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Research article

Understanding the mediating role of labor out-migration in household income generation and distribution under a reforestation policy in rural China

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ABSTRACT

Income inequality is a critical issue of socio-economic development, particularly in rural areas where forest-dependent people are often vulnerable to the intervention of forest policies. This paper aims to elucidate income distribution and inequality of rural households influenced by China's largest reforestation policy implemented in early 2000s. Drawing on socioeconomic and demographic data from household surveys in two rural sites, we applied the Gini coefficient to measure income inequality and used a regression-based approach to examine the underlying factors that are associated with income generation among households. We also performed a mediation analysis to test the role of labor out-migration in shaping household income distribution under the reforestation policy. Results show that remittances sent by rural out-migrants substantially contribute to household income but tend to worsen inequality, particularly for households having retired cropland for reforestation. The inequality in total income depends on capital accumulation for land endowment and labor availability that render diversified livelihoods possible. Such linkage reveals regional disparity, which, along with policy-implementing institutions (e.g., rules for tree species choice for reforestation), can influence income generation from a given source (e.g., agriculture). Rural out-migration of female labor significantly mediates the economic benefits of the policy delivered to the households with an estimated mediating share of 11.7%. These findings add value to the knowledge of poverty-environment interrelationships in a sense that supporting rural livelihoods of the more vulnerable and underrepresented groups is essential for securing and sustaining the stewardship of forests. Policymaking for such forest restoration programs needs to integrate strategies for targeted or precise poverty alleviation to strengthen the conservation effectiveness.

1. Introduction

Inequality is a critical issue for socio-economic development. Despite the rapid economic growth over the last few decades, the uneven distribution of resources (e.g., capital, income, information) persists, compromising human wellbeing (Boix, 2010; Ravallion, 2014; Xie and Zhou, 2014; Zhang and Awaworyi Churchill, 2020) and the efforts to achieve UN Sustainable Development Goals, such as zero hunger and poverty eradiation (Liu and Cheng, 2022; United Nations, 2015). The inequality issue is even more acute in rural areas, where livelihoods are often vulnerable to unexpected shocks and uncertainties, and the rural communities are usually intimately tied with the natural environment (Andersson and Agrawal, 2011; Cheng et al., 2018). A study in Zambia, for instance, suggested that serious concerns about poverty reduction had arisen when elite land capture worsens rural income inequality (Sitko and Jayne, 2014). Ignoring such aspects of disparities would distract the effort for sustainable development through policy interventions.

Payments for environmental services (PES) has been recognized as a novel policy tool for sustainable environmental conservation (Wunder

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et al., 2020). The principle of PES leverages a "rewarding" mechanism (e.g., financial incentives) to link ecosystem services to economic incentives. Through channeling a transaction flow from the ecosystem service beneficiaries to the ecosystem service providers, a third party (e.g., the government) often acts as an intermediate agency to initiate the payment-making process. Expecting to produce a win-win result (Muradian et al., 2013; Schirpke et al., 2018; Wu et al., 2019), the ecosystem service providers receive the compensation that help alleviate their burden of forgoing nature-based livelihoods in exchange of securing the environmental service deliveries (e.g., clean water, climate warming mitigation). Studies have well documented the socioeconomic-ecological impacts of PES programs worldwide (Aguilar and Wen, 2021) and suggested that the socioeconomic aspects play a critical role in making PES programs successful. The success in securing ecosystem services relies on the improved livelihoods in a long run (Alix-Garcia et al., 2018; Ezzine-de-Blas et al., 2019).

China has initiated multiple ecological projects at the national level based on the PES principles (Lu et al., 2018). Among the new forest policy initiatives, the Conversion of Cropland to Forest Program (CCFP), has attracted attention worldwide due to magnitude of investment, spatial scale, and the engagement of its population. To compensate for the opportunity cost of reforestation on previously cultivated cropland, the Chinese central government provided participating households with cash or in-kind subsidies. During the land-targeting process of the CCFP, the poor households with cropland on environmentally sensitive areas are more likely to be encouraged to enroll their land parcels into the CCFP (He and Lang, 2015; Song et al., 2014). As a results, the CCFP carries a side goal of alleviating rural poverty and improving social welfare. By 2017, forty one million rural households have participated in the CCFP, creating 10.2 million ha of plantation forests on cropland on steep slopes or otherwise ecologically fragile areas for soil and water conservation. The Chinese government paid a total of $55 billion in cash compensation to these households for the soil and water conservation services these lands provide (Lu and Yin, 2020; NFGA, 2018). The CCFP and a series of other concurrent greening efforts have pushed China's forest change to a turning point, a transition from deforestation to forest regeneration (Chen et al., 2019; He et al., 2014; Ke et al., 2020; Youn et al., 2017).

One socioeconomic aspect of the CCFP impacts is income distribution and inequality among households (Table S1), as studies suggested that the program may affect local livelihoods through influencing income stability (Chang et al., 2021). Income inequality also relates to the sustainability of forests the program has created. To fully retain the ecosystem services by the newly planted trees, the targeted cropland parcels should form a patch of forest stand sufficiently large in size. The targeting process is no easy task, as the governmental agency needs to encourage a group of households to voluntarily enroll their land parcels adjacent to each other. Even more essential is to sustain the forest stands, which involves "collective decisions" (Bennett et al., 2014; Zhang et al., 2017). The enhancement of livelihoods for the participating households is critical to fulfilling the obligation of land stewardship. This echoes the expectation that the success of PES programs, such as the CCFP, often relies on the change of local livelihoods with income-generating activities (Gauvin et al., 2010; Groom and Palmer, 2012; He and Lang, 2015; Jack et al., 2008).

Income of rural households can be sourced from multiple and diversified livelihood activities (Liu and Lan, 2015). Previous research has shown that households participating in the CCFP may change livelihoods by allocating more labor to conduct non-agricultural activities, such as off-farm employment (Démurger and Wan, 2012; Lin and Yao, 2014; Treacy et al., 2018). Among all livelihood activities, rural out-migration has become the most important source of income, as households with migrants receive remittance (Delang, 2019; Kelly and Huo, 2013; L. Li et al., 2021; Treacy et al., 2018; Wu et al., 2019; Yao et al., 2010). Studies suggested that remittance can account over 25% of total household income and nearly 50% of total non-agricultural income (Zhang et al., 2019). However, some migrants may encounter difficulty in seeking stable employment and maintain the financial support for their origin households, which indirectly causing disparity of household income that relying primarily on non-agricultural livelihoods. Furthermore, general contextual factors (e.g., local physical environmental condition) can further influence the capability of migration and hence their behavior of sending remittances. Whether households with migrants can capitalize such high-risk, high reward livelihood strategy remains elusive and uncertain. Migration can be a major linkage between the forest policy and household livelihood outcomes.

This study examines income distribution and inequality engendered by out-migration affected by China's largest reforestation program, the CCFP. The analyses draw on data from household surveys in two geographic regions with contrasting contextual conditions, one located in a subtropical monsoon climate and the other situated in the semi-arid Loess Plateau. We aim to answer the research question: how does the CCFP influence household income inequality and what is the underlying mechanism? Given remittance from migrants often accounts for the greatest share of total income in these rural regions, the mediation role of labor allocation for migration is evaluated as a pathway of policy impacts on household income.

2. Theoretical framework

The analysis in this research is framed by the widely recognized idea of sustainable livelihoods (DFID, 1999; Ellis, 2008; Scoones, 1998) with extended theory in migration-environment nexus (Bilsborrow and Henry, 2012; de Sherbinin et al., 2008; Neumann and Hilderink, 2015) (Fig. 1). The development thinking for poverty reduction concerns how households conduct livelihood activities to improve their welfare. The acting performance highlights transformations among different types of capital (i.e., financial, physical, natural, human, social). Households are deemed risk-averse, aiming at minimizing potential disastrous consequences from shocks and uncertainties, such as market failure in agriculture (Davis and Lopez-Carr, 2014). The nexus of migration and the environment acknowledges the interrelationships between household livelihoods and land use change (Bilsborrow and Henry, 2012). For instance, the loss of farm labor due to migration may incur fallow innocuous to the recovery of land productivity (Davis and Lopez-Carr, 2014). One limitation of the sustainable livelihood framework is that it attenuates the macro-level context, such as institution, market, and policy, in shaping household behaviors. Regarding the policy intervention, PES programs influence households' livelihood decisions via land conversion and cash compensation. The outcomes from multi-dimensional perspectives can be used for policy evaluation and adjustment.

Guided by the "sustainable livelihoods" framework, this study formulates three hypotheses as follows. H1: Under the CCFP, the composition of household income sources changes through a livelihood shift from on-farm to off-farm activities, contributing to income generation while also influencing income inequality among households. H2: The distribution of household income depends on households' capital setting and building, namely the endowment of the different capital forms and the contextual factors representing regional conditions. H3: Labor migration with expectation of remittances sent to the origin households play a mediating role in forming household income distribution and migrants with different genders affect the disparity of income inequality among households under the CCFP.

3. Data and methods

3.1. Study areas and data

The study draws on data collected from household surveys in two rural areas of China (Fig. S1). One study area encompasses two neighboring townships, Checheng and Jichang (C&J hereafter) Townships,

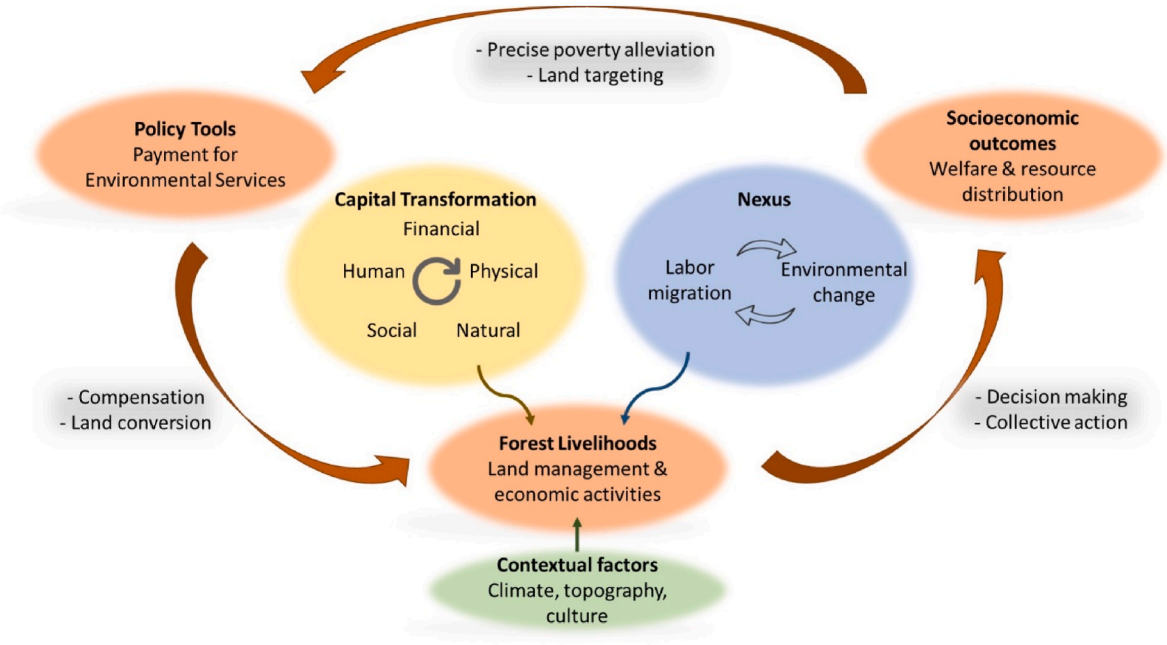

Fig. 1. Conceptual framework for analyzing household income generation and distribution from livelihood activities based on capital settings under the influence of the forest policy.

located in the Loess Plateau in southwest Shanxi, China. The other study area, Tiantangzhai (TTZ hereafter) Township, is situated in western Anhui in the Dabie Mountain Ranges with a subtropical monsoon climate. Farm households in both areas earn income from multiple avenues, including growing subsidence crops (e.g., rice, corn, wheat), raising livestock (e.g., goat, cattle, and poultry), pursuing local non-farm employment, running small non-farm local business, and sending out migrants. Governmental subsidies (e.g., for fertilizer and farm machinery) also contributed to their income. The CCFP was implemented in both areas in 2002, encouraging farm households to retire marginal cropland parcels on steep slopes for forest plantation. Meanwhile, both study area witnessed non-trivial trends of rural-to-urban migration (Zhang et al., 2020). Out migration can potentially bring significant remittances to origin households. The migration has become a major diversification of rural livelihoods, with implications to the sustainability of forests created by the CCFP.

We carried out two household surveys in TTZ of Anhui in 2014 and C&J of Shanxi in 2015. Using a two-stage stratified disproportionate sampling scheme (Bilsborrow, 2016), two survey teams of well-trained graduate students interviewed the sampled households. Ideally, the household head should be chosen as the respondent, but a household member who has knowledge in day-to-day activities (e.g., spouse or parent) would also be qualified as a substitute if the head was not available. In case no household member was qualified, the household would not be interviewed. All respondents were clearly informed with the research aims and scopes and our strategy of confidential information protection. Any respondent who refused to take the survey would not be interviewed. The survey questions cover a wide range of topics, such as land use, individual migration status, income sources, expenditures, and CCFP participation, which allow the examination of household income and distributions. Data were collected for 481 and 251 households in TTZ and C&J, respectively. Among the interviewed households in C&J, seven households did not provide any information on income sources and were excluded. Thus, the final sample size in this study includes 725 households.

3.2. Identification of income sources from different livelihoods

Household income in the study areas comes from agricultural activities, non-agricultural activities, and governmental subsidies (Aguilar and Wen, 2021). Farm households generate agricultural income from crops and livestock, while earning non-agricultural income through non-farm employment or self-employed small businesses. Since remittances are often the major share of household income (Song et al., 2014), we separated remittance from other sources. In addition, CCFP compensation was also separated as an independent source despite its nature similar to other governmental subsidies under the umbrella of general agri-environmental policies. In occasional cases, households receive income from miscellaneous sources such as social gifts following the local traditions. Therefore, we identified income sources into six categories: agricultural income, CCFP payment, non-agricultural income (excluding remittance), remittance from out-migrants, governmental subsidies (excluding CCFP payment), and other income.

Agricultural income from crops and livestock consists of two parts: one for sale and the other for self-consumption. The part sold was directly reported during the interview, while the self-consumed part was estimated based on the unit price in the local area. Agricultural income was the sum of the two parts subtracting the associated costs (e.g., fertilizer, labor employment expenditure). The CCFP payment was calculated as the product of the amount of cropland enrolled in the program and the areal payment rate. Non-agricultural income was the sum of the profit of running local non-farm businesses and the earned salaries of local non-farm employment. Finally, total household income was the sum of net income from all the six income sources. For a given household, its net income from each of the six sources can be computed using the following equations.

$$Agricultural\ income: Y_1 = \sum_{m=1}^{M}(H_m + \eta_m D_m) \tag{1a}$$

$$CCFP\ payment: Y_2 = \sum_{m=1}^{M}\eta_m A_m \tag{1b}$$

$$Non\ agricultural\ income: Y_3 = \sum_{m=1}^{M} {W_m}^I (B_m - E_m)^{1-I} \tag{1c}$$

$$Remittance: Y_4 = \sum_{m=1}^{M} T_m \tag{1d}$$

$$Governmental\ subsidy: Y_5 = \sum_{m=1}^{M} U_m \tag{1e}$$

$$Other: Y_6 = \sum_{m=1}^{M} O_m \tag{1f}$$

In Eqs. (1a)–(1f), Y_1, Y_2, Y_3, Y_4, Y_5, and Y_6 refer to incomes from agriculture, CCFP, non-agriculture, remittance, subsidy, and other sources, respectively; m indicates an item for a category of income source (e.g., Y_1 *for income from* crops and livestock). M is the number of income items from each source, and it is different for each source. In Eq. (1a), H is the amount of income from selling harvested crops or raised domestic animals; η is the unit price from a certain crop or livestock; D is the amount of harvested or possessed items (e.g., the number of goats raised). In Eq. (1b), γ is the payment rate of the CCFP; A is the amount of cropland enrolled in the program. In Eq. (1c), W is the wage earned from local non-farm employment; B and E are gross income and cost from running a non-farm business; I is an indicator of the source type, 1 denoting employment and 0 denoting business. In Eq. (1d), T is the amount of remittance from a migrant. In Eq. (1e), U is the amount of subsidy from a certain type (e.g., fertilizer). In Eq. (1f), O is the amount of income from other sources (e.g., social gifts).

3.3. Gini coefficients and income inequality decomposition

We used the Gini coefficient to measure income distribution and inequality since it is widely applied and can be decomposed into parts of multiple income sources with straightforward meanings (Novignon, 2017). Gini can be derived based on the numerical integration of the Lorenz curve, or analytically estimated with the distribution of income and its ranking form. Given a sufficiently large number of observations, the estimated Gini values will be nearly the same based on the two methods (Leibbrandt, 2000). Here, we took advantage of the Lorenz curves for graphical visualization and used the analytical methods for Gini calculation because the latter is more straightforward for Gini decomposition into various sources. Let y_i be total income for household i and r (y_i) be the rank of y_i divided by the number of households, Gini can be calculated as:

$$G = \frac{\sigma([y_1, y_2, y_3, \ldots, y_n], [r(y_1), r(y_2), r(y_3), \ldots, r(y_n)])}{(1/2n)\sum_{i=1}^{n} y_i} \tag{2}$$

where n is the total number of households of interest; σ is the covariance between two vectors of household income and normalized rank of income.

Suppose that total income from K sources, total income inequality can be formed from the sum of the product of three parts of each source (Stark et al., 1986). The first is inequality measured in Gini of income of source k itself (G_k); the second is the correlation of income of source k with total income ranking (R_k); the last is the proportion of income of source k in total income (S_k). Equations for calculating each part and their relationships with total income inequality are as follows.

$$Part\ 1: G_k = \frac{\sigma([y_{1k}, y_{2k}, y_{3k}, \ldots, y_{nk}], [r(y_{1k}), r(y_{2k}), r(y_{3k}), \ldots, r(y_{nk})])}{(1/2n)\sum_{i=1}^{n} y_{ik}} \tag{3a}$$

$$Part\ 2: R_k = \frac{\sigma([y_{1k}, y_{2k}, y_{3k}, \ldots, y_{nk}], [r(y_1), r(y_2), r(y_3), \ldots, r(y_n)])}{\sigma([y_{1k}, y_{2k}, y_{3k}, \ldots, y_{nk}], [r(y_{1k}), r(y_{2k}), r(y_{3k}), \ldots, r(y_{nk})])} \tag{3b}$$

$$Part\ 3: S_k = \frac{\sum_{i=1}^{n} y_{ik}}{\sum_{i=1}^{n} y_i} \tag{3c}$$

$$Decomposition: G = \sum_{k=1}^{K} G_k R_k S_k \tag{3d}$$

where y_{ik} is the income of source k by household i, and r (y_{ik}) is the rank of income of source k by household i among all households; σ denotes the function of covariance.

One useful information based on the Gini decomposition is provided by pseudo-Gini coefficient (C_k), calculated as $C_k = R_k \times G_k$ and interpreted as the relative contribution of income of source k to total income inequality (Raffinetti et al., 2017). If $C_k > G$, source k income worsens total income inequality; if $C_k < G$, it lessens total income inequality; G can be viewed as the reference degree of inequality regarding Gini decomposition. Furthermore, to test the sensitivity of G to a small change of income of source k, the absolute (δ_k) and relative (φ_k) marginal effect of an increase in income of source k from some exogenous intervention can be derived. Let θ_k be a small amount of the change factor to income of source k for a household (e.g., a 1% increase), the two effects are calculated as:

$$Absolute\ marginal\ effect: \delta_k = \frac{\partial G}{\partial \theta_k} = G_k R_k S_k - G S_k \tag{4a}$$

$$Relative\ marginal\ effect: \varphi_k = \frac{\partial G}{G \cdot \partial \theta_k} = \frac{G_k R_k S_k}{G} - S_k \tag{4b}$$

Rural households may receive zero income, which is rare for total income but common for some income sources. For example, a substantial number of households did not send any out-migrant and hence received no remittance. Those receiving zero income can bend down the Lorenz curve in lower income ranks and substantially enlarge income inequality of that source and of all. Thus, it offers additional information when only non-zero incomes are considered for inequality among a given source. The equations for calculating the non-zero proportion (P_k) and inequality of non-zero incomes ($G_{A,k}$) are:

$$P_k = \frac{\sum_{i=1}^{n} i(i|y_{ik} > 0)}{\sum_{i=1}^{n} i} \tag{5a}$$

$$G_{A,k} = \frac{G_k - 1}{P_k} + 1 \tag{5b}$$

3.4. Mixed-effects modeling

We followed the livelihood framework (Ellis, 2008) to guide the modeling of income generation and understanding its distribution as well as inequality. Rural households utilize and transform capital in multiple forms (e.g., physical capital) to generate income as financial capital. For example, land endowment enables or facilitates the extraction of natural capital such as fuelwood and crops, and such livelihoods rely on the availability of labor force as human capital. With the increasing trends of rural-to-urban migration, theories in migration can also shed light on how origin households expect and seek economic return through investing with farm labor. According to the New Economics of Labor Migration (Stark and Bloom, 1985), households are the unit of making decisions to allocate labor for out-migration with an aim of risk diversification.

We estimate household income based on models driven by livelihood capitals and the contextual factors (Table S2), including demographic factors, migration status, livestock ownership, cropland area, farm and non-farm labor, forest resource availability, and household wellness

status (Table S3). Meanwhile, the CCFP, which directly converted previously cultivated land into forest, was included as an exogenous variable representing the policy effect. To consider the regional difference, a dummy variable for the study site was also created, capturing the systematic differences of contextual factors such as climatic and topographic conditions. Finally, migration behavior by gender has been shown to be different (Zhang et al., 2018), which may have different effects on household income. Thus, we derived three variables pertaining to *i) migration in general*, *ii) female migrants*, *iii) male migrants*, and tested their effects with three separate models. Based on statistical tests, there exist statistically significant differences between the two study areas for most explanatory variables. For example, TTZ (with subtropical climate in Anhui) is 24.5% more likely than C&J (with semi-arid climate in Shanxi) to send at least one migrant since 2003; the difference is even more prominent for female migrants, as the difference is as large as 25.2%.

We used the mixed-effects approach to construct the models. The mixed effects include both fixed and random effects that are versatile in handling hierarchical data or data with implicit nested characteristics (Pan and Bilsborrow, 2005). For example, a household member may take advantage of the social networks to seek migration opportunities to cities where other migrants from the same resident group may facilitate the process. Thus, households within the same resident group may pursue similar livelihood options than those from different resident groups, making it worthwhile to estimate variance among resident groups. Using the natural logarithm of income as the outcome variable, the model performed in STATA can be written as:

$$ln(y_j) = X_j\beta + Z_j\xi_j + \varepsilon \tag{6}$$

where j indicates the resident group that a household belongs to; y_j is an $n \times 1$ vector of household income; X_j is an $n \times p$ matrix of explanatory variables; Z_j is an $n \times q$ matrix corresponding to the cluster random effects and set to be the scalar of 1 in this study; β capture the fixed effects of the explanatory variables; ξ captures the random effects at the group level; ε captures the random effects among households.

3.5. Contributions of explanatory factors to income inequality

To estimate the share of contribution of each explanatory variable to inequality of household total income, we adopted the regression-based method (Wan and Zhou, 2005) for the analysis. This approach, despite its computational intensity, is powerful in linking underlying factors to household income distribution and inequality (Luh and Wei, 2019). The underlying principle is to compare predicted income distribution with and without setting the value of a given variable into its mean for all households. However, the computing process involves multiple rounds of settings with rapid increase in complexity when more explanatory variables are included, which can be elucidated as follows. Let G [.] be the function of deriving the Gini coefficient and $F(.)$ be the function of the modeling income, given an explanatory variable X_p (vector of $n \times 1$) or the pth predictor, the initial round (Round 0) of estimation is:

Round 0 (initial):

$$\Delta G_0 = G[Y] - G\left[F_Y\left(X \mid X_p = \mu_p\right)\right] \tag{7}$$

where Y is an $n \times 1$ vector of household income; X is an $n \times P$ matrix of the explanatory variable; μ is an $n \times 1$ vector of the mean values of the explanatory variables. This equation estimates the extent to which income inequality would change if the values of the explanatory variable were equal for all households while others remain as they were.

In the next round (Round 1), the estimation pertains to two explanatory variables, X_p and X_t ($t \neq p$), measuring the difference of income inequality between the settings of both variables at their means and that of only X_p at its mean. When there is more than one variable for X_t, the estimation takes the average of the differences for all possible X_t. The number of the possibilities is a combination of choosing one variable from all P-1 variables (excluding X_p), noted as $C_{P\text{-}1,1}$. The equations are:

Round 1:

$$\Delta G_{1,t} = G[F_Y(X \mid X_t = \mu_t)] - G\left[F_Y\left(X \mid X_t = \mu_t, X_p = \mu_p\right)\right]$$

$$\Delta G_1 = \frac{1}{C_{P-1,1}} \sum_{1}^{C_{P-1,1}} \Delta G_{1,t} \tag{8}$$

Following this thread, in a given round (Round r), where an $n \times r$ vector X_T is involved, more general formulas are:

Round r:

$$\Delta G_{r,T} = G[F_Y(X \mid X_T = \mu_T)] - G\left[F_Y\left(X \mid X_T = \mu_T, X_p = \mu_p\right)\right]$$

$$\Delta G_r = \frac{1}{C_{P-1,r}} \sum_{1}^{C_{P-1,r}} \Delta G_{1,T} \tag{9}$$

Therefore, the total number of all possible combinations are $C = 1 + C_{P\text{-}1,1} + \ldots + C_{P\text{-}1,P\text{-}1}$; the final contribution of explanatory variable p to total income inequality is estimated as:

$$\Delta G = \frac{1}{P} \sum_{r=0}^{P-1} \Delta G_r \tag{10}$$

This process applies to all explanatory variables included in the model. All equations in this section were performed with R and the Gini coefficients were estimated using the "Gini_RSV" function (Raffinetti et al., 2015). Based on the estimated effects of explanatory variables to total income inequality, the contributions of the factors relative to the Gini coefficients of their own were also derived.

3.6. Mediation analysis of CCFP effects on income generation through out-migration

Mediation analysis is useful to test the pathways of effects from an independent variable to an outcome variable that is transmitted through a third variable, while it also relies upon strong causal directions based on theory or empirical understanding (Fiedler et al., 2011). In this case, the CCFP has been shown to influence household labor allocation on migration since it frees farm labor from land cultivation with the land retirement for reforestation (Démurger and Wan, 2012; Lin and Yao, 2014). Therefore, we test the intermediate role of migration in income generation from the CCFP, constructing the models as follows.

$$ln(Income) = \gamma_1 + \tau \cdot CCFP + \beta X + \varepsilon_1 \tag{12a}$$

$$Migration = \gamma_2 + \lambda \cdot CCFP + \beta X + \varepsilon_2 \tag{12b}$$

$$ln(Income) = \gamma_3 + \kappa \cdot CCFP + \omega \cdot Migration + \beta X + \varepsilon_3 \tag{12c}$$

where γ_1, γ_2 and γ_3 are intercepts; ε_1, ε_2 and ε_3 are error terms; X are control variables, β being their fixed effects; τ captures the total effects of the CCFP on household income; the product of λ and ω, $\lambda\omega$, captures the mediating effects from CCFP to income through migration; κ captures the direct effects of CCFP on income. The share of the mediating effect is the total effect is $\lambda\omega/\tau$. We again evaluated three mediators including whether a household sent out any migrant, any female migrant, or any male migrant outside the county boundaries.

4. Results

4.1. Descriptive statistics of income levels from diverse sources

Among the sampled households, 56% (271) of the 481 sampled in the TTZ and 51% (127) of the 251sample in the C&J are CCFP participants, who had retired some cropland to establish new forests. The levels of total household income and income from diverse sources are different

between the two study areas (Fig. S2). In C&J, income from agricultural activities constitute the majority of total income, which is followed by income from local non-agricultural activities such as off-farm employment. In TTZ, however, local non-agricultural income and remittance make up the lion's share of total income, although agricultural income is still substantial. The effect of CCFP on household income is large and statistically significant ($p = 0.06$) in the C&J site, with mean total annual income being 38,184 Yuan (~US$6139) and 28,618 Yuan (~US$4601) for participants and nonparticipants, respectively. In contrast, the CCFP effect on household income in the TTZ is not as large and strong with mean total annual income for participating households being 35,541 Yuan (~US$5714), which is only 5% (statistically insignificant) higher than nonparticipants (33,726 Yuan, or ~ US$5422). Comparing the two study sites, households in C&J receive significantly more agricultural income and CCFP income but less non-agricultural income and remittance than those in TTZ. The income from governmental subsidies and other sources are similar between the two sites.

4.2. Total household income inequality and decomposed effects of income sources

Dividing households into CCFP participants and nonparticipants, the total household inequality manifested from the Lorenz curves reveals different shapes between the two study sites (Fig. S3). In both sites, the rankings of CCFP participants show similar curve shapes, suggesting similar levels of income inequality. However, the curve for the TTZ nonparticipants is closer to the line of perfect equality with a relatively low Gini coefficient (0.438) compared to participants (0.462). However,

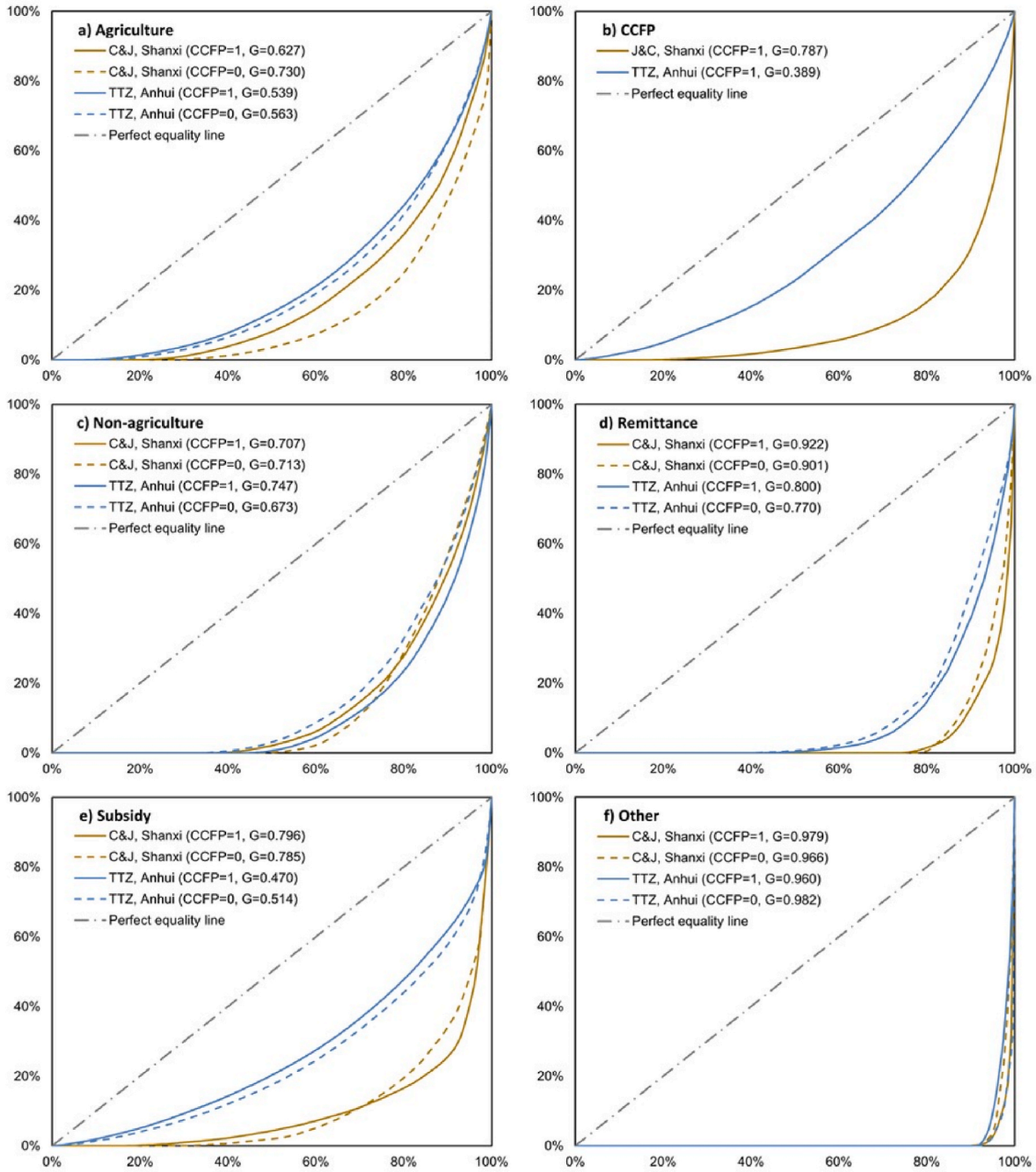

Fig. 2. Lorenz curves for inequality of income of different sources by CCFP participation. Note: G denotes Gini coefficient. In panel (b), Lorenz curves of CCFP payments for nonparticipants are not applicable since nonparticipants do not receive any compensation from the program.

the curve for the J&C nonparticipants exhibits a bent curve farther away from the line of perfect equality showing a much stronger inequality (0.534) than their counterparts (0.458). Thus, relative to non-participants, CCFP participants in the semi-arid J&C have a lessened inequality while those in subtropical TTZ have a slightly worsened inequality.

By separating total income to incomes from various sources, differences exist between households with and without CCFP participation as well as between the two study areas, as shown from the Lorenz curves and Gini coefficients (Fig. 2). The largest regional discrepancy of the inequality levels is reflected through CCFP, remittance, and government subsidies. Compared to TTZ, households in J&C showed much higher degrees of inequality for the income from CCFP (for participants only), remittance, and other governmental subsidies. Among them, remittance sent by migrants stands out with an extremely high level of inequality ($G > 0.90$ for J&C, and $G > 0.77$ for TTZ); many households receive zero remittance due to either no remittance sent by any migrant or no migrant at all, as seen from the flat parts of the curves composed by over 40% of lower-ranking households (also see P_k in Table 1). Finally, agricultural income reveals a more uneven distribution for non-participants ($G = 0.730$) than participants ($G = 0.627$) in J&C, while the difference in TTZ is comparatively small.

The comparison of the pseudo-Gini coefficient (C_k) of each income source and the Gini coefficient (G) as the baseline further demonstrates the substantial effects of certain source income (e.g., remittance) on total income inequality (Fig. 3). For CCFP participants in both sites, remittances from migrants have higher values of C_k than G, worsening total inequality. Other sources that worsen G include local non-agricultural activities in TTZ and agricultural activities in J&C, while the remaining sources tend to lessen G for both participants and non-participants in both sites. By analyzing the detailed components for calculating G and C_k (Table 1), the relationship of C_k of each income source with G can be explained from the following aspects. In C&J, the proportion of households receiving non-zero income (P_k) from remittance is only 26% for participants (24% for nonparticipants) which is the smallest among all the sources, meaning that most households do not receive any income from migration. Given its high Gini coefficients (G_k) ranging 0.90–0.92, the inequality in remittance itself can worsen total income inequality despite its moderate correlation with total income (R_k). In subtropical TTZ, both the large proportions of remittance-receiving households (58%–61%) and the high correlations with total income (0.71–0.72) contribute to the much greater extent to which remittance expands total household income. Regarding agricultural and non-agricultural sources, agricultural income positively contributes to G while non-agricultural income negatively contributes to G, in C&J; the effects are opposite in TTZ.

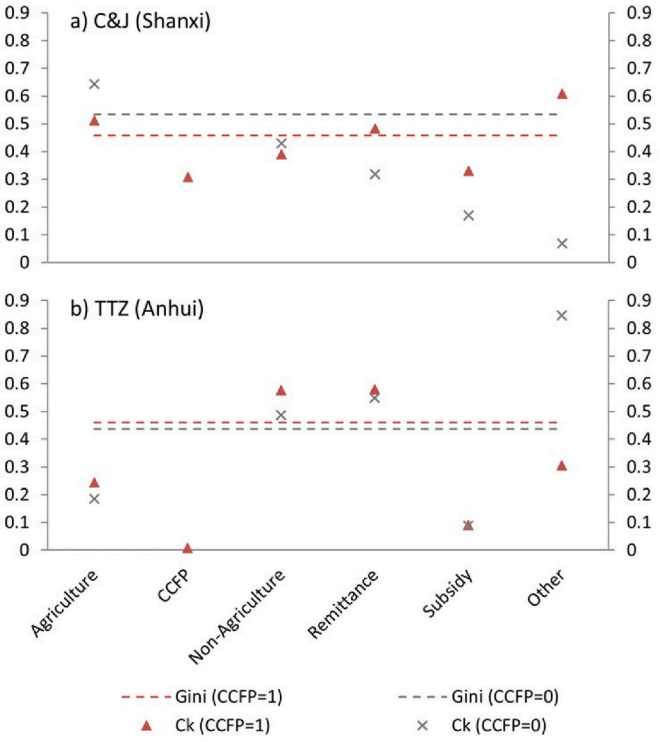

Fig. 3. Pseudo-Gini and Gini coefficients by income sources.
Note: A pseudo-Gini coefficient value of a given income source above the reference line of the Gini coefficient value means that the increase in income from that source worsens income inequality; a lower pseudo-Gini value below the reference line indicates a mitigating effect. Gini coefficients at the reference lines in TTZ (Anhui) are 0.461 (CCFP participants) and 0.438 (nonparticipants); Gini coefficients at the reference lines in C&J (Shanxi) are 0.458 (CCFP participants) and 0.560 (nonparticipants). Statistics of components for calculating pseudo-Gini and Gini coefficients are shown in Table 1.

4.3. Estimated effects of explanatory factors on income distribution and inequality

According to the mixed-effects models, the distribution and

Table 1
Components of Gini coefficients by CCFP participation.

Source	CCFP Participants (CCFP = 1)							Non-participants (CCFP = 0)						
	S_k	R_k	G_k	δ_k	φ_k	P_k	$G_{A,k}$	S_k	R_k	G_k	δ_k	φ_k	P_k	$G_{A,k}$
C&J (Shanxi)														
Agriculture	0.55	0.82	0.63	0.030	0.065	84%	0.56	0.60	0.88	0.73	0.066	0.123	76%	0.64
CCFP	0.05	0.39	0.79	−0.008	−0.018	83%	0.74	0.00	N/A	N/A	N/A	N/A	N/A	N/A
Non-Agriculture	0.24	0.55	0.71	−0.017	−0.036	64%	0.54	0.27	0.60	0.71	−0.028	−0.053	52%	0.45
Remittance	0.06	0.52	0.92	0.002	0.003	26%	0.70	0.06	0.35	0.90	−0.014	−0.026	24%	0.59
Subsidy	0.07	0.41	0.80	−0.009	−0.020	84%	0.76	0.05	0.22	0.79	−0.019	−0.036	71%	0.70
Other	0.02	0.62	0.98	0.003	0.006	10%	0.79	0.01	0.07	0.97	−0.005	−0.009	8%	0.56
TTZ (Anhui)														
Agriculture	0.24	0.45	0.54	−0.052	−0.112	93%	0.50	0.19	0.33	0.56	−0.047	−0.107	89%	0.51
CCFP	0.01	0.02	0.39	−0.003	−0.007	100%	0.39	0.00	N/A	N/A	N/A	N/A	N/A	N/A
Non-Agriculture	0.38	0.77	0.75	0.044	0.095	56%	0.55	0.41	0.72	0.67	0.020	0.045	66%	0.51
Remittance	0.30	0.72	0.80	0.036	0.078	58%	0.65	0.31	0.71	0.77	0.035	0.079	61%	0.62
Subsidy	0.06	0.19	0.47	−0.024	−0.051	100%	0.47	0.06	0.17	0.51	−0.021	−0.049	100%	0.51
Other	0.01	0.32	0.96	−0.001	−0.003	8%	0.53	0.03	0.86	0.98	0.014	0.031	8%	0.78

Note: G_k - Inequality indicated by Gini coefficient of income distribution by source k; R_k - Correlation between income of source k with total household income; S_k - Share of income of source k in total household income; δ_k - Absolute change of inequality of total household income with a unit of marginal increase in income of source k; φ_k - Relative change of inequality of total household income with a unit of marginal increase in income of source k; P_k - Proportion of non-zero income of source k, i.e., income source applicable for households; $G_{A,k}$ - Inequality indicated by Gini coefficient for non-zero income of source k; N/A - Not applicable.

inequality of income among rural households can be explained by a variety of factors (Table S4). First, there exist systematic differences between the two study sites, which are captured by the significant effects of the regional dummy variable on household income distribution. Second, the participation in the CCFP positively influences income generation with statistically significant effects, whose magnitudes and significance levels are shown to be robust across all the three models. CCFP participation contributes about 3.4%–4.5% to the annual household total income in J&C and 4.8%–6.4% in TTZ. Third, regarding migration as a main household livelihood strategy, sending an out-migrant(s) can significantly increase household income (coef. = 0.260, $p < 0.05$) and explains 3.3% and 2.7% of income inequality in J&C and TTZ, respectively (Model 1). The positive effect (Model 2) of sending a female migrant(s) is comparatively stronger (coef. = 0.324, $p < 0.10$); the share of contribution to income inequality is less in J&C (2.1%) than in TTZ (4.4%), suggesting that female migration in the subtropical site accounts more for the discrepancy of income among households comparing to the semi-arid Loess Plateau site. Moving onto male migration (Model 3), despite its statistical significance ($p < 0.10$), the effect is much weaker (coef. = 0.133), which subsequently leads to relatively small contributing shares (only 1.5%) in both study sites. Last, other factors of capital endowment (e.g., physical capital including transportation tools) that indicate multiple livelihood activities also reveal significant effects on bringing economic return and well explain inequality reflected with regional differences (J. Li et al., 2021). For example, large cropland size significantly contributes to household income in semi-arid J&C, differentiating income levels to a greater degree with agricultural production than in subtropical TTZ.

After estimating the effect of an explanatory variable on income inequality based on Eqs. (7)–(10), we then linked this effect to the inequality of the given variable (Table S5). Specifically, for an explanatory variable (e.g., education), we derived the ratio of its effect on income inequality to the Gini coefficient of this variable, and defined this ratio as the relative contribution of the variable to income inequality. Across the three models regarding migration (i.e., migration of both genders, male migration, and female migration) as well as separation by study sites, nearly all factors exhibit consistent and stable effects, their own inequality being the base. Regarding CCFP and migration of primary interest in this study, we observe rather robust effects of CCFP on income generation, but major differences exist in migration of different genders (Fig. S4). Specifically, given the base Gini coefficient (0.451) of CCFP participation, the relative contribution is slightly higher for the model controlling for male migration (5.5%) than the other two models controlling for migration of both genders (4.3%) and female only (4.4%). Meanwhile, compared with Gini of male migration (0.548), the Gini coefficient of sending female migrants (0.655) is higher with larger relative contribution (2.7% vs. 1.2%). Such difference from both aspects is more prominent in the subtropical TTZ site (3.3% vs. 1.4%), suggesting that discrepancy in female migration in this region accounts more for the inequality of total household income.

4.4. Estimated results of mediation analysis

Based on the estimated results of the mediation analysis (Table S4, Table S6), the path diagrams show the influencing paths (κ) from CCFP to household income, as well the mediation path ($\lambda\omega$) through migration (Fig. 4). Without considering gender, the mediated effect ($\lambda\omega/\tau$) of sending a household member for out-migration accounts for 11.4% of the total influence of CCFP on household income. The mediation effect is shown to be strong as demonstrated by the statistically significant associations between the variables along the pathway from CCFP to household income. When considering the female migration, sending a female migrant exhibit a slightly stronger effect for mediating CCFP's influence to household income (11.7%) with the path correlations statistically significant. Last, we do not find evidence that supports the mediation effect of male migration, given the insignificant association along the path from CCFP to male migration. Regional difference plays a substantial role in household income as well as migration decisions, particularly male migration (Table S6). Social development policy in migration destinations may influence the success in migration and subsequently their behaviors of sending remittances (Koley, 2022). Focusing on labor migration as a livelihood strategy, these results suggest that the effects of the reforestation policy on the generation and inequality of household income can be shaped by household decision on mainly allocating female laborers for migration regardless of the systematic difference incurred by different geographic regions.

5. Discussion

This study investigates household income inequality and its underlying influencing factors with an emphasis on rural out-migration affected by a reforestation policy. We analyzed the role migration in shaping household income distribution in the context of China's CCFP. A major finding is that there exists difference in income inequality between CCFP participants and non-participants, and such difference also differs between the two study areas (Table 1). The difference may be explained by the local contextual factors that influence the composition of income sources (Fig. S2). In the semi-arid Loess Plateau (J&C), agricultural activities (including orchards) generate much more income than alternatives supporting household livelihoods, while the CCFP offering a substantial number of economic trees (e.g., walnut), adding to such income sources with profitable outputs, as in many cases in other regions of China (He and Lang, 2015; Wang and Maclaren, 2012). This can be evidenced by that inequality of agricultural income is much more lessened among the participant group (G = 0.63) when compared to the non-participant group (G = 0.73), and that the former is made up with more households with non-zero income from this source (84% vs. 76%). The composition of income sources highlights the major contribution from non-agricultural activities (local off-farm work and remittance). One consistent outcome in both study areas is that remittances from rural out-migrants negatively contribute to the distribution of total household income (Fig. 3), namely worsening inequality (except for the non-participant group in J&C), which motivates the scrutinization of

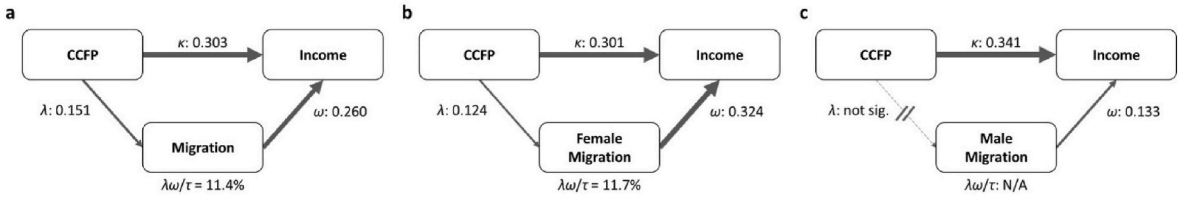

Fig. 4. Estimated mediation effects of a) migration, b) female migration, and c) male migration on household income generation under impacts of CCFP participation and their shares in total effects.
Note: τ is the total effect of the CCFP on household income; $\lambda\omega$ is the mediating effect of migration from CCFP to income; κ is the direct effect of CCFP; $\lambda\omega/\tau$ (100%) is the share of the mediating effect in the total effect. Effects are estimated based on mixed-effects models specified in Eq. (12a,b,c). Solid lines are effects that are statistically significant with line widths corresponding to the effect magnitudes; the dash line is the effect that is not statistically significant.

this source and its associated livelihood strategy.

In line with the expectation of livelihood change, labor migration has the potential of abridging the discrepancy in economy between rural areas and urban areas through the flows of materials and information (Howell, 2017; Luo et al., 2020). However, on the destination side, whether rural migrants can be successful in cities can be impeded by multiple factors such as institutional restriction of registration, insurance coverage, etc. (Song et al., 2014; Wang and Bennett, 2008); on the side of the origin households, obstacles such as lacking access to market or social connections further hamper the initiation of the migration process, especially for households possessing less livelihood capitals (Mullan et al., 2011). Within the context of development policy and demographic processes (J. Li et al., 2021), income distribution can be conditioned on these two aspects: the capability of initiating migration by origin households and the success of out-migrants in substantializing the origin households via remittance. In our study, the subtropical area (TTZ) witnessed a more outstanding adjustment of household livelihoods (Fig. 2 and Table 1), a shift from farm to non-farm work (particularly migration) echoing findings in previous studies (Lin and Yao, 2014; Qu et al., 2011). Offering assistance for skill-lacking out--migrants in cities can be beneficial for realizing the expected economic return via remittances received by the origin households. In the semi-arid Loess Plateau area (J&C), development policy tools aiming at the poorer households limited by natural capital (e.g., agricultural land) should emphasize the needs for the local households to overcome local barriers (e.g., inaccessibility to market) and hence create opportunities for poorer households to start migration. This can be further corroborated by the significant effects of the various livelihood capitals, such as cropland in lessening income inequality (Table S4 and Table S5).

Previous studies documented the gender role of rural-to-urban migration and their effects on household income (Bastia et al., 2020; Fan, 2003; Irudaya Rajan and Bhagat, 2018) and some covered the same topic within the context of forest policy (Andersson and Agrawal, 2011; Colfer et al., 2016; Sijapati Basnett, 2013). Our study adds value to understanding household livelihoods and income inequality under forest policy through the lens of migration with gender differences. Regression-based decomposition also suggests that compared to male migration (1.5%), female migration possesses a higher contributing share (2.1%–4.4%) of income inequality measured in Gini (Table S4). In both study areas, the opportunity for female labor to migrate out is lower than that for male labor indicated by the greater Gini of the former. Grounded by the evidence of relaxed labor liquidity constraints under the CCFP (Kelly and Huo, 2013; Lu and Yin, 2020; Uchida et al., 2009), our major finding takes a step forward by emphasizing the role of female migration in alleviating inequality and mitigating poverty. The results suggest that CCFP may yield additional livelihood changes regarding the decision-making of out-migration by female laborers. Such implicit additionality is estimated to be nearly 12% (Fig. 4) of the overall socio-economic benefits as measured in household income. This gender difference may also contribute to expanding the explanations in the literature for the seemingly controversy in farm labor transfer under the CCFP (Li et al., 2011; L. Li et al., 2021; Treacy et al., 2018; Wu et al., 2019; Yin et al., 2014).

Our research not only advances theoretical understanding of human-environment interrelationships in land systems (Rindfuss et al., 2004; Verburg et al., 2015) but also broaden scopes of policy practices aiming at ecological conservation and rural development (Koley, 2022; Wunder et al., 2020). Rural households intricately and frequently interact with the environment through land management, which can be reflected by conducting resource-based livelihoods. The poorer often constitutes the vulnerable group that often faces the most critical challenges in livelihood diversification towards sustainability (Liu and Lan, 2015). With the incrementally augmented reliance on natural capital (e.g., farming crops, harvesting timber, hunting wildlife), a dearth of livelihood options would be expected to be concomitantly aggravated, the so-called poverty trap (Grosjean and Kontoleon, 2009) or the plight of "vicious circle of poverty" (Cheng et al., 2018; Liu and Cheng, 2022). Capital transformation is theoretically considered as a solution for getting the poor get out of poverty traps. A typical example revealed in our case is the household labor allocation for migration, a way of investment in human capital in expectation for economic return as financial capital while risking the natural capital of land resources due to the loss of farm labor. The CCFP, both providing cash subsidy and converting land use types, is believed to ease the land security of participating households (Mullan et al., 2011) that are strongly motivated to sending out migrants. Such behavior can potentially modify the human-environmental relationships by strengthening (or weakening) the efforts of ecological restoration (Jokisch et al., 2019; Yin et al., 2020). On the one hand, households with successful migrants may take advantage of the remittances received to expand portfolio for sustainable livelihoods, being more willing to keep the trees planted (Song et al., 2014). On the other hand, migrants facing challenges tend to incur extra burden on their origin households, worsening the situation of the latter in socio-economic capital building. Therefore, the uneven distribution of remittances for CCFP-participating households would eventually compromise the integrity of forests. Forest policies based PES principles, like the CCFP, should be implemented in combination with strategies that facilitate targeted poverty alleviation (Liu and Cheng, 2022) for the vulnerable and marginalized groups needing the most.

6. Conclusions

This study focuses on understanding the mediating effects of rural out-migration on household income inequality in rural China where the largest reforestation program, the CCFP, was implement. We found that remittance from migrants contributes to income generation and inequality, while female and male migrants play different roles in shaping household income inequality under the CCFP. Policymakers need to take into account income distribution among participating households in order to better manage natural resources from the forests created by the policy. Developing mechanisms helping rural migrants to overcome difficulty in seeking economic opportunities is recommended to alleviate income gaps and strengthen the sustainability of both forests and local livelihoods in rural areas. We acknowledge the limitations of this study. Our main aim is to examine the factors of capital setting that shape the income distribution of rural households, but the results cannot reflect the dynamics of livelihood outcomes due to the lack of panel data. Nor does our work examine the contextual factors and unexpected events (e.g., global economic slowdown, COVID-19 pandemic, natural hazards) in a rigorous manner, as it requires an expansion of study scopes in terms of geographic regions, data acquisitions, and research topics. Following-up efforts include designing research methodologies within the context of macro-level changes, obtaining datasets for the same household samples or in other regions with high levels of representativeness, and/or elevating the study scope from a global perspective via comparative analysis with other policy tools in different countries.

Credit author statement

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Declaration of competing interest

The authors declare no conflicts of interest.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2023.118539.

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