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Environmental Evidence

SYSTEMATIC REVIEW

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China's conversion of cropland to forest program: a systematic review of the environmental and socioeconomic effects

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Abstract

Background: Farming on sloping lands has historically led to forest loss and degradation in China, which coupled with unsustainable timber extraction activities, was deemed responsible for catastrophic flooding events in the late 1990s. These events led to the introduction of forest policies targeting ecological conservation and rural development in China, a process epitomized by the launch of the conversion of cropland to forest program (CCFP) in 1999. This systematic review responds to the question: *What are the environmental and socioeconomic effects of China's Conversion of Cropland to Forest Program after the first 15 years of implementation?*

Methods: Based on the published protocol, we searched for English language studies published between 1999 and 2014, and screened them for relevance and eligibility in two stages (titles and abstracts followed by full texts), after which they were further assessed for potential sources of bias before data extraction and analyses. Following initial screening of 879 titles and abstracts, 169 studies underwent full text screening, followed by 61 studies being subjected to quality assessment. Eighteen papers did not meet minimum quality criteria, while the remaining 43 papers were eligible and underwent data extraction and subsequent analyses. Among the final set of 43 studies were four national-level studies, seven regional-level studies, and 32 county-level (or below) studies. The majority of studies were published after 2009 and evaluated impacts within the first 5 years of CCFP implementation, such that the long-term impacts of the program remain open for further investigation.

Results: A skewed temporal and geographic distribution of the examined studies limits the generalizability of the results, though the evidence base confirms a substantial increase in forest cover and associated carbon stocks linked to reallocation of sloping agricultural land to forest. To some degree, soil erosion has been controlled and flood risk reduced at local scales. Meanwhile household incomes have increased and rural employment has readjusted towards off-farm sectors. However, some studies also indicate instances of diminished food security and increasing social inequality. Finally, several studies indicate suboptimal regional or localized trade-offs among specific ecosystem services, including carbon sequestration vs. water discharge rates, flood control vs. riparian soil replacement, and forest productivity vs. biodiversity.

Conclusions: Additional research on long-term environmental impacts and program effects in under-studied regions, particularly southern and western provinces, is necessary. In terms of recommendations for future research on the CCFP, there is a significant need to examine confounding factors, ideally through the selection of matching control groups to CCFP participants, and to ensure that sampling methodologies are more representative of selected study sites and the overall targeted area. There remain many opportunities to assess specific socioecological effects, upon which to base future policy decisions and more broadly inform ecological restoration and eco-compensation in both theory and practice.

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Background

The Conversion of Cropland to Forest Program (CCFP), also known as the Sloping Land Conversion Program (SLCP) or 'Grain for Green', was one of a number of forestry programs initiated in response to growing ecological crises and increasing environmental awareness in China [1]. In 1997 the Yellow River Basin was afflicted by a severe 267 day drought [2], followed in 1998 by massive floods over vast swaths of land in both the Yangtze and Songhua River basins, which, in addition to causing widespread economic losses, destroyed the homes of 13.2 million people and led to the deaths of 3600 people [3, 4].

While the extreme weather conditions of 1997–98 was the proximate cause of the flooding (associated with an El Niño Southern Oscillation (ENSO) event [3]), the effects were widely believed to have been exacerbated by growing anthropogenic pressures [5, 6]. In particular, the overlogging of state forest farms and forest clearing on steep slopes for smallholder agriculture contributed to soil erosion [7, 8] which, coupled with the artificial desiccation and siltation of lakes [9], increased flood risk throughout major river basins. Despite more recent research questioning the role of forests in preventing large-scale floods [10], the Chinese government decided to address widespread environmental degradation and pursue large scale reforestation, radically reorienting national forest policy away from a focus on timber production towards forest conservation and restoration. A range of new programs ensued, which together are known as the Priority Forestry Programs (or the Six Key National Forestry Programs). Of these, the first and furthest reaching were the Natural Forest Protection Program[1] (NFPP)—launched in 1998 to ban logging in the upper reaches of the Yangtze River and upper-middle reaches of the Yellow River—and the CCFP, launched the following year through a series of pilot projects in Shaanxi, Gansu and Sichuan provinces to restore vegetation on sloping croplands and lands classified as 'waste' or 'barren' land [11].

With an initial target of reducing flooding and soil erosion, the CCFP was revised after several years to incorporate goals of rural livelihood improvement and poverty alleviation to align with the emerging national poverty reduction strategy [12–14]. The CCFP can thus be described as an afforestation program or a large-scale Public Payment for Ecosystem Services (PPES) scheme featuring a compensatory approach for economically disadvantaged populations in hilly, mountainous and upstream areas, who play a key role in providing downstream populations with forest ecosystem services. To these smallholders living largely in remote and marginal landscapes, the scheme has been an important form of monetary compensation from both central and local governments, which, in addition to supporting afforestation, also contributes to a broader trend of redirecting rural labor from on-farm towards off-farm sectors.

At the beginning of the program, compensation included a one-time payment for the purchase of saplings or seeds, an annual living allowance (paid per unit area of cropland enrolled), and an annual grain/cash subsidy[2] to compensate for lost agricultural income, with different amounts for households in the Yangtze River watershed and the Yellow River watershed regions [11, 15]. The payment period of these three-tiered compensation system also depended on post-conversion land-use, with 2 years of payments provided for converting cropland into grasslands,[3] 5 years for converting cropland into forests of 'economic trees' (i.e. trees with direct economic returns) and 8 years for converting cropland into forests of 'ecological trees' (i.e. trees with higher use restrictions). Program participants are paid conditionally upon maintaining a tree survival rate of at least 70–85 %, depending on local criteria, which is verified via annual site inspections [15].

This three-tiered subsidy system was later simplified to a single cash payment integrating grain compensation and livelihood subsidies, while subsidies for seedlings were also provided in cash form (in one lump sum payment). Since 2007, half of the CCFP investment has also been used to fund complementary activities including cropland improvement, replanting on CCFP land, and rural energy development (e.g. biogas). Also since 2007, subsidies to farmers were halved from the annual compensation received between 1999 and 2006. Subsidy levels vary by locale, as some provincial governments have contributed additional funding to increase compensation to farmers above the national compensation

[1] The NFPP was approved in 1998 so as to stop natural forest loss and degradation [15]. The introduction of this 'logging ban' policy meant the re-structuring of state-owned forestry enterprises, for which government subsidies were channeled to compensate laid-off workers and alleviate the economic crisis faced by these companies in the late 1990s.

[2] Since 2004, grain transfers were completely replaced by cash.

[3] Although the CCFP initially included the conversion of cropland into grassland, this land-use transformation no longer forms part of the program, and has become a different program that is currently managed by the Ministry of Agriculture.

standards. The CCFP is implemented by county-level government, of which the Forestry Bureaus are responsible for the overall management of the program, including identifying land eligible for conversion. Finance Bureaus later allocate funds to participating households based on inspection results conducted by the Forestry Bureaus.

The CCFP is currently implemented in 1897 counties in 25 province-level jurisdictions; but does not include those located along the eastern coast (Shandong, Jiangsu, Shanghai municipality, Zhejiang, Fujian and Guangdong) or several municipalities and special administrative regions. Since 1999 more than 28 million ha have already been afforested by the CCFP (comprised of 9.06 million ha of cropland, 16.6 million ha of barren land classified as 'wasteland,' and 2.95 million ha of 'closed hillsides to facilitate afforestation'), providing direct subsidies to 32 million households (around 124 million people) [16, 17]. In terms of its scale and magnitude, with 299.2 billion Chinese yuan (CNY) (~US$49.85 billion) already invested (between 1999 and 2014) [18], the CCFP is one of the most significant forest policies implemented in the developing world [11].

The core assumption behind the CCFP is that forest restoration on sloping agricultural lands will lead to a decrease in soil erosion and flooding in these rural areas. The targeting of sloping lands and suitable households will also affect the sustainability of land conversion and thus the achievement of its broader environmental goals. It is expected that farmers who have sufficient livelihood alternatives (i.e. availability of non-targeted farmland or sources of off-farm income), and willingly choose to participate, will be less likely to convert lands back to agriculture after subsidies end. On the other hand, if disadvantaged farmers and groups are not effectively targeted, this could also be a deterrent for achieving both the environmental and socioeconomic goals of the program. Subsequently, within the systematic review, we will evaluate the effectiveness of the CCFP in achieving both its environmental and socioeconomic objectives, as defined by soil erosion control, flood prevention and poverty reduction. Moreover, we will also assess the range of both intended and unintended outcomes of the CCFP.

Objective of the review

This systematic review evaluates the CCFP's impacts on the natural environment and human populations over the course of its implementation from 1999 to 2014. The review also aims to provide reliable evidence to inform the CCFP's on-going and future implementation, while identifying knowledge gaps and suggesting areas for new research. This review also contributes to the Center for International Forestry Research (CIFOR)'s Sloping Lands in Transition (SLANT) project, which addresses the outcomes of smallholder forest restoration and management in hilly and mountainous regions. Although we performed searches for relevant Chinese literature as per the protocol [19], time restrictions have led us to constrain this review to the English literature.

Research questions

The primary research question of the systematic review is:

- What are the environmental and socioeconomic effects of China's CCFP after the first 15 years of implementation?

Secondary questions of the review include:

1. How effective has the CCFP been in achieving the stated objectives of soil erosion control, flood prevention and poverty reduction?
2. Under what circumstances do farmers revert forestland back to cropland?
3. Are there any unintended environmental and socioeconomic outcomes?

To operationalize our research questions, theoretical hypotheses and database searches, we have defined a population-intervention-comparator-Outcome (PICO) model, which represents different elements of the primary question (see Table 1). More information on this framework is also contained in the protocol associated with this systematic review [19].

Methods

Searches

Our search strategy was structured according to the collaboration for environmental evidence's guidelines [20] and our PICO framework to consider the CCFP's impacts on both land resources and human populations. Searches were conducted in English in June 2014 on Web of Science, Scopus, CAB abstracts and AGRIS, and were limited to studies published in and after 1999, the first year of CCFP implementation (see protocol for a detailed discussion on the comprehensiveness of the search [19]). We also used google scholar to conduct internet searches for literature, and we further searched for gray literature on institutional websites, although we did not find any relevant results. Additional file 1 includes the list of terms and search string combinations used in these searches. Finally, we issued a call for gray literature on the CIFOR website and distributed brochures at relevant meetings and conferences; although no additional studies were identified by this means.

Table 1 PICO elements of the systematic review

Population (s)	Intervention (s)	Comparator (s)	Outcome (s)
CCFP enrolled lands (cropland/wasteland/ecological trees/economic trees)	CCFP (subsidies, skill-training, and enforcement with field checks)	Non-enrolled sloping lands, and lands prior to CCFP implementation	Environmental outcomes (changes in water discharge, soil erosion, flood risk, local biodiversity, etc.)
CCFP households and their individual members	CCFP (subsidies, skill-training, and enforcement with field checks)	Non-participant households, and households prior to CCFP implementation	Socioeconomic outcomes (changes in household income structure, migration, etc.)

Article screening and study inclusion criteria

As defined in the review protocol, we first conducted title and abstract screening of all search results, then performed full text screening of the remaining studies [19], all according to the following inclusion criteria:

Relevant subjects

Both human populations and land resources were included as relevant populations, including CCFP participant households, their individual members and their CCFP enrolled lands (cropland, wasteland, ecological trees, and economic trees). Grasslands were excluded from our analysis since they no longer form part of the CCFP (they are under the administration of the Ministry of Agriculture), and because they contribute to significantly different environmental outcomes as compared with forests.

Relevant interventions

These include CCFP compensation subsidies, skill training for local farmers, and enforcement work with field checks. When possible, we retrieved all information on other types of subsidies that might have an impact on household livelihoods and the environment. Broadly speaking, the NFPP does not overlap with the CCFP, as the former is related to state forestland whereas the latter mainly occurs in collective forestland. Therefore, the NFPP is not included in our analysis (although it is taken into account as a contextual factor).

Relevant comparators

We were interested in assessing the existing evidence comparing the effects of the CCFP between participating and non-participating CCFP households. This systematic review simultaneously considered the available evidence about CCFP land resource comparators such as both enrolled and non-enrolled lands (under the management by both types of households living upstream). This systematic review also used the available empirical data to track those 'before-and-after' comparators in both human populations (i.e. the socioeconomic status of both participant and non-participant households before and after the CCFP interventions) and land resources (i.e. the environmental status of both enrolled and non-enrolled lands before and after the CCFP intervention).

Relevant outcomes

We identified a number of relevant environmental outcomes, i.e. soil erosion and flood prevention, reconversion of forestland to cropland, land-use and forest cover change, tree survival rates, biomass and carbon storage, and biodiversity. We identified the following socioeconomic outcomes: income, employment, food security, land access and social equality, and migration. Studies assessing potential or future outcomes of the CCFP, including model projections or other predictions of program impact, were not included, as this review only seeks to assess the actual impacts of CCFP implementation (i.e. those which have already taken place).

Relevant types of study design

Primary studies using quantitative and qualitative methods were considered; these included experimental and quasi-experimental designs, case-control experiments and broad sample-size surveys of participant and non-participant populations (i.e. cross-sectional analyses), surveys of populations prior to and following CCFP implementation (i.e. longitudinal analyses), and individual case studies of populations that have been targeted for CCFP interventions. Studies must use primary data to present actual impacts that have already happened, and are causally linked or correlated to the CCFP interventions. Primary studies concerning farmers' perceptions of CCFP impacts were also included, provided that a robust and reliable methodology was used, as these perceptions can be used as a proxy for measuring certain socioeconomic impacts. Modeling exercises that use primary data to calculate actual impacts were included for further analysis, whereas models that project potential or future impacts were not included. With regards to qualitative evidence, we considered the following design/methods: participant and non-participant observations, structured, semi-structured, and unstructured interviews, focus group discussions, and qualitative data from surveys and questionnaires. For quantitative evidence, we considered the following design/methods: direct measurements of observed phenomena, including use of geo-spatial technologies (GIS and remote sensing) as well as the use of polls, questionnaires, and surveys where answers are restricted to given choices.

At the beginning of each stage of screening, four reviewers individually screened a sample of 50 studies to determine their level of agreement through the calculation of Randolph's free-marginal multi-rater kappa [21]. Where the kappa statistic fell below the threshold level of 0.6, the reviewers discussed the points of disagreement and conducted subsequent rounds of screening until an acceptable level of agreement was reached. The remaining studies were then screened independently. Kappa tests were conducted first on the title and abstracts and then on the full-texts to ensure screening decisions remained consistent. Figure 1 shows the results of the screening process as well as the subsequent quality assessment.

Study quality assessment

The study quality assessment involved the assessment and scoring of studies against five criteria: (1) clarity and replicability of data collection methods; (2) clarity and representativeness of sample size; (3) clear and replicable data analysis methods (whether quantitative or qualitative); (4) logic and evidentiary support of results/conclusions; and (5) consideration and explanation of confounding factors (Table 2). These five criteria were used in the screening process by members of the research team (independently from each other), whose assessments were also cross-checked to maintain inter-rater consistency across different team members.

We documented individual study quality based on each of these five criteria. For each study, we recorded yes/no answers for each criterion, where "yes" is equal to a score of one and "no" equal to a score of zero. Each study thus received a quality assessment score of 0–5, where scores of 3–5 were considered eligible while studies with scores of 0–2 were considered ineligible for further data extraction. For our systematic review, we considered and compared the outcomes from both sets of studies to determine whether the ineligible studies demonstrate significantly different results from those of eligible studies.

We acknowledge potential subjectivity in the application of quality assessment criteria, which we sought to minimize through repeated kappa testing between review team members. Nonetheless, the decision to exclude studies with quality assessment scores lower than three may also introduce potential biases in the inclusion (and exclusion) of studies that may have only just met or failed to meet this criterion; nonetheless, we considered this to be a necessary, if flawed, method to ensure that the lowest quality studies are indeed excluded from our synthesis.

Data extraction strategy

For all studies that met our critical appraisal criteria after full-text screening, we extracted data following the general structure of our PICO framework and incorporated the potential effect modifiers listed above. The data extraction categories have been explained in detail in the protocol [19].

Study metadata and methodology

- Bibliographic information: author, year, title, institution of the lead author.
- Type of study: environmental/socioeconomic/environmental-and -socioeconomic study.
- Journal/reference.
- Funding.
- Data aggregation level.
- Geographic location: province/county.
- Time-span covered by the study.
- CCFP implementation duration at study site.
- Data collection methods.
- Case comparator: longitudinal (before/after CCFP); cross-sectional (site or population with/without CCFP); both comparators.
- Data analysis methods.
- Methods of study.

Population

- Type of population: human population, land resources population, or both.
- Unit of comparative analysis (scale): household/individual, village/community, county, provincial or national levels.
- Sample size and land area: number of households covered by study or land area covered by the study.

Intervention

- Type and duration of intervention: compensation subsidies (grain or cash), tree-sapling provision, skill-training, enforcement with field checks, forestland tenure certificates, other interventions (one or multiple intervention types can be present).

Outcomes

- Environmental outcome categories: soil erosion and flood prevention, reconversion of forestland to cropland, land-use and forest cover change, tree survival rates, biomass and carbon storage, and biodiversity.
- Socioeconomic outcome categories: income, employment, food security, land access and social equality, migration.

Potential effect modifiers and reasons for heterogeneity

The following variables were included in data extraction as potential effect modifiers:

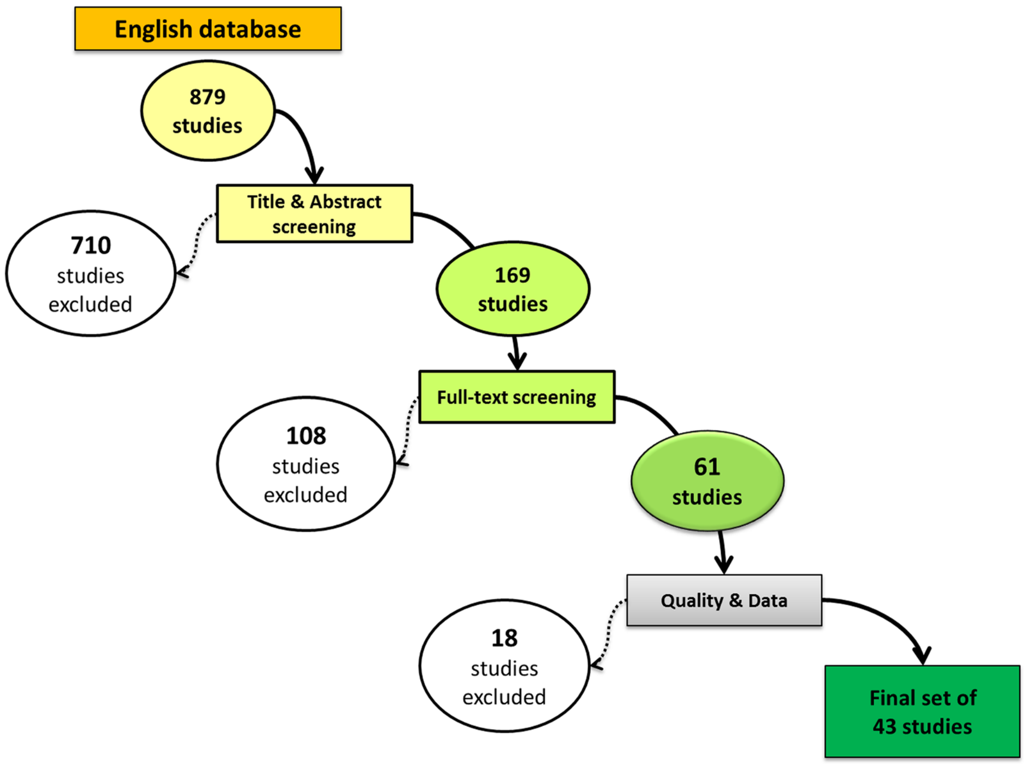

Fig. 1 Systematic review screening process

Table 2 Five criteria used in quality assessment (61 studies)

Quality criterion	Definition	Percentage of all papers meeting criteria (%)
1	Data collection methods are thoroughly explained, clear and replicable	68.9 (42 papers)
2	Sample size is well explained and representative of the population	54.1 (33 papers)
3	Qualitative or quantitative analysis methods are thoroughly explained, clear and replicable; key terms and variables are well defined	70.5 (43 papers)
4	Results/conclusions are logically derived and supported by presented evidence	80.3 (49 papers)
5	Confounding factors are considered and well explained	54.1 (33 papers)

Socioeconomic factors: household members' age, gender, education, income group and ethnicity.
Environmental factors: land orientation, slope, size, distance to home, and elevation of land plots.
Other factors: degree of voluntary participation in CCFP.

Data synthesis and presentation

First, we present a systematic map based on the results of title-abstract and full text screening, along with descriptive statistics on the geographic and temporal distribution of the eligible studies.

Second, we systematically present a narrative synthesis that includes the results of the study quality assessment. Given the broad heterogeneity of study designs, quantitative meta-analysis could not be carried out, and instead a qualitative synthesis and descriptive statistics are used. The narrative synthesis is structured as follows:

- Study quality assessment.
- CCFP interventions: targeting of land plots, subsidies (grain, cash, tree saplings); inspection regime, promotion and training; degree of farmer autonomy (voluntary participation).
- CCFP environmental effects: soil erosion and flood prevention; reconversion of forestland to cropland; other environmental effects (land-use and forest

cover change, tree survival rates, biomass and carbon storage, biodiversity).
- CCFP socioeconomic effects: poverty alleviation and livelihoods (income, employment, food security, land access and social equality) and other socioeconomic effects (migration).

Results

Review descriptive statistics, systematic map

Our literature search yielded the following results: 486 hits in Web of Science, 253 hits in Scopus, 144 hits in CAB Abstracts and 21 hits in AGRIS, for a total of 879 unique records after duplicate removal. 710 studies were excluded after title and abstract screening, leaving 169 studies for full text screening (see Fig. 1). 108 studies were excluded following full-text screening (see Additional file 2 for a full database of screened studies and detailed account of reasons for exclusion), resulting in a total of 61 relevant studies. Following the quality assessment, 18 studies were found to be ineligible and 43 studies eligible for data extraction.

We identified the geographic and temporal scope of the studies to assess the number of studies conducted in each region and year since CCFP implementation began. The 43 studies in this review include four national-level studies (covering more than 20 provinces), seven regional studies (each of which spans two to six provinces), and 32 county-level (or below) studies (each of which is located within a single province). With the exception of the four national-level studies and the seven regional studies, the total number of provinces, autonomous regions (ARs), and municipalities (henceforth referred to together as 'provinces') included in the remaining 32 county-level studies represent 12 of the 25 provinces participating in the CCFP (Fig. 2). This final set of 43 eligible studies further comprises a total of 99 individual study sites.

Significantly, 44.4 % of the 99 case study sites were based on data from Shaanxi province alone (with 44 sample sites in 25 different counties). Within Shaanxi, Yanchang County saw the most research attention (seven studies), followed by Wuqi (six studies), Yanchuan (six studies) and Ansai (five studies).

Figure 3 presents the number of studies published per year, showing a five-year gap between the start of the CCFP in 1999 and its first evaluation in the English literature in 2004. The number of published studies increased significantly after 2009, following 10 years of CCFP implementation.

Narrative synthesis including study quality assessment

Of the 61 papers that underwent quality assessment, 18 papers were found to be ineligible for data extraction by meeting fewer than three quality criteria (Table 2). Deficiencies in sampling methodology (criterion no. 2) and consideration of confounding factors (criterion no. 5) were especially pronounced, with 15 of the 18 ineligible papers failing to meet at least one of these two criteria, and at least 25 % of the 43 eligible papers failing to do the same. Performance against the other criteria was better; Table 2 below illustrates the overall quality of all 61 papers that met the inclusion criteria at full text screening. Papers performed best in ensuring that their results and conclusions were logically derived and supported by evidence (criterion no. 4), and performed worst in ensuring the representativeness of the selected population (criterion no. 2) and in considering potential confounding factors that may have contributed to the stated socioeconomic and environmental outcomes of the CCFP (criterion no. 5).

As for the methodologies used across the 43 eligible studies, nine environmental studies are based on descriptive statistics, mathematical models, and soil erosion models such as the universal soil loss equation (USLE) or the revised universal soil loss equation (RUSLE). The 22 socioeconomic studies mostly use descriptive statistics, regression models, cost-benefit analyses, fixed effects models, and 'differences-in-differences' plus 'matching methods'. The 12 mixed socioeconomic-environmental studies, being quite similar to the previous socioeconomic studies, use similar methods with the addition of land-use change models.

On the other hand, of the 22 studies examining socioeconomic outcomes, 21 used a household unit of analysis (while one study was based on individuals). Twelve studies analyzed both socioeconomic and environmental outcomes using household units, three of which also used satellite images. Only nine studies focused exclusively on environmental outcomes, and examined results on forest area and ecology, soil ecology and watersheds, and household perceptions of CCFP's environmental effects.

An important difference between environmental and socioeconomic studies is the duration of CCFP implementation at the time of study. Environmental studies were conducted on an average of 8 years after the start of the program, while the majority of socioeconomic studies were conducted on an average of 5 years after the start of the program. Studies examining both types of outcomes were conducted on an average of 6.8 years after CCFP implementation.

CCFP interventions

This section summarizes study data on key components of CCFP program implementation—including targeting of land plots, subsidies, inspection regime, promotion of the program and farmer training, and farmer autonomy—that were likely to affect socioeconomic and environmental outcomes.

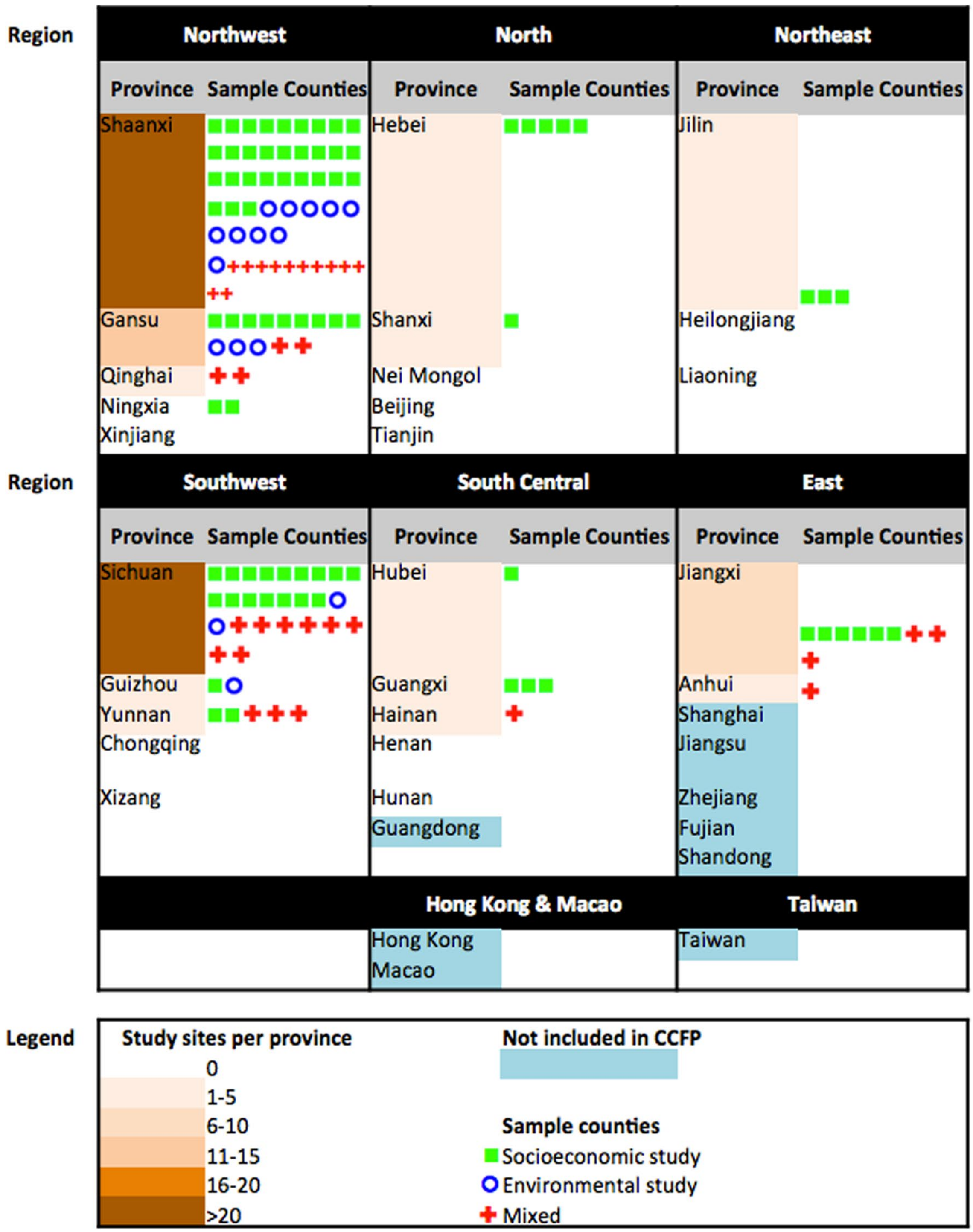

Fig. 2 Geographical distribution of studies. Apart from the case studies represented in this figure, four national-level studies and seven regional studies contained aggregate data not displayed here. Provinces in *white* are targeted by the CCFP but were not represented by specific study sites or case studies in the reviewed literature

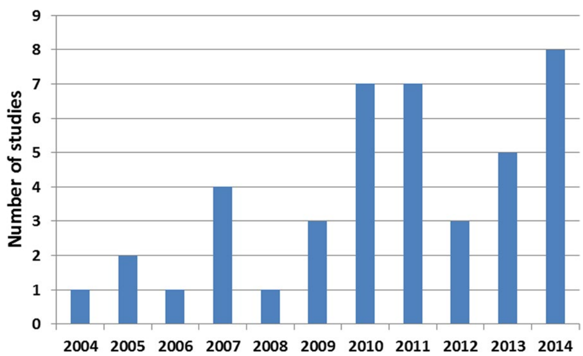

Fig. 3 Temporal distribution of studies

Targeting of land plots Based on national-level research [22], 54.5 % of CCFP plots were located on steep slopes, 13.7 % on lands affected by sand erosion, while 31.8 % of plots consisted of other land types, indicating difficulties in the initial step of identifying and targeting sloping lands. From the perspective of regional-level studies (i.e. data analysis and results aggregated across several provinces), the CCFP targeting process has consisted first of prioritizing the selection of land plots (to be converted into forests), then followed by the selection of households who will plant the trees (voluntary participation has therefore been secondary to land-plot allocation over the whole targeting process). Regional studies show most enrolled plots to be located on steep slopes, although there was a considerable share of sloping lands not enrolled in the program and even some flat plots that were included [11, 23]. In the study by Xu et al. [14], authors collected empirical data showing that the land selection process targeted more appropriate land in Shaanxi and Sichuan provinces than in Gansu province [24]. In Gansu, only 48 % of the CCFP-converted plots had slopes higher than 25° and low-to-medium productivity, and 19 % of converted area had slopes below 15° and medium-to-high productivity [24]. In contrast, 63 % of CCFP plots in Shaanxi and 75 % of plots in Sichuan were located on slopes higher than 25° and with low-to-medium productivity, while 10 and 11 % of converted area, respectively, had slopes of less than 15° [24].

Subsidies—transfers of grain, cash, and tree saplings Shortages in grain compensation were reported in two papers [24, 25] whereas other papers only reported grain compensation standards. In the former two papers, compensation fell short of the policy standard of 1500 kg/ha in the Yellow River Basin and 2250 kg/ha in the Yangtze River Basin, and varied greatly within and across provinces. For instance, surveyed townships in Gansu received anywhere from no grain compensation to a maximum of 1170 kg/ha, which still falls below the prescribed 1500 kg/ha, with average compensations of 810 and 322.5 kg/ha reported in 2002 for Jingning and Linxia counties, respectively [24, 25]. Similarly in Shaanxi province, townships in Yanchuan county received an average of 232.5 kg/ha in 2002, while townships in Liquan county received an average of 1215 kg/ha in the same year [24, 25]. Finally, in Sichuan province, Chaotian and Lixian counties received 2025 and 1927.5 kg/ha in 2002, which is closer to the standard of 2250 kg/ha [24, 25].

Monetary compensation for land conversion was also rarely reported in terms of the actual amounts received by participants. Only eight papers reported such information (with two using the same data set), whereas all other papers quoted the policy standard of 300 RMB/ha. Where survey information is present, the majority of cases reported less money distributed than the amount prescribed. In Gansu province, respondents in Jingning and Linxia counties received 255 and 30 RMB/ha respectively in 2002 [24]. Even less compensation was reported in Shaanxi province, with 60 and 90 RMB/ha received in Yanchuan and Liquan counties [24]. Finally, in Sichuan, respondents in Chaotian and Lixian counties received 45 and 195 RMB/ha, respectively, in 2002 [24]. A number of case studies reported cash subsidies in terms of money received per household per year without reference to the amount of land converted; these figures varied from a low of 43.3 RMB per year in Binxian county in Shaanxi between 2003 and 2004 [26] to a maximum of 1929 RMB in Shaanxi in 2006 [27]. In two other cases, monetary compensation exceeded the prescribed level of 300 RMB/ha, with respondents from Longyang district in Yunnan province receiving an average of 3330 RMB/ha in 2003 [28], and those in Liping county, Guizhou province received an average of 415.6 USD/ha in 2003 [29].

Another national-level study conducted between the China National Forestry Economics and Development Research Center (FEDRC) and Beijing Forestry University (BFU) [22] used two survey data sets with questions to farmers on whether they had received the full subsidy they were owed. According to the FEDRC 1999–2009 panel monitoring data of 1165 households, 95 % of respondents said they had received their full subsidy, while the once-off BFU survey data (3119 households) found that only 77.08 % had been paid in full, 8.9 % had only received partial payment, and 14.2 % said it was "*unclear*". On the other hand, another aggregate study conducted in the CCFP pilot region (Shaanxi, Gansu, Sichuan) reported that participating households were negatively affected by shortages in delivery of compensation subsidies during the first years of its implementation [23]. These shortages may be explained in part by the rapid scaling-up of the CCFP, which made required monitoring tasks difficult to perform and prompted local governments to retain some subsidies to offset revenue losses that followed CCFP land-use restructuring, i.e. lost tax revenues from former agricultural land and agricultural products. Despite the scarcity of data detailing actual compensations received, the existing evidence points to a trend of underpayment at certain locations during the first years of program implementation, which may have led to greater participant dissatisfaction with the CCFP, and thus poorer socioeconomic and environmental outcomes.

Four studies assessed farmer perceptions in relation to the opportunity costs of conversion and satisfaction with the amount of compensation received. A regional study carried out in Anhui, Hubei and Shanxi asked households to what degree the CCFP subsidy compensated them for the opportunity cost of land conversion [16]. Respondents in Hubei and Anhui were largely satisfied that compensations exceeded opportunity costs, while respondents in Shanxi saw much greater variation/ambivalence. In a study across five counties in Northern Shaanxi [30], interviewees' generally responded that"*economic losses had been compensated*", ranging between 29.1 and 80.97 % (between the lowest-percentage county and highest-percentage county), "*had not been compensated*" ranged between 15.4 and 44.7 %, and"*had no opinion*" ranged between 3.64 and 38.1 %. In Foping Nature Reserve, and Yangxian and Foping counties (also in Shaanxi province), 93.8, 98.0 and 75 % of households were satisfied with government subsidies, respectively [31]. In a study of two villages in Yunnan, the perception of the subsidy amount was 8.8 % "*too low*", 41.2 % "*low*", and 50 % "*reasonable*" in the case located in Longyang; and 6.2 % (*too low*), 25.0 % (*low*), and 68.8 % (*reasonable*) in Tengchong [32]. In another study conducted in Ningxia and Guizhou provinces, the payments paid to farmers for entering their plots into the program largely exceed the plot's opportunity cost, although there was a considerable degree in differentiation between lower-yielding plots' over-compensation (mostly in Ningxia) and high-yielding plots' under-compensation (mostly in Guizhou) [11].

Seventy three case studies (in 29 papers) reported the year in which CCFP's local implementation began as well as the year in which the study was conducted, allowing us to calculate the duration of CCFP implementation at these sites (Fig. 4). The majority of studies (44 cases, or 60 %) were conducted within the first 5 years. Twenty six case studies (36 %) were conducted between the sixth and the tenth year of CCFP implementation, and three case studies (4 %) were conducted 11–13 years after CCFP implementation. On the other hand, in a regional-level study conducted in Shaanxi, Gansu and Sichuan provinces [25], managerial and start-up costs involved in program implementation were reported to have not fully been taken into account within the CCFP design.

Inspection regime, promotion, and training Two papers reported on field inspections of CCFP forest plots. The first reported inspection rates of 88.1 % in Jie county (Shanxi province), 89 % in Mulan township (Hubei province), and 95.5 % in Jinzhai county (Anhui province) [16]. The second reported that CCFP plots in Shaanxi, Gansu, and Sichuan provinces were inspected on average 7.6 months after enrolment, with a range from less than 1–38 months [33]. Only one reviewed paper described public promotion of the CCFP prior to implementation, with villagers in Shaanxi province required to attend briefings with local officials on the program and its implementation [34]. Meanwhile, there was no data on training associated with the program reported.

Degree of farmer autonomy There is little agreement in the English literature with regards to the degree of voluntarism or coercion in CCFP participation, and figures vary with geographic and other differences. Twenty two studies assessed either the percentage of farmers who chose to participate or the percentage who had no choice but to participate. We combined these figures and calculated a rough picture of the degree of voluntarism in CCFP program implementation. In these studies, the estimated degree of voluntarism ranged from a low of 8.1 % in Jingnin and Linxia counties in Gansu province [24] to a maximum 90.9 % in Jinzhai county in Anhui province [16]. More light is shed on farmer willingness to adopt the CCFP based on a regional study conducted in Anhui, Hubei and Shanxi provinces, which indicates that local people were attracted to participate due to the promised income increases [16]. In Anhui, the vast majority of participating households (84.1 %) did so because "*subsidies increase* [their] *household income*", compared to 9.1 % who participated because "*it was required*". Similar proportions were reported in Hubei and Shanxi.

CCFP environmental effects

Soil erosion and flood prevention The empirical evidence regarding the soil erosion and flood prevention outcomes of the CCFP is restricted to the Loess Plateau, and is mostly concentrated within Shaanxi province. Within these limitations, there is some evidence for a positive effect on both soil erosion (measured by retention of soil mass and nutrient levels) and flood control (measured by changes in water yield).

Reduced soil erosion was reported in the southern part of the region in a quantitative study carried out in Yulin and Yan'An comparing soil conservation in lands converted to forests vs. to grasslands or shrubs: land

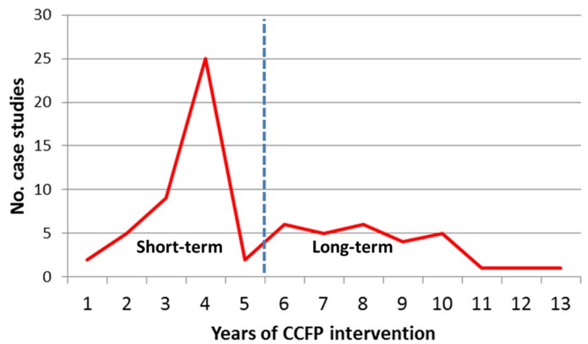

Fig. 4 Case studies by year of CCFP intervention. The *blue line* marks the boundary between short-term and long-term studies, i.e. less than 5 years of CCFP implementation (*left* of the *line*), or above 5 years of CCFP implementation (*right* of the *line*)

conversion to forests led to the greatest increase in soil conservation/retention [35]. A 38.8 % reduction of soil erosion over 10 years from 1999 was reported in the Zuli River Basin, an area which belongs to the Loess plateau and Gansu province. This estimation predicated on an overall modelling accuracy rate of 67 % [36].

Percentages of converted lands within certain slope ranges were used as a proxy of soil erosion control in another study conducted in Shaanxi (Yanchuan county). Specifically, "*44.57 % of the sloping cropland (with slope between 6° and 15°), 48.87 % (with slope between 15° and 25°), and 70.78 % (more than 25 degrees) were converted,*" although no direct measures were provided for reduction in soil erosion [37]. Finally evidence of soil nutrient conservation is presented in a study conducted in Yulin county, where CCFP converted lands showed higher nutrient levels than non-CCFP lands, especially within the shallow soil range between 0 and 20 cm [38].

Reliable data for the CCFP's effect on flood prevention is scant in the English literature, with only two articles passing screening. One study conducted in Yulin and Yan'An counties (Shaanxi province) [35], found that water yield from CCFP lands was significantly reduced due to the effect of increased evapotranspiration by planted shrubs and trees. The study found that after 8 years, land converted from cropland to shrubs retained 3.16 times the water of unconverted cropland. Land converted to forest reduced surface water by three times overall and per unit area [32].

In the other relevant study, the CCFP was reported to reduce water yield in the Loess Plateau, with some marked variations related to annual precipitation: "*Relative to the 1999 baseline, in wet years (e.g. 2003) there was a 10 % decrease in water yield attributed to the CCFP; in dry years (e.g. 2005), on the other hand, there was a 56 % decrease in water yield attributed to the CCFP.*" Overall, in this latter paper the authors recommended quantifying regional hydrological response to ensure sustainable ecological restoration in the Loess Plateau. Whereas reduction of water yield through increased evapotranspiration is one measure of flood prevention, it comes with the negative effects of decreased water available locally and downstream for use in growing trees and crops; an effect that necessitates careful consideration in terms of spatial planning and choice of ground cover (species planted, trees vs. grasses or shrubs) [39].

Reconversion of forestland to cropland The intentions of farmers to reconvert CCFP lands back to agriculture, as well as their general environmental awareness, potentially sheds some light on the long term sustainability of the CCFP. With respect to the probability of reconversion based on farmer's stated intentions, the body of evidence is dispersed geographically as presented in four studies: one regional study in the CCFP pilot region, another study across Anhui-Hubei-Shanxi provinces, and two studies in Shaanxi Province. Moreover, there is great variability in farmers' responses, which reflect the geographical variation in both socioeconomic and environmental conditions across rural China. This parameter of 'reconversion plans' can be gauged as a key issue for the ultimate success of the CCFP in expanding and maintaining the area of forest cover.

According to one of the above-mentioned articles using 2003 SFA statistics [25], 9.4, 21.4, and 38.2 % of participants in Gansu, Shaanxi and Sichuan (CCFP pilot region), respectively, either were not sure or stated they would definitely reconvert their lands back to agriculture after subsidies cease. In another study undertaken in five counties in Shaanxi Province using 2005 data [30], an average of 37.2 % of individual respondents (n = 1768) declared that they would re-convert after the end of the program, 23.82 % said they had no opinion, whereas 38.96 % stated they would not reconvert. In this study, there was significant variation across the five counties. Households in Yanchang County expressed the highest tendency to reconvert (60.42 %) while those in Luochuan showed little predisposition to reconvert (only 7.27 %). Only one county (Jie county) in a study conducted in three provinces (Anhui, Hubei, and Shanxi) [16] showed a relatively high intention to reconvert (34.5 % of respondents).

Finally, a study carried out in Foping and Yangxian counties in Shaanxi [31], found a relationship between the level of environmental disturbance and farmers' predisposition for reconversion. In an "*intensively-disturbed zone*" in Yangxian, 47.2 % stated they would reconvert after the program, compared to 18 % in a "*moderately-disturbed zone*" in Foping, and only 15.6 % in a nature reserve in Foping county.

It remains to be seen whether CCFP-induced land-use change is sustainable or if the program's end will be succeeded by significant conversions of forestland back to agriculture. One potential mediating factor is environmental awareness. In one of the reviewed studies [30], 57.8 % of interviewed participants in five counties in Shaanxi agreed with the statement that "*the environment is at least as important as the economy*" and 44.4 % thought that the environment was badly degraded, which could negatively affect their health.

Other environmental effects

Land-use and forest cover change Most studies in the review confirm the expected impact of the CCFP on land-use, i.e. a substantial increase in the area under forest cover and planted trees. The data take the form of either aggregate or per-household figures/percentages. Results are presented in three ways: (i) change in percentage of forest cover [26, 31, 35, 37, 40–43], (ii) change in area over which trees are planted [22, 24, 28, 32, 44], and (iii) change in area of trees planted per household or per capita [15, 22, 26, 27, 45, 46]. In line with the general regional trends of economic transformation, land-use changes have been relatively more extensive in the Yellow River Basin (with lower population densities and bigger land plots) as opposed to those more intensive changes in the Yangtze River Basin (higher densities and smaller land plots).

National-level figures [22] indicate a 25.3 % increase in forest area in 100 monitored CCFP counties in 21 provinces, already reaching 10.79 million ha within those counties in 2009. This equates to 32.93 % forest cover in 2009, an increase of 7.75 % points over 1998 estimates. The estimated forest cover increase in CCFP counties was 5.6 % points higher than the national average, which increased from 18.21 to 20.36 % over the same period (i.e. an increase of 2.15 % points over 1998). At the household level, according to the same source, the area of forest land held by 1165 sample households expanded five-fold, from 3.48 mu per household in 1999[4] (in CCFP pilot sites) to 23.11 mu per participating household in 2009 [22].

Such aggregated figures do not, however, reveal the high degree of variability in the program around the country. According to one study, conducted in Jiangxi, Shaanxi, and Sichuan (southern provinces implementing the CCFP) and Hebei, the per-household area returned to forest is much greater in Shaanxi (Northern China) than in the Yangtze River Basin. In the former, CCFP enrolment per household reached 6.58 mu in 2000 and 14.9 mu by 2004, compared to 0.73 mu in 2000 and 2.06 mu in 2004 in the Yangtze River Basin [23]. These data illustrate the higher availability of land per household for conversion in Shaanxi (Northern China) vs. these southern provinces.

Tree survival rates Tree survival rates have been used as an indicator to quantitatively assess the environmental outcomes of the program to date. In the English language literature reviewed, tree survival rates have been estimated based on figures reported by farmers in household surveys or, in a geographically more-restricted paper [40], measured using random onsite sampling techniques. The broadest study to date in terms of geographic area estimates that 79 % of households reported tree survival rates above 70 % [22]. Conducted by BFU and FEDRC (sample size of 2808 households), this study established that 39.63 % of sampled participating households reported tree survival rates above 90, 39.87 % reported 70–90 %, whereas the rest (21 %) of sampled participating households reported tree survival rates below 70 %.

Tree survival is affected not only by environmental factors but also by a host of socioeconomic and cultural factors. One group of studies by Bennett et al. [25, 33] relies on reported survival as a dependent variable upon which to base analyses of institutional efficacy and associated behavior vis-à-vis tree planting and subsequent care. Based on SFA statistics presented in one study conducted in Shaanxi–Gansu–Sichuan (with sample sizes of 103, 85 and 76 households, respectively) [25], important variation in household-reported tree survival rates was found across regions and time, reflecting very different environmental and socioeconomic conditions. A related study in the same provinces shows the influence of different local socio-cultural characteristics on tree survivorship, which is positively affected by the level of autonomy farmers have in deciding what and where to plant, and which increases as a function of farmers' learning about tree management [33].

Finally, an unrelated study carried out in northern Shaanxi province (across Jingbian, Ansai, Baota, Yanchang, Luochuan counties), tree survival rates decreased from 55.7 % in the first year of conversion (1999) to 49.0 % in the 6th year after conversion [40]. In this case, this result was linked to other environmental variables which will be explained in detail later.

Biomass and carbon storage There were two relevant studies that showed the CCFP having made a positive contribution in terms of carbon fixation in Sichuan province (South China) and Shaanxi province (North China).

The first study used allometric estimations for Sichuan and Shaanxi provinces, and assessed stored carbon attributable to the CCFP at 13.2 million and 14 million tonnes for each province, respectively [47]. At the national-level,

[4] mu is a widespread-used unit for measuring land areas in China: 15 mu equals 1 ha.

between 103 and 209 million tonnes (114.1 million tonnes median; 132.3 million tonnes average) of carbon were sequestered by the conversion of cropland only (i.e. excluding barren/waste land) between 1999 and 2009. Additional carbon has been stored through conversion of barren land (54 % of an estimated national total, against a 46 % contribution by cropland).

The other study carried out in northern Shaanxi found that "*NPP [net primary productivity] grew 2.35 times in the area where croplands were converted to forestlands and 2.28 times for per unit area, the highest in all transformation types. Shrubs have fixed roughly thrice the carbon of that in croplands and generally twice the amount on averaged cropland area after eight years.*" [35]. It is important to note that the carbon sequestration outcome of the CCFP in this article is analyzed as a trade-off with water yield, an important consideration for planning in regions subject to drought and downstream agricultural areas.

Biodiversity There is limited evidence on the CCFP's impacts on biodiversity; however, three studies that touched on biodiversity suggest negative effects arose from the establishment of inappropriate species and/or monoculture plantations.

On Hainan island, for example, an expansion of monocultures (e.g. rubber, eucalyptus) replaced biodiverse traditional swidden systems. The authors attribute this conversion to monocultures linked to the CCFP because both rubber and eucalyptus plantations expanded faster on slopes above 25° in 1995–2005 compared to 1988–1995 [43].

Evidence of poor matching of selected tree species to local environmental conditions was found in a study conducted in five counties in Shaanxi province. There, after 7 years of CCFP implementation, vegetation cover and the area of soil covered by natural lichens (a measure of soil health in arid climates) was higher in plots that were abandoned than in plots planted with CCFP tree species [40].

Finally, another study conducted in two locations in Yunnan province [32] suggests that local implementation using native species might produce better biodiversity outcomes. In Longyang district, the CCFP initially planted an exotic and unsuitable pear species which was later replaced with an indigenous walnut. In Tengchong, the CCFP was implemented using a 'wide variety of timber species'.

CCFP socioeconomic effects

Poverty alleviation and livelihoods In addition to the environmental targets of reducing flooding and soil erosion, the CCFP includes rural livelihood improvement and poverty alleviation goals to align with the emerging national poverty reduction strategy [12–14]. Poverty alleviation is a multidimensional variable measured by several interrelated outcomes, including income and employment, food security, land access and social equality, which are discussed below in relation to the associated CCFP impacts.

Income There is evidence of CCFP's positive contribution to farmers' incomes, due to both the direct provision of subsidies as well as the program's impact on labor structure. These effects are highly variable, however, both over time and at different geographic scales. While studies conducted in Shaanxi–Gansu–Sichuan provide empirical evidence for an overall increase in farmers' incomes [23–25], it was only after several years that the CCFP effectively promoted a shift in employment from agriculture to livestock-rearing, and then towards off-farm activities, thus enabling CCFP participants to increase their incomes [27, 48]. Of China's Six Priority Forestry Programs, the CCFP was identified as being the most significant contributing factor to the increase in farmers' household income from off-farm sources [45]. These trends vary at the local level: in some northern regions, agricultural incomes were greatly reduced due to the implementation of the CCFP (e.g. Dunhua county in Jilin province and Yanchang in Shaanxi province) [41, 49]. In another study conducted in Ningxia Province (northwest China) and Guizhou province (southwest China), farmers could increase their incomes due to a combination of subsidy delivery and engagement in off-farm employment [11].

National-level data collected across 21 provinces by FEDRC reflect a large change in income structure between 1998 and 2009, over which time "*the percentage of crop production revenue in farmer's total family production revenue drop[ed] from 71.28 to 39.45 %*" while "*forestry revenue percentage [increased] from 4.46 to 18.86 %*" [22]. While farm labor was largely reoriented towards off-farm jobs, some labor resources were also directed towards livestock and tree management, and away from cropping on environmentally fragile sloping lands. At the same time, the proportion of CCFP subsidies in overall household income decreased from an average of 26.96 % in 2002 to 9.19 % in 2009 [22].

Several studies provided more nuanced interpretations of variability in income effects over time and at local scales, with families in some places initially hard hit by the CCFP land retirement and its associated decrease in agricultural production. Thus, in Dunhua county, Jilin province (North China), authors reported in 2005 that: (a) 27 % of sampled households perceived a reduction in quality of life following the implementation of the program; (b) these households were more likely to claim that the land conversion program was a forced government action; and (c) the higher the plot income before the program, the worse the quality of life after the program [50]. In a second study conducted later in Dunhua, "*at the household level, 58 % of the families involved in afforestation felt that their income had declined after the SLCP [CCFP]*" [49]. In Yunnan province, nearly all farmers interviewed in two villages said they did not receive 'direct benefits from (planting) trees' between 2002 and 2010.

Elsewhere, however, a number of studies—and notably three studies conducted in Shaanxi province—suggest overall improvement, despite variability associated with implementation regimes and local environmental conditions. One study, for example, states that *"[a]lthough farmers have limited autonomy in determining whether to participate[…] most say that they are better-off […] Some farmers say they are worse-off, but others say they would like to enroll even larger areas than they have*" [34]. In the northern part of the province, 64.4 % of respondents perceived that the CCFP had not adversely affected their income and 71.7 % that the CCFP had not adversely affected their livelihood; conversely, conversion of 'wasteland' in particular was seen by 42 % to have negatively affected their livelihood [11]. Finally, also in Shaanxi, between 56.8 and 86 % of households in and around Foping Nature Reserve said the CCFP had increased their income [31].

In the cross-provincial Anhui-Hubei-Shanxi study, authors reported that around 45 % of households were better off due to the CCFP, 45 % experienced no change, and 3.5 % were worse off [16]. In Liping county, Guizhou, 78 % of sample households indicated that their economic conditions had improved [51].

Employment A broad body of evidence shows that the CCFP has contributed to a change in the structure of labor from agricultural work towards forest management and off-farm employment. In support of the former change, two case studies, one using data from the FEDRC's 1999–2009 CCFP monitoring survey and the other, a 2010 survey organized by BFU, found that 81.29–88.52 % of households were directly managing their contracted CCFP land plots. Additionally, 42.57 % of households were actively investing in forest management according to the FEDRC survey-based study [22].

The shift to off-farm employment appears more significant in terms of labor allocation and associated income effects. For some farmers the shift has been gradual, with an initial transition into increased livestock rearing activities followed by off-farm employment, whereas for other households the move to off-farm activities was more abrupt, particularly at the beginning of CCFP. There is even more consistent evidence supporting this transition across the well-studied and socio-ecologically diverse CCFP pilot regions (Sichuan, Shaanxi and Gansu provinces), as well as broader contextual evidence for an economic and land-use transition favored by the CCFP.

In the CCFP pilot region (Shaanxi, Gansu, and Sichuan), a series of papers describe a shift in the allocation of labor in sloping landscapes from agriculture, initially to on-farm livestock investment, followed by an increase in off-farm jobs [23, 24, 52, 53]. In Sichuan and Shaanxi provinces, after CCFP implementation, labor invested in land-based activities contracted while off-farm labor expanded. In Sichuan, average per-household labor invested in land activities decreased from 321 person-days in 1999 to 232 person-days in 2008, while off-farm labor increased from 133 person-days to 246 person-days. In Shaanxi, average per-household (land) labor decreased from 227 person-days in 1999 to 175 person-days in 2008, while off-farm labor increased from 66 person-days to 238 person-days [27]. This study provides empirical evidence from Sichuan supporting the socioeconomic transformation from farm labor to off-farm employment, by comparing CCFP-participant households with non-CCFP households. CCFP-participant households have had a quicker increase in off-farm labor than non-CCFP households.

Evidence from other case studies supports a rapid transition towards off-farm employment driven by both push factors associated with the CCFP, and pull factors from the urban employment sector [28, 42]. Farmer perceptions also support the role of the CCFP in promoting the redeployment of labor away from cultivation of sloping lands towards employment in other sectors [42]. Another study conducted at the provincial level in Shaanxi [16] found that CCFP enrolment had a small but significant and robust positive effect on non-farm employment, although it was explained not by its role in alleviating constraints, but rather by simple farm to non-farm labor substitution. In contrast, in a study conducted in Ningxia and Guizhou provinces (South China), the impact of the CCFP on households' off-farm labor was found to differ radically across households, as 'constrained' households with children under 16 years of age and elderly members had reduced off-farm labor supply [54]. The remoteness from credit agencies significantly reduces off-farm labor supply, while the development of the land rental market significantly increases off-farm labor supply [54].

In another study carried out in Shaanxi Province [55], using a 'Difference-in-Difference' model, the CCFP was found to increase the likelihood of off-farm employment by 11 % at the 0.05 significance level. The greater the intensity of program participation (in terms of the cumulative area converted), the greater the increase in off-farm employment. When using a 'Propensity-Scores-Matching' model, results more strongly supported this effect: participation in CCFP increased the likelihood of an individual to engage in off-farm employment by 17.3–22.8 %, statistically significant at the 1 % level. Using covariate matching, the study found that *"program participation increased the likelihood of an individual working off-farm by 23.5 %, statistically significant at the 1 % level"*. In conclusion, the CCFP has significantly increased the likelihood of off-farm work [55].

Broader contextual evidence for the shift to off-farm work includes a cross-regional study conducted in four provinces [45], characterizing socioeconomic changes between 1995 and 2005 associated with implementation of all of China's Six Priority Forestry Programs (including the CCFP), with a total sample size consisted of 1968 households (of which 861 were enrolled in the CCFP and 948 in the NFPP). This study found a contraction of labor inputs for land-based activities from an average 236.12 person-days per household in 1995 to 220.52 person-days per household in 2004; off-farm employment, meanwhile, nearly doubled from 1995 to 2004 from an average of 104.72 to 200.36 person-days per household.

A significant effect on both land-based labor and land-based expenditures associated with the CCFP was reported in another study [56] (sample size = 2070 households across six provinces): from 1999 to 2008, participating households directed 21.9 % more labor towards land-based activities (per ha) than non-participating households and, simultaneously, the former participating households directed 21.2 % more other non-labor expenditures towards land-based activities (per ha) than the latter non-participating households. This implies that, in spite of households' move away from sloping agriculture due to land-retirement, they have continued working on those sloping lands in forest management activities and intensifying production on their remaining agricultural land.

In contrast, two other studies (based on more restricted sample sizes) claim that the CCFP actually did not promote the above-mentioned shift to off-farm employment, though a switch from cultivation to forest management in sloping lands was reported in these places [57, 58]. It is plausible that in some locations labor has been directed more towards agroforestry rather than the more common pattern elsewhere of planting trees and pursuing off-farm jobs.

Food security The CCFP-led shift away from grain production on sloping lands has had implications for food security[5] at local and household levels, but not at regional or national levels. The national-level report based on a sample of 1165 households in 21 provinces estimated a 31.49 % decrease in household-level grain production from 1998 to 2009. However, county and national-level grain production grew 11.51 and 3.92 %, respectively, though the direct effect of the CCFP on those increases is not assessed [22].

Despite these positive figures of production at higher scales, local studies provide evidence that the CCFP has reduced food production in some locales. In Liping County, Guizhou Province, *"grain output per capita in 2002 was only 281 kg, almost the same as that of 1989"*, which was estimated to be insufficient [29]. In Yanchang county, Shaanxi province, annual grain production fell from a high of 64,000 tons in 1998 to slightly over 20,000 tons in 2008, attributed to CCFP-induced land-use change. As the area of cropland decreased from 290 km^2 in 1998 to ca. 100 km^2, the yearly per-capita output of grain also fell from 460 to 200 kg during the same period [41].

In two villages located within the Dulong valley [59], Yunnan province, local CCFP land-use change put an end to swidden cultivation in 2002 (i.e. an end to the traditional practice of cyclical clearing of forest patches for agriculture, being later abandoned following the subsequent decrease in agricultural land fertility), and by 2009 there had been a 50 % decrease in absolute numbers of livestock (pigs, chickens, cattle, goats, sheep and equines). According to the authors, villagers had abandoned animal husbandry due to a lack of grain for feed, leading to reduced dietary diversity and access to traditional foods [20]. Another study from Yunnan reports a decrease in grain output and associated production of livestock and income following land conversion. Cropland areas were reduced by half in the small watersheds of both Zhongyuan and Chashan, and in Chashan *"the remaining croplands of some households could not satisfy [farmers'] food demand"*. 71.4 % of surveyed farmers in Zhongyuan and 54.4 % in Chashan attested to a sharp decline in domestic pigs due to reduced availability of fodder [28].

In Dunhua County, Jilin Province, croplands in sampled townships decreased by 59 % between 1999 and 2003, or from 0.76 to 0.31 ha per capita, and farmers' basic needs for grain were still satisfied [49]. However, 10 % of surveyed households converted the entirety of their cropland to forest, which the authors say directly reduced their food security [49]. Finally, in Tianquan county, Sichuan province [42], the CCFP was judged to

[5] Here considered as a function of local grain/livestock production (local food self-reliance /local food sovereignty), and not as a function of measured calorie availability or instances of hunger.

introduce "*a new uncertainty into some farmers' lives.*" One informant stated that "*[l]ife was tough before [the CCFP], but basics like food were guaranteed. Now our food is not a certainty and I'm worried that I can't support my large family.*"

Finally, Wuqi county from Shaanxi province provides evidence on how its fast CCFP land-use conversion led to the intensification of agriculture on remaining cropland. In the first few years (1999–2001), agricultural total factor productivity sharply declined due to the CCFP causing both decreased technological and scale efficiencies, whereas technical efficiency (i.e. the optimization of the available inputs) started increasing. After 2001 total factor productivity grew, driven by technical efficiency, implying that remaining agricultural land uses had been intensified. The CCFP promoted a yield increase in corn and potato, respectively, from 3356 to 4422 kg/ha, and 8076 to 9974 kg/ha (between 1998 and 2004) [60]. Total output of these two crops had only been reduced by 24.03 and 20.36 %, taking into account the vast reduction of arable land induced by CCFP in Wuqi; while total output in minor crops during the same period decreased by 79.54 % and goat rearing (land-extensive husbandry) was substituted by pig livestock (land-intensive husbandry).

Land access and social equality Because CCFP implementation is based on household-level management, the program included provision of forestland tenure certificates by county forestry bureaus. Though few relevant papers on this topic passed screening, the available evidence shows that the majority of eligible households had received land tenure certificates, although with some variability.

Another large-sample paper (2070 households) [56] details how different income groups have been contracting CCFP land plots between 1999 and 2008, with households categorized as the "poorest" receiving the least amount of CCFP land. "Poor", "middle income" and "rich" farmers received the most land, amounting to an average of 4.96, 4.94 and 4.30 mu per household by 2008, respectively (refer to Table 8 in the same study, p. 244 bottom). In contrast, the "poorest" and "richest" income groups received 2.27 and 3.83 mu, respectively (Table 8, ibid.). Distribution was more equitable at the start of the program in 1999, when contracts averaged 0.50 mu to the poorest, 0.58 mu to the poor, 0.60 mu to middle income households, 0.86 mu to the rich, and 0.59 mu to the richest [56].

Finally, a perception-based study conducted in two villages in Yunnan [32] found that 76.5 % of sampled participant households in Longyang and 97.9 % in Tengchong had received their land tenure certificates following program implementation.

Though there were only three studies examining changes in social equality, there are indications that the CCFP led to improved social equality initially, but more recently has been unable to cope with rural inequalities associated with the development of off-farm income in the context of rapid urbanization. Two regional studies, conducted across the same six provinces (Hebei, Jiangxi, Shaanxi, Sichuan, Guangxi, Shandong), support this finding. The first of these credited the CCFP with a significant contribution to income mobility and the decrease in the Gini coefficient[6] from 0.44 in 1998 to 0.35 in 2006, although followed by a reversal between from 0.35 in 2006 to 0.45 in 2008 [56]. The second study [61] found the CCFP to have also reduced inequality initially, but has not been effective in offsetting increased inequalities related to the development of off-farm income. Finally, a provincial-level study in Shaanxi [58] found that the CCFP had a greater effect than other subsidized programs: a 1 % increase in CCFP subsidies to participating households vs. a 1 % increase in other subsidies to non-participating households was associated with decreases in the Gini index of 9.96 % compared to 4.2 %, respectively.

Other socioeconomic effects

Migration Only two eligible papers addressed migration, and none addressed policies of 'ecological migration' (i.e. targeted resettlement from ecologically sensitive zones).[7] Both papers report on the CCFP as being a 'push factor' promoting out-migration of farmers searching for off-farm employment [41, 42]. In Tianquan county (in Sichuan province) and Yanchang county (in Shaanxi province) declining agricultural output (measured in production, or as perceived by farmers) after program implementation and insufficient local job opportunities were the main factors explaining out-migration. In Tianquan, 63 % of households with off-farm jobs had to migrate to find work, whereas farmers in Wuqi County in Shaanxi Province were able to remain there as jobs were available locally in the petroleum industry. In Yanchang, more than half of the population in approximately 87 % of 46 sampled villages—and especially those aged between 20 and 40—were away for work for some part of the year. Finally, a summary of the evidence on both environmental and socioeconomic outcomes of CCFP is provided in Table 3.

[6] The Gini coefficient is a measure of income distribution that ranges between 0 and 1, 0 indicating perfect income equality and 1 indicating maximal income inequality. In practice there are different ways of calculating income distribution, although the Gini coefficient is the most frequent approach.

[7] In China, this term is usually referred to environmentally-degraded situations where local farmers were obliged to resettle into other regions.

Table 3 Summary of environmental and socioeconomic outcomes of the CCFP

	Environmental outcomes supported by evidence		Socioeconomic outcomes supported by evidence
Land-use and forest cover change	The CCFP has contributed to rapid land-use change and afforestation. Forest area has increased much faster in the CCFP counties as compared with the rest of China, i.e. CCFP counties had a forest-cover increase of 5 % above the national average	Income	The CCFP has contributed to increased average levels of income for CCFP participant households. In some locations, households also perceived a negative impact of the CCFP on livelihoods, income and food production and/or food security
Tree survival rates	Around 80 % of CCFP participating households have achieved tree survival rates above 70 %	Employment	The CCFP has contributed to the re-deployment of labor in hilly and mountainous areas, away from agriculture on slopes towards livestock rearing (in some areas, initially) and off-farm employment (generally)
Plans for reconversion back to cropland	There is a high degree of variability across different regions with different geographical and socioeconomic conditions	Land access and management	Individual forestland certificates have been issued to the majority of CCFP participant households, which has been associated with a differentiation effect in households' access to CCFP land plots
Biodiversity	Though studies are few and limited in geographic scope, there are some localized indications of substitution of local species by monocultures, which can affect ecological functionality and provision of ecosystem services as well as economic and cultural value	Food security	The CCFP has reduced grain production with negative impacts on food security of participant households in some locations; however at the county and national levels, overall grain production has increased
Soil erosion and flood prevention	Some positive results reported, although limited results in soil erosion control and flood prevention. Retention of nutrients has improved and water-yields reduced in some instances, but as mentioned, conservation strategies and their local possibilities should be weighed against each other	Social equality	The CCFP initially had a positive effect on both social equality and income mobility; this effect has been limited in recent years at least in part due to confounding factors related to the off-farm labor market
Biomass and carbon storage	The CCFP has contributed to carbon sequestration, with the expansion of forest area and tree cover and associated biomass. Trade-offs between water and carbon ecosystem services have been identified	Migration	Research is limited as to the CCFP's effects on the growing trend of rural-to-urban migration, but available evidence suggests the program's effects on land-use and rural labor are 'push' factors that at least complement the 'pull' of off-farm employment and the urbanization of China

Discussion

Reasons for heterogeneity

The heterogeneity of results presented in this review reflects the great diversity of socioeconomic and environmental contexts across which studies have been conducted over different periods of time. High heterogeneity across the studies, which represents a challenge to both CCFP program design and success, derived from either and often both environmental and socioeconomic reasons, many of which likely interact in significant ways with the others.

While certainly of greater actual scope due to geographic, geologic, and climate factors over China's huge territory, heterogeneity associated with primarily *environmental* causes identified in this review included the degree of accuracy in targeting sloping agricultural land plots for conversion; the site-suitability of selected tree species; the positive and negative feedbacks (tradeoffs) among ecosystem services.

Reasons for heterogeneity in environmental results include the fact that the targeting process for sloping agricultural lands was not consistently applied from the onset of the program and across regions. The BFU survey included in a national-level report [22] found that trees were being planted not only on slopes >25° but also on flatter lands that are potentially fertile and suitable for agricultural production. This likely occurred due to (1) rapid implementation at the outset of the program privileging scale over accuracy in targeting sites; (2) selection of adjacent land plots to minimize costs of afforestation and subsequent management; (3) the use of a simplified compensation standard taking into account only rough distinctions between the Yellow River and Yangtze River watersheds, rather than more localized environmental conditions.

Across China, ecological conditions vary greatly, and selection of tree species (or shrubs and grasses) have not sufficiently taken into account that variability, which entails very different results in terms of tree establishment, survivorship, and performance. For example, in arid conditions where annual precipitation is near or below the potential evapotranspiration, exotic tree species have performed badly, and have even worsened local environmental conditions. On tropical Hainan island meanwhile, the excessive use of plantation monocultures at the expense of natural forests and traditional swidden cultivation systems has had especially pronounced effects on biodiversity [43].

Additionally, local soil and weather conditions differentially affect the tradeoffs between the positive effects of the CCFP on soil erosion and flood control and the negative effect of insufficient water yield due to increased evapotranspiration. In dryer regions of the Loess plateau and Yellow River valley, the latter effect is problematic. Additionally, in some locations decreased erosion entails reduced transfer of nutrient-rich sediments from upstream to riparian agricultural zones downstream.

Heterogeneity associated with primarily *socioeconomic* causes included: locally specific effects of land conversion on livelihoods [23–25, 31, 41, 48, 51]; uneven granting of individualized land contracts to households [56] and increasing social inequality [58, 61]; differential availability of local livelihood alternatives [food security: 20, 22, 28, 29, 41, 42, 49, 60]; and variable perceptions of costs and benefits of participation [11, 16, 31, 34, 49–51]. These factors all play into the likelihood of forestland reconversion back to cropland for economic reasons [16, 25, 30].

Among counties implementing the CCFP, land conversion entailed either a loss in both household grain production [20, 22, 29, 41] and overall income, or a net increase in income [23–25], 45]. Differences in income effects were particularly pronounced at the start of the program, when reduced household-level food security had to be compensated for with distributions of grain stocks from prior years. On one hand, the reduction of agricultural land affected grain output [22]; on the other, the program's cash compensation and redeployment of household labor represented new opportunities, which varied depending on local land endowments and conditions as well as the economic context [23, 24, 27, 42, 45, 52–55]. These new opportunities ranged from off-farm employment to forest management, in which a minority of households came to specialize [57, 58].

Another source of heterogeneity of study results relates to the uneven rate of distribution of, household individualized land contracts, which are fundamental to land-use classifications across rural China. The poorest groups have benefited less from, and lagged behind in, receiving land allocations, a central factor affecting implementation of the CCFP [56]. Economic opportunities from local rural industries or alternative forestry livelihoods to absorb surplus labor freed up by cropland conversion have supported the increase in forest cover contributing to the CCFP, but these opportunities vary depending on local economic conditions. In Wuqi county, for example, a strong petroleum industry (albeit its questionable environmental sustainability) provided an alternative livelihood from agriculture [42]. Conversely, in Tianquan county, where such opportunities did not exist, CCFP implementation pushed local farmers to become migrant workers [42].

In addition to actual income effects, perceived costs vs. benefits of CCFP participation have likely resulted in diverse outcomes across the program. For example, in the case of Dunhua county [49], farmers thought family income was more important than water-soil erosion and forest protection: "*most families expected the government to bring about a greater chance to increase income and alleviate poverty.*" It was also noted in the same study that "*environmental benefits were lowest in Heishi and Emu townships where no plots…had slopes of more than 15°.*" In contrast, another paper [28] writing on a biodiversity region located in Yunnan featured farmers holding the opinion that the CCFP is good because it is conducive to improvement in the environment, promotes disaster mitigation, mountainous afforestation, as well as benefitting future generations. Finally, another regional study focused on northern Shaanxi [30] provides evidence indicating that: (a) 57.8 % farmers considered "*the environment is as least as important as the economy*" (24.8 % replied '*not*' and 17.4 % replied that had "*no opinion*"); (b) 44.4 % farmers replied affirmatively when asked "*is the environment badly degraded?*" (37.0 replied '*no*' and 18.6 % had "*no opinion*"); and (c) 44.4 % farmers replied affirmatively to the question "*does the environmental degradation affect your health?*" (39.7 % replied '*not*' and 15.9 % had "*no opinion*").

In the long term, the interactions among the above heterogeneous socioeconomic factors affecting results may predict scenarios in which CCFP participating households reconvert forest to sloping cropland, particularly in case program subsidies should be withdrawn [16, 25, 30, 31]. The empirical evidence indicates that farmers are in need of alternative livelihood strategies that allow them to meet their needs, food requirements and improve their own quality of life [30]. If post-conversion lands combined with non-agricultural benefits do not provide farmers with enough food and income, they are likely to turn forests back to cropland. In a study conducted in northern Shaanxi Province, farmers' responses prioritized agricultural development projects (67.3 % respondents) over urban jobs (18.4 % respondents) [30], contradicting the notion that farmers uniformly wish to relocate to cities and urban jobs, but also presaging reconversion should local economic conditions not favor maintenance of forest lands.

Review limitations

This review has several limitations, which need to be taken into account when using the information herein. First, the present review has been limited by time restrictions, and it thus focused only on English language studies on the topic. As there may be many relevant studies published only in Chinese, an eventual combined review of the literature in both languages will be more comprehensive.

Second, the degree to which the evidence presented is generalizable across CCFP implementation areas is limited due to a geographic over-representation of studies within the CCFP's 'pilot area' (Shaanxi, Sichuan and Gansu provinces), where the CCFP has been under implementation since 1999. There are several provinces where the CCFP is being implemented yet so far there are no English studies available from these areas which met the eligibility criteria of our review (provinces in white on Fig. 2).

Third, the evidence presented is stronger in examining socioeconomic effects and short-term outcomes than environmental effects and long-term outcomes. Studies specific to socioeconomic effects (n = 22), mostly conducted through household interviews, dominate the English CCFP literature. Although many of these studies were conducted early in the program's implementation, they are more geographically representative (they cover more provinces) than the generally more localized biophysical studies (n = 9). Measurement-based assessments of environmental change, especially over large areas (such as the CCFP implementation area and downstream areas of impact), will require longer-term data series and geographically representative field sampling. For this reason, the evidence of environmental effects in this review should be considered more illustrative than comprehensive or conclusive. The papers that address both socioeconomic and environmental effects (n = 12) are a strength of the body of evidence in English, but generally do not feature results based on data from biophysical measurements beyond remote-sensing analyses or farmer perceptions.

Fourth, the degree to which this review was able to compare evidence across geographies and time frames, and thereby control for socioeconomic and environmental heterogeneity over China's large population and territory, was limited due to a lack of consistent methodologies. Site selection and sample sizes across the studies varied widely, and most studies failed to select comparators or control groups, thus limiting their internal validity. The evidence base is therefore underdeveloped due to study designs of variable robustness, which entails susceptibility to bias and requires a careful approach to generalization.

Fifth, one research gap of great importance consists of the lack of research between ecosystem tradeoffs, e.g. as fundamental compromises were found between enhanced soil properties (reduced erosion) and decreased water-yields, and also between forest biodiversity and carbon storage. An additional research gap of this systematic review lies in the fact that research designs found in the English literature are constrained by the CCFP framework itself, most cases without questioning the program's core assumptions, i.e. income growth, rural-to-urban migration, and urbanization, which are key concepts of contemporary China's development and CCFP strategy. New studies could fill in an important knowledge gap that needs rigorous and robust research, both at the local village scale and on rural-to-urban life transitions. Apart from the empirical evidence on quantitative income differentiation, so far little research has been devoted to qualitative gender issues/social inequalities, as well as to ethnicity and/or ageing populations in CCFP pilot counties.

Despite these limitations, the authors are confident that the findings presented here represent a succinct summary of the most reliable evidence to date compiled on the overall environmental and socioeconomic outcomes of the CCFP.

Review conclusions

The following implications for future program implementation and research directions are based on the above narrative synthesis; again, these conclusions should be qualified by the limitations posed by the available evidence base. Nonetheless, the broad trajectories and case studies presented in the literature support the recommendations below.

Implications for policy/management

Several conclusions are provided in this section, with the caveat that evidence base is underdeveloped due to uneven territorial and temporal coverage of research to date, study designs of variable evidentiary strength, and potential resulting biases. Therefore a careful treatment underlies the following concluding remarks, which may serve as guidance for future research foci as well as program implementation.

Since the inception of the CCFP, farmer incomes and forest area have expanded, though with some area-specific costs in terms of food self-reliance and biodiversity. Several tradeoffs among ecosystem service benefits have been identified, including between carbon storage and water demand of tree plantations, and between soil erosion prevention and water delivery in arid regions, among others. Going forward, the program is in need of novel strategies targeting ecological restoration and livelihood improvement in more holistic and socially inclusive ways. Ideally, site selection should minimize encroachment on indispensible fertile agricultural lands and biodiversity, to safeguard local food security and ecosystem service delivery in the long term. Conversion decisions and management practices therefore need to be based on alignments of multiple desired outcomes to ensure that land-use configurations and species distributions fulfill simultaneous goals of environmental improvement and diversification of livelihood options. At the same time, program design needs to predict and mitigate tradeoffs between ecological and social benefits at different geographic and political scales, as well as among ecosystem services over short and long time frames. The targeting of state subsidies, as well as urban-to-rural (or downstream-to upstream) compensation payments, not only need to compensate for the opportunity costs of land retirement, but also require adaptive targeting to ensure distributional equity among both rural and urban populations, migrants, and groups facing specific identity- or context-related challenges. Land-use planning, meanwhile, should foresee multiple stages of landscape transformation over which ecosystem service effects and feedbacks are not linear.

Implications for research

Long-term research is required to better quantify the CCFP's environmental outcomes, which has not only applied value for policy implementation in China, but also theoretical value for restoration ecology globally. The program provides a unique opportunity to assess the contribution of forest restoration to many fields, including climate change mitigation and adaptation, conservation, and ecosystem services. Notably, the biodiversity effects of the program have been inadequately studied. Future studies should extend—beyond the deleterious effects of monoculture expansion and prescriptions for site-species matching using native species—to the role of restoration in enhancing functional diversity and diversifying ecological niches at the landscape level.[8] Other lines of enquiry which have not been addressed include the direct and indirect effects on soil and water pollution from agricultural inputs, and the relationship between forest restoration and the emergence of forest pathogens and pests requiring management. Additional studies on the tradeoffs among ecosystem services (e.g. between carbon capture and water demand, or erosion prevention and water delivery) will be useful going forward.

In terms of socioeconomic outcomes, inadequately explored areas include studies on gendered and ethnicity-specific effects of land reclassifications, and the feedbacks between the CCFP and China's broader demographic shifts. The latter include aging of the rural labor force and rural-to-urban migration, among others. All of these interactions have implications for equity and social equality. Finally, future research should better address confounding factors through better incorporation of control groups and control sites to ensure representative sampling of populations and geographies at scale. A review of the Chinese literature on the CCFP is expected to round out the body of evidence on some of the above gaps; others will require more geographically dispersed and longer term field studies to address.

[8] See, e.g. Chazdon [62]'s call for more attention to the incorporation of natural processes, including natural regeneration and succession, in the design of restoration projects.

Additional files

Additional file 1: PICO search terms, search strings and combinations.

Additional file 2: Full bibliographies and data extraction of included studies.

Abbreviations

BFU: Beijing Forestry University; CCFP: Conversion of Cropland to Forest Program; CIFOR: Center for International Forestry Research; CNY: Chinese yuan; ENSO: El Niño Southern Oscillation; FEDRC: China National Forestry Economics and Development Research Center, China State Forestry Administration; NFPP: Natural Forest Protection Program; PPES: Public Payments for Ecosystem Services; SLCP: Sloping Land Conversion Program.

Authors' contributions

All authors took part in the systematic review meeting held in Kunming in April 2014. NH carried out initial database searches of English studies, and provided key research inputs to this review. LP and CX provided key research guidance for the definition of primary and secondary questions. LGR, NH, WZ, LP, KZ and CX participated in pilot Kappa tests for study screening. LGR carried out literature scoping in English databases, led the review, its analyses and writing. All authors read and approved the final manuscript.

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Competing interests

Some authors of this systematic review had previously published several studies that are included within the 43 CCFP studies' database (Additional file 2). In order to assure the objectivity of this review, the authors in question were excluded from the process of reviewing their own published studies (i.e. they did not participate in the review of their own produced studies).

Availability of data and materials

See Additional files for PICO search terms, search strings and combinations along with full bibliographies and data extraction of included studies.

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