	1.89	1.78	0.116	2.16	1.99	0.170*
Tea income	0.929	0.540	0.390***	0.960	0.590	0.370***	0.786	0.383	0.403***	1.030	0.790	0.243***
Inflow area of tea gardens	0.049	0.0511	−0.0022	0.137	0.0797	0.0574	0.0679	0.0677	0.0002	0.0663	0.0308	0.0355
Outflow area of tea gardens	0.055	0.150	−0.0945**	0.0326	0	0.0326*	0.0543	0.0472	0.007	0.0534	0.0998	−0.0464
Quantity of green technology adoption	2.89	2.66	0.235	3.04	2.33	0.714**	2.03	2.12	−0.0833	3.31	2.95	0.357**
Time of green technology adoption	3.55	3.69	−0.141	3.68	3.49	0.192	3.73	3.79	−0.0556	3.51	3.53	−0.0201
SWB	11.2	10.3	0.842***	11	11	−0.0412	10.5	10.3	0.153	11.1	10.8	0.290

Note: ***, ** and * indicate the significance at 1%, 5% and 10% levels, respectively.

For the quantity of green technology adoption, tea farmers with junior high education or higher exhibited a significant increase in the use of green technologies. Their higher educational attainment enhanced their ability to learn and adopt new practices, such as green production methods, while also reflecting a stronger preference for ecological sustainability and environmental quality.

For SWB, tea farmers with primary education experienced a substantial increase of 84.2% (ATT = 0.842), while no significant effect was observed for higher-educated farmers. This difference might have been related to the older age of lower-educated farmers: socialized services free up leisure time for hobbies and personal interests, and their lower life pressures, often associated with retirement or reduced work responsibilities, contribute to enhanced well-being.

4.6.2 Group difference analysis based on village characteristics

The data in Table 7 shows that in villages with better road infrastructure, total income was significantly higher (ATT = 0.403, representing a 40.3% increase). Improved transportation enhanced access to off-farm employment and non-agricultural activities, thereby increasing non-farm income and overall household earnings.

For tea income, socialized service adoption had a significant positive effect in both villages with better and poorer road infrastructure at the 1% level. However, the effect was more pronounced in villages with poorer infrastructure, indicating that in less developed areas, socialized services substantially improve productivity and efficiency, resulting in greater income growth.

For the quantity of green technology adoption, villages with better road infrastructure exhibited a stronger positive effect from socialized service adoption (ATT = 0.357, a 35.7% increase). Improved infrastructure facilitated the implementation and operability of green production technologies, making adoption both more feasible and effective.

Although heterogeneity analysis offers valuable insights into differentiated effects, it is important to acknowledge its potential limitations, including reduced statistical power and systematic differences arising from sample partitioning. These constraints do not diminish the value of the current findings. Future research could leverage panel data from longitudinal surveys or use machine learning techniques to identify natural groupings more effectively.

4.7 Endogeneity test

In this study, total income might have potentially had a reverse influence on the adoption of socialized services. To address this potential endogeneity, we followed the approach of Yao and Li[46], applying the instrumental variable (IV) method. The

chosen IV is the GI count (geographical indications count). The rationale was twofold. First, GI certification typically requires tea farmers to adopt specific cultivation and processing techniques, which incentivizes greater reliance on socialized services. In the first stage regression, the IV significantly affects the adoption of socialized services ($p < 0.05$), satisfying the relevance condition of IV estimation. Second, the designation of GIs is generally based on historical reputation, natural conditions, or traditional practices, rather than contemporaneous economic behavior of tea farmers, making it unlikely to correlate with current total income in a way that would induce reverse causality. This satisfies the exogeneity condition for a valid IV. The IV regression results are presented in Table 8.

As shown in Table 8, in the first stage, the IV GI count had a statistically significant effect on socialized service adoption ($p < 0.05$), leading to the rejection of the null hypothesis and indicating that there was no issue of weak identification. The weak instrument test yielded a value of 22.9, well above the Stock-Yogo threshold of 16.4 at the 10% significance level, confirming the strength of the instrument. In the second stage, after addressing endogeneity, socialized service adoption remained a significant positive determinant of total income ($p < 0.05$), consistent with the baseline results. This robustness check reinforced the conclusion that socialized services increase income, even after controlling for potential reverse causality.

4.8 Exploration of the happiness code

This study examined not only the influencing factors and multidimensional effects of tea farmer adoption of socialized services but also how such adoption impacts their SWB, revealing the underlying happiness code.

Specifically, this study used a bootstrap method in Stata with 5000 resamples at a 95% confidence interval. Starting from the adoption of socialized services and extending to SWB, we tested the mediating effects of total income, tea income and the quantity of green technology adoptions. Compared to standard stepwise regression, the bootstrap method provides more accurate confidence intervals and greater statistical power for evaluating multiple mediating pathways. The results are presented in Table 9.

Total income as a mediator: In the pathway, socialized service adoption → total income → SWB, the indirect effect was 0.095 (95% CI of 0.029–0.162, $p = 0.005$), indicating a significant partial mediating effect. This indicates that total income partially mediated the relationship between socialized service adoption and SWB. A possible explanation is that adopting socialized services improved production efficiency and reduced costs, thereby increasing total income. This allows tea farmers to earn more without additional labor input, enhancing their SWB by alleviating work-related burdens.

Tea income as a mediator: In the pathway, socialized service

Table 8 IV test result

Variable	First stage	Second stage
	Socialized services adoption	Total income
Socialized services adoption		1.26***
		(0.395)
GI count	0.156***	
	(0.0330)	
Constant	–0.673*	2.56***
	(0.388)	(0.801)
Control variables	Yes	Yes
Under identification test	22.7***	
Weak identification test	22.9	
Sample	895	895

Note: ***, ** and * indicate the significance at 1%, 5% and 10% levels, respectively, standard errors in parentheses.

Table 9 Mediation effect result

Mediation pathway	Mediating effect		95% CI		*p*-value
	Coe	Std	Upper limit	Lowe limit	
Socialized services adoption → Total income → SWB	0.095	0.034	0.029	0.162	0.005
Socialized services adoption → Tea income → SWB	0.100	0.029	0.042	0.157	0.001
Socialized services adoption → Quantity of green technology adoptions → SWB	0.081	0.120	0.029	0.132	0.002
Socialized services adoption → Leisure time → SWB	0.087	0.029	0.030	0.143	0.003

adoption → tea income → SWB, the indirect effect was 0.1 (95% CI of 0.042–0.157, p = 0.001), indicating a significant partial mediating effect. This indicates that tea income partially mediated the relationship between socialized service adoption and SWB. The mechanism could involve reduced search and purchase costs for production inputs, optimized production processes and improved agricultural efficiency[24], which collectively increased tea income and enhanced farmer well-being.

Quantity of green technology adoptions: In the pathway, socialized service adoption → quantity of green technology adoptions → SWB, the indirect effect was 0.081 (95% CI of 0.029–0.132, p = 0.002), confirming a significant partial mediating effect. This indicates that the adoption of green technologies partially mediated the relationship between socialized service adoption and tea farmer SWB. By increasing the use of green technologies, farmers improved ecological practices and production efficiency, which contributed to enhanced well-being. A plausible explanation is that adopting socialized services reduces the use of fertilizers and pesticides[47], promotes green transformation and increases the adoption of green technologies. This improves the ecological environment, mitigates agricultural pollution and enhances living quality, thereby boosting tea farmer SWB. Thus, Hypothesis H9 is validated.

Leisure time: In the pathway, socialized service adoption → leisure time → SWB, the indirect effect was 0.087 (95% CI of 0.030–0.143), with a p-value of 0.003, indicating statistical significance at the 1% level. These results confirm a significant mediating effect, showing that leisure time partially mediated the relationship between socialized service adoption and SWB. The underlying mechanism is that agricultural socialized services restructure the time allocation of farmers, reducing high-intensity labor and freeing them to engage in family interactions and personal development activities. This increase in leisure time ultimately enhances SWB, supporting Hypothesis H9 It should be noted that although mechanization through socialized services reduces labor time, some tea farmers still choose to extend their working hours. This behavior is closely linked to the local productivity perception that diligence can make up for lack of ability.

Although this study revealed the potential pathways through which social services affect SWB via leisure time, certain measurement limitations must be acknowledged. We used the number of close contacts as a proxy for leisure time rather than directly measuring its duration. This decision was based on two main considerations. First, rural China is characterized by an acquaintance society, where leisure activities in a village are largely embedded in social interactions within the community. As Wang[48] noted, the dense network of acquaintance-based relationships means that farmer leisure is primarily realized through village-level social interaction. Second, previous studies have confirmed a significant link between social interaction and leisure time[49–51]. Thus, using the number of close contacts as a proxy for leisure time is reasonable to some extent. Nevertheless, we recognized limitations such as potential estimation bias arising from the absence of direct measurement of leisure duration. Therefore, future research should adopt more precise methods, such as time diaries, to further validate and refine the findings of this study.

5 Conclusions and policy implications

5.1 Conclusions

This study constructed a multidimensional theoretical framework to examine tea farmer adoption of socialized services, utilizing field survey data from key tea-producing

regions in Anhui, Shaanxi and Sichuan Provinces of China. Using PSM and mediation effect models, we empirically analyzed the determinants and multidimensional effects of socialized service adoption and further explore its relationship with tea farmer SWB. The key findings were as follows.

The age of the household head, health status, number of agricultural laborers, productive tea garden area, government technical training, presence of green production demonstration zones and participation in cooperatives all had significant positive effects on tea farmer adoption of socialized services, whereas tea garden slope, government penalties and family social status had negative effects. Also, the factors influencing tea farmer adoption of socialized services differed across various service links.

The adoption of socialized services by tea farmers had multidimensional impacts: it effectively curbed land outflow, increased the quantity of green technology adoption, elevated income levels and enhanced SWB. Specifically, the adoption of pre-production socialized services significantly improved total income and SWB, during-production service adoption strongly reduced the outflow area of tea gardens and post-production service adoption significantly enhanced total income, tea income, the adoption of green technologies and SWB.

There were notable differences in the multidimensional effects of tea farmer adoption of socialized services across varying educational levels of household heads and different village endowments. Compared with farmers at other educational levels, household heads who had attained junior high school education or above gained stronger benefits from adopting socialized services, including increased tea income, expanded tea garden outflow areas and greater adoption of green technologies. Similarly, villages with superior road infrastructure gained more pronounced positive effects from socialized service adoption on total income, tea income and the quantity of green technology adoption compared with villages with less developed endowments.

Further mechanism analysis indicated that the adoption of socialized services by tea farmers can indirectly influence their SWB through total income, tea income and the extent of green technology adoption. In other words, total income, tea income and green production act as mediating factors between the adoption of socialized services and farmer SWB.

5.2 Policy implications

Based on the above conclusions, the following policy implications are proposed.

To strengthen positive driving factors and mitigate negative inhibitory factors, several strategies can be implemented. First, design age-appropriate socialized service programs for elderly tea farmers, such as providing lightweight mechanized services and remote technical guidance to reduce physical dependence. Second, policy incentives should encourage returning youth to engage in the tea industry, thereby enriching the agricultural labor force and leveraging the scale effects of family agricultural labor. At the same time, financial subsidies and tax incentives can reduce cooperative operation costs, promoting cooperatives to deliver comprehensive chain services, including pre-production technical guidance, during-production mechanized services and post-production unified sales, thus enhancing the organizational capacity of tea framers. Finally, in areas with steep tea garden slopes, intensify research and development and promote mechanized equipment for mountainous tea gardens to alleviate terrain-related constraints on socialized service implementation. Simultaneously, government supervision should be standardized by minimizing penalties and replacing punitive measures with educational guidance and demonstration initiatives.

Socialized tea services should be tailored to the characteristics of individual tea farmers by accurately identifying differences in their resource allocation and improving services through localized adaptations. In promoting the adoption of socialized services, emphasis should be placed on coordinating service modes, costs and household resource endowments for farmers. Service providers are encouraged to develop customized service packages based on the specific characteristics of farmers, enhancing participation through demand-oriented approaches and thereby strengthening the effectiveness and mechanism of socialized services within the tea industry.

Differentiated social service policies for tea farmers should be designed according to the characteristics of different groups. First, tea farmers with lower educational levels should be prioritized in training and publicity programs related to socialized tea services to raise their awareness and enhance adoption effectiveness. Second, in villages with poor infrastructure, the effectiveness of socialized services can be improved through precise technical adaptations and innovative

service models, such as shared equipment initiatives that compensate for infrastructural shortcomings.

Efforts should be made to consolidate existing achievements in socialized tea services while addressing the subjective and spiritual well-being of farmers. Governments and research institutions should focus on improving or maintaining mechanical efficiency in current processes and in less mechanized segments, advanced technological elements can be introduced through outsourced services to substitute for agricultural labor and enhance productivity. This approach would allow tea farmers to allocate more leisure time to non-agricultural activities and personal pursuits, ultimately improving their SWB.

Although this study constructed a multidimensional theoretical framework for tea farmer adoption of socialized services, empirically analyzed the influencing factors and multidimensional effects using the PSM model and mediating effect model, explored the determinants of tea farmer SWB and provided targeted policy recommendations based on the empirical results, it is important to acknowledge certain limitations. Specifically, the use of cross-sectional data might fail to capture dynamic changes and unobserved heterogeneity among individuals could affect the findings. Additionally, the study has some limitations regarding mechanism of analysis and endogeneity; the mechanisms adopted are not fully comprehensive and the handling of endogeneity might be insufficient, potentially introducing bias. Although these issues have been addressed as much as possible following expert guidance, the primary focus of this study remained on evaluating the factors influencing socialized service adoption and its multidimensional impacts. Future research can further deepen understanding of the mechanisms linking socialized services to tea farmer well-being.

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Compliance with ethics guidelines

Xueqing Wu, Lipeng Li, and Tichen Shan declare that they have no conflicts of interest or financial conflicts to disclose. This article does not contain any studies with human or animal subjects performed by any of the authors.

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