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Assessing the Effect of a Crop-Tree Intercropping Program on Smallholders' Incomes in Rural Xinjiang, China

Xiaoqing Dai [1], Lijie Pu [1] and Fangping Rao [2,*]

[1] Department of Land Resources and Tourism Sciences, Nanjing University, Nanjing 210023, China; daixqnju@126.com (X.D.); ljpu@nju.edu.cn (L.P.)
[2] College of Public Administration, Nanjing Agricultural University, Nanjing 210095, China
* Correspondence: raofp04@126.com; Tel.: +86-025-84395700

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Abstract: Governments in developing counties often promote intercropping (crops intercropped with fruit trees on cultivated land) schemes in order to improve smallholders' income. However, the implementation of such schemes is often hindered by inappropriate institutional environments and inefficient project management. It is important to assess the impacts of such intercropping programs, especially since such a cultivation strategy can often align closely with smallholders' livelihood strategies, particularly in poor and remote rural regions. This paper attempts to assess the impact of an intercropping program on participants' incomes in rural Xinjiang (China), and to explore the possible shortcomings in the program's design and implementation. We apply a propensity score matching method, based on a survey dataset of 352 households, supplemented with descriptive analysis based on our anecdotal field observations. The findings demonstrate that the intercropping program had negative effects on the incomes that participants derived from farming, their off-farm income and their gross income. Overall, participants experienced significant losses of income. Anecdotal observations show that land tenure insecurity played a crucial role in negating the anticipated income improvement effect of this program. Farmer's perceptions that they have limited security of tenure made them reluctant to invest the necessary time and resources to make the new cropping systems a success, while the available subsidies only partially covered the costs involved. In addition, the program led to a significant drop in yields of field crops as the trees were competing for a limiting and fixed supply of irrigation water.

Keywords: program assessment; intercropping; income; implementation constraint; rural Xinjiang

1. Introduction

One of the core missions of economic development is to find feasible ways of alleviating poverty. One popular option is to promote intercropping. This strategy, also known as tree-based intercropping, involves the mixed cultivation of trees for wood/timber or fruit/nuts and annual crops in the same field [1]. Mixed cultivation has been advocated as an alternative to traditional farming systems, with the potential to increase the productivity of land and to diversify production [2,3]. It is widely seen as a sustainable agricultural innovation, with enormous ecological, agronomic and economic potential [4–6]. As such, it has been widely promoted since the late 1970s, particularly in marginal regions with fragile ecosystems, experiencing land degradation, water scarcity and unsustainable exploitation of natural resources [7].

In rural China, intercropping systems have been widely promoted in order to diversify households' income generation sources and to improve the sustainability of land use [8]. It is estimated that the intercropped area has grown to more than 28 million hectares, which is most concentrated in the

country's western arid and semi-arid regions [9,10]. In our case study, where intercropping is being promoted by the regional government in Xinjiang, there is a large program to encourage small-scale farmers, most of whom are of Uyghur origin, to plant fruit trees among their crops with the aim of improving agricultural output [11]. The program also aims to reverse the ecological problems of the increasing shortages of irrigation water and the degradation of arable land. Participants involved in this program are required to set-aside part of their land for intercropping. In return, the local government reimburses some of their initial investment costs (either in cash and/or in-kind).

Many studies have focused on the overall income effect of intercropping and the sale (or consumption) of timber, fruits and firewood, and found program participation positively contributes to smallholders' gross income [12–14]. However, some others argue that the income, particularly of the landless and the poor, remains unchanged (or even decreased) primarily due to inequalities in land endowments, limited market access and/or poor road transportation [15,16]. Moreover, shortcomings in program implementation, caused by inadequate budgets, lack of institutional environment support and/or inefficient project management can also undermine the effectiveness of such programs [17,18].

In addition, the impact of such similar agroforestry schemes in stimulating a transfer away from off-farm transfer also gives rise to concern, especially since off-farm employment is increasingly recognized as an important way of reducing poverty. (While China has experienced remarkable economic growth in recent decades, social scientists and policy makers continue to be concerned about the widespread and persistent rural poverty, particularly in the western part of the country [19]. There is a widespread view that off-farm employment is the main way of escaping poverty [20,21]. For many rural households, off-farm income is a critical, if not most important, income source and off-farm income helps to narrow the income gap between rural households [22]. However, it is recognized that households in developing countries often confront a range of barriers, specifically a lack of human capital and constraining institutional environments that make it difficult for them to be involved in off-farm activities [23]. For instance, in China, the combination of insecure land tenure rights, and poorly developed rural land and credit markets generates high transaction costs for farm labor immigration [18,24]. As such, the topic of off-farm transfer is of on-going concern.) Analysis of the American experience indicates participation in agroforestry programs often leads to participants to reduce their off-farm employment [25,26]. Ahearn et al. found that participation in Payment for Environmental Service (PES) program is negatively correlated with the likelihood of off-farm income generating activities [26]. In China, similar studies have produced mixed conclusions. A widely studied Chinese example is the Sloping Land Conversion Program (SLCP) (the SLCP involves converting croplands on land prone to erosion into forests and/or grassland—see Xu et al. and Uchida et al. [27,28]. Groom et al. found that the SLCP increased participants' off-farm involvement, particularly among lower income households [28], while Uchida et al. found that smallholders' off-farm activities are negatively related to participation in the SLCP [29]. (Liu et al. found that the SLCP had a significantly positive effect on rural income growth (based on a sample of 1968 households and covering the period between 1996 and 2004) [30]. By contrast, Xu et al. found no significant effect on aggregate income between 1999 and 2002 [27]. Uchida et al. emphasized that the effect of the SLCP is location-specific and that participants in Gansu and Sichuan experienced a net loss, but those in Ningxia and Shaanxi experienced a net gain [28].)

Thus, there are question marks over the income impacts of intercropping programs. Major international donors, such as the World Bank, often conduct poverty alleviation assessments of their or others' programs [31]. (Almost every policy or program proposed for developing countries by the World Bank and other international donors has a key focus on poverty reduction, thus assessing the effect that these policies and programs have on poverty reduction is a central and key issue [31].) Assessing the impacts of an intercropping program on smallholders' incomes in poor regions facing ecological degradation is critically significant. Given the central role of intercropping systems in the land use strategies and livelihoods of farmers, it is surprising to find very little evidence of such studies

being conducted within the context of rural China. Two exceptions to this are the scant evidence that exists to the description by Spoor and Shi, and Spoor et al., who reported that the introduction of crop-tree intercropping system diversified small-scale farmers sources of income, but that they faced potential marketing risks as the program they studied was expanding too quickly [11,32].

Given complex institutional environments that surround program implementation and the local variations in these, it is pertinent to question how the implementation of agroforestry programs influences participants' incomes [30,33]. The intercropping program in rural Xinjiang offers an interesting case study. First, it is home to a large number of rural poor [32]. This remote and less-developed region is experiencing soil salinity and frequent droughts [34]. Intercropping is thought to have the potential to help change land use patterns within a region with fragile ecosystems and to help local smallholder farmers to escape from the poverty trap. Second, arable land plays an essential role in supporting smallholders' livelihoods [11]. An assessment of the program's impact on farmer's incomes is policy relevant, as it will help focus future policy interventions. Third, unlike elsewhere in China, where off-farm activities are a main source of income, a large number of the rural labor force in this region work in agriculture [35]. An analysis of the impacts of the program will provide an important contribution to understanding the links between agriculture, the rural labor market and the incidence of poverty in this poor region. Finally, this is a politically sensitive area [36,37], which makes it difficult (particularly for foreigners) to conduct field survey in the countryside, which means developments in this region are under-reported [38–40]. The unique household dataset we have gathered provides a rich research resource and valuable empirical evidence for assessing and for furthering the debate about the effects that agroforestry schemes have on smallholder farmers' incomes.

The objectives of this study are twofold. First, it aims to assess the impact that the intercropping program has had on smallholder farmers' incomes and, second, to explore the issues and constraints experienced in implementing the program. The paper contributes to the literature that it makes use of what is known as the propensity score matching (PSM) technique to addressing the problem of potentially missing data in assessing a program's performance. More specifically, it is impossible to observe one unit (such as a household or farmer) simultaneously in two different states, making it difficult to find a valid comparison (control) group for the treatment group [41]. (For instance, suppose Y_i^1 = the outcome after participation in the program (treatment), and Y_i^0 = the outcome without participation (control), then the program impact $E(Y) = E(Y^1 - Y^0)$. Assessing the different impact between different units ($E(Y) = E(Y_i^1 - Y_{i+j}^0)$) could be biased because the units have different characteristics. Ideally, one should compare the same unit in two different states at the same time ($E(Y) = E(Y_i^1 - Y_i^0)$). However, data on these two states is lacking (and thus unobservable) since each unit either participates or does not participate in a program, giving rise to what is known as the missing data problem [42].) The PSM deals with this missing data problem by generating two groups of units that are statistically distinguishable and identical, with the sole exception that one group (the treatment group) participates in the program and the other (the control group) does not [42–44]. Findings can contribute to the deliberation of the income effects of agroforestry program for poverty reduction in transition economics in developing counties.

The remainder of this paper is organized as follows. Section 2 provides a theoretical background that discusses the links between intercropping and incomes. Section 3 introduces the research area and the ways in which intercropping has been encouraged within it. The following section presents an empirical assessment of the impact of the intercropping program on participants' incomes by using the propensity score matching technique, supplemented with some anecdotal observations. The conclusions and policy implications are reported in Section 5.

2. The Theoretical Links between Intercropping and Income

In this section, we develop a conceptual framework to explain the likely effects of intercropping program on smallholders' incomes. We distinguish two different effects: the direct effects induced by more intensive labor input, the availability of subsidies (in cash and or in kind), the effects that these

have on farmer's propensity to participate in the off-farm labor market, and the indirect effects which are induced by enhancing land tenure security.

The direct income effect stems from the fact that intercropping is a labor-intensive practice and this can influence program participants' propensity to take up off-farm jobs [45,46]. Our field observations confirm that the crop-tree intercropping system demands more labor input in terms of field management, than a mono-cropping system (for detailed discussion on the intercropping system, see Section 3), which means that, when households adopt intercropping, they have less time to take up off-farm activities. It is worth noting that the availability of labor force is usually the key constraint facing rural households in developing countries who want to improve their livelihoods [15]. This is particularly the case in rural China. Chinese agriculture production is more labor-intensive than in many other developing countries [47]. As such, adopting intercropping is expected to have opportunity costs for households' off-farm income.

Another direct income effect is related to the availability of subsidies. Participants in intercropping programs are provided with a governmental subsidy, whether in cash and/or in kind [27]. The cash element of this subsidy can be used as "windfall" income, which can reduce the pressure to work off–farm or use it to make agricultural investments [18,48]. In other words, the subsidies associated with program participation can provide households with supplementary income and relax the monetary constraints facing them [29]. (Households may also face high monetary and temporal transaction costs (such as transportation and job hunting) when doing off-farm jobs. This is particularly the case, as in many rural areas in developing countries, because of poorly developed labor and credit markets [23,49]. Governmental measures could be applied to reduce these transaction cost constraints [29].) As such, the subsidy element of the intercropping program should enhance participants' income, but depending at a large extent on the subsidy deliver in program implementation.

The indirect income effect arises from the potential of intercropping to increase efficiency by leading to a rearrangement of the labor-land input ratio in farming. This can have a two way effect. On the one hand, insecure land tenure may discourage farmers from investing their labor and dedicating their land to intercropping as there is a risk that they will not reap the future yields. Meanwhile, farmers may be constrained from switching from farming to off-farming due to worries about losing land that they are no longer using. However, intercropping can also help secure land tenure by giving land users more rights and thus lower the risk of losing the land, and consequently leads participants to rearrange their labor-land input ratio in farming [50,51]. This is particularly relevant in China, as it has been demonstrated that the adaptation of intercropping can significantly enhance land tenure security [8].

More specifically, land tenure insecurity can often discourage households' land-related investment incentives and jeopardize agricultural productivity [52–54]. At the same time, insecure land tenure also inhibits households' participation in land rental markets, since with no secure tenure it is not possible to sell, mortgage or rent out land [18]. Successive land reforms in rural China, have provided peasant farmers with usufruct rights with different lease lengths, but it is widely argued that they have done little to enhance land tenure security [55,56]. (For instance, the 2007 Property Law granted farmers the right to retain and inherit their land rights when the 30-year period is ended, implicitly giving farmers perpetual possession of land in the future [57]. In 2008, the central government further extended the land contract period from thirty years to an unspecified "long-term" period and it was also specified that land certificates should be issued to farmers [56,58].) One main reason for this is that the central government has not clarified how the legal and institutional arrangements should be implemented [59,60]. Thus, these rules have not been effectively enforced [57,61]. As a result, unintended policy outcomes have occurred. Local governments in many rural areas are often unwilling to issue land certificates [62]. In rural China, the land registration systems are ill-defined and the legal system incomplete [62]. Land tenure insecurity remains widespread, as there is often a very real risk of expropriation through land adjustments at the village level [56,63]. The tenure framework that exists in China constrains rural labor from transferring from agricultural production to more profitable off-farm

jobs because of fears of losing land left behind after migration [29]. This implies that farmers who are capable to engage in more profitable off-farm activities may be blocked in agricultural production, resulting to a mismatch between the composition of labor and land inputs at the household level.

Numerous empirical studies have demonstrated that intercropping trees on cultivated land can enhance land tenure security [58,64]. This is mainly because farmers treat tree planting as a type of long-term investment and believe it helps to extend land use and occupation [50,51]. Growing trees is a long-term project, usually extending over decades. Thus, farmers often begin growing trees as a coping strategy, to protest against land expropriation or third party infringement [50,51]. In this sense, intercropping enhances land tenure security. Secure land tenure can be expected to stimulate investment in agricultural production [8,51]. In addition, the land rental market and participation in off farm activities can also both be stimulated as there is less risk of losing rented-out land, thereby relaxing the farm-labor transfer and improving the balance between inputs of labor and land. Through these mechanisms, intercropping is likely to induce households' enthusiasm to invest in increasing the productivity of their land (leading to higher farming income), and to boost their participation in the off-farm labor market.

Farmers in rural Xinjiang face a relatively lower possibility of land expropriation, as there have been fewer land adjustments there than in other central and eastern rural regions of China [11]. However, Rao et al. identified that formal tenure institutions only play a modest role in this region in shaping land tenure security [65]. Informal tenure arrangements (mainly based on a foundation of trust between villagers) play a much more central role. Intercropping trees on land are often be motivated by the desire to establish assets on the land, and more importantly, to extend the land occupation period [8]. From the perspective of enhancing security of tenure, intercropping is likely to increase both farming income and off-farm income.

Analysis above shows that participation in an intercropping program can affect farmers' decisions about how to allocate labor and land, and directly or indirectly influence the (farm and off-farm) income derived by participating farm households. However, these influences can pull in different directions. The effect of this program on participants' incomes will be determined by the combination of these direct and indirect effects, and we now turn our attention to empirically establishing these effects.

3. Research Site and Data

3.1. Intercropping: Towards a Diversified Income Generation Strategy

Our research site is located in the Xinjiang Uygur Autonomous Region (XJUAR), in the west of China. The largest ethnic group is of Uyghur descent (45.94% in 2012) [66]. It is a typical arid and semi-arid area, with an annual average of less than 150 mm precipitation (and less than 100 mm in the southern parts of the province) [34]. Water scarcity is an increasing problem, particularly during the hot summer period [67]. Agricultural production relies heavily on the availability of irrigation water [68].

The abundant radiation and heat resources make Xinjiang an ideal place to produce cotton: it is China's leading cotton producing region, producing more than 60% (around 7.2 million tons) of China's seed cotton in 2014 [69,70]. Cotton production for a long time has been a central pillar of local farmers' livelihood strategies. However, it does not significantly contribute to income growth or help alleviate local poverty, partly due to natural resource constraints, particularly the lack of irrigation water and the degradation of arable land [32,71].

The factor market in Xinjiang is poorly developed. A number of constraints limit the off-farm opportunities that are available to local farmers, particularly the language barriers and a traditional attachment to land-based livelihoods [8]. The rural land rental market is still at an embryonic stage of development [11]. Our 2008 field survey data show that only 34 out of 352 households (9.7%) rent land, with only 8.2% of land area is involved. Most of these land rental activities take place within kinship relations or between fellows in the same villages (Fieldwork notes from Aksu, January 2014).

Fruit farming in rural Xinjiang has been practiced for a long time as the area has ideal climatic conditions. However, the government-led crop-tree intercropping system was only launched in late 2004. Before, this fruit growing was mostly traditional, scattered and small-scale with trees planted mostly in the homestead and grown for self-consumption. Facing a scarcity of irrigation water and increasing salinization of arable land, the XJUAR government proposed diversifying households' sources of income by introducing a crop-tree intercropping system. Since then, fruit farming in rural Xinjiang has developed rapidly.

Various programs have been established in the region to expand intercropping (see Table A1 in Appendix A). One example was the Fruit Management Efficiency Improvement Campaign that ran between 2008 and 2010. It supported farmers to introduce fruit and/or nut trees into cotton or grain fields, under the slogan "stabilize grain, reduce cotton and extend fruit". According to a local governmental official in the Forestry Bureau of Aksu Prefecture, "intercropping with fruit (and nut) trees can improve irrigation efficiency because it irrigates both the fruit trees and the crops simultaneously. This practice also facilitates a continual stream of income for smallholders, because the life cycle of fruit (and nut) trees lasts quite a long time (usually over 30 years). Although the investment demand was sizeable in early stage (in the first 3–5 years) of tree planting, the county government was able to provide multifaceted support including technical assistance, seedlings, subsidies and fertilizer" (fieldwork notes from Aksu, January 2014). It is estimated that the expenditure on this project rose from 5 million Yuan in 2009 to almost 9.5 million Yuan in 2010 (Source: Data provided by Xinjiang Forestry Bureau during the fieldwork, March 2008).

The last decade has seen a dramatic expansion of intercropping growing [11]. It is estimated that the planting area of fruit trees increased from 344.2 thousand hectares in 2003 to just over one million hectares in 2012, with the majority (86.90%) planted in the southern part of Xinjiang, the poorest part of the province [72]. (The title of poor and non-poor is defined by the Office of Poverty Alleviation and Development. Rural Xinjiang had 30 poor counties amounted before 2012, which fell to 27 thereafter. Twenty-one of these were in the south, please refer to the following link: http://www.cpad.gov.cn/ (accessed on 15 July 2014).

3.2. Dataset and Description

The dataset we use is from a rural household questionnaire survey, conducted in three townships in Awati county in Aksu prefecture during the winter of 2008. Households were sampled randomly from a household list provided by the local village cadres from nine villages, distributed almost equally over the three townships.

The main purpose of the survey was to explore the impacts of participating in the crop-tree intercropping program on small farmers' land use, income sources and livelihoods. Detailed information was collected from households on their agricultural production, demographic characteristics, land endowments, intercropping participation, and varied income generation sources. This was complemented by information collected at the village-level.

For the purpose of our analysis, we used data from 352 households (out of the original 361), of whom 236 were program participants. To obtain an intuitive interpretation of differences between participants and non-participants, we tested the differences of mean values between different incomes. Results are displayed in Table 1.

It can be found that adopters of intercropping devoted significantly less time (71.87 days annually) to off-farm employment than non-adopters (96.16 days annually). (We define a household participating in off-farm activities as one where any single family member is engaged in off-farm activities, either within or outside the village.) This suggests that participation in an intercropping program reduced off-farm participation. In addition, households who participated in the program owned lower off-farm income (2554.77 Yuan per household) and farming income (16,031.70 Yuan per household) than those who did not. Overall, the gross income (Gross income is the sum of agricultural income, off-farm income, and other incomes such as government subsidies and so forth) among participants

(28,108 Yuan per household) was higher than among non-participants (25,033 Yuan per household per household), meaning that wealthier households are more likely to participate in the program, and that the program is poorly targeted.

Table 1. Comparison of off-farm participation and varied incomes between participants and non-participants.

Variables	Full Sample Average	Non-Participants	Participants	Diff. and *T*-Test
Off-farm employment participation				
Off-farm employment time (days per year)	79.88	96.16	71.87	24.28 *
Income				
Off-farm income (Yuan per household)	2623.00	2762.85	2554.77	208.07
Farming income (Yuan per household)	16,192.00	16,520.98	16,031.70	489.28
Gross income (Yuan per household)	27,095.00	25,033.00	28,108.00	−3075.00
Obs.	352	116	236	

Note: * represents 10% statistical significance level; Source: own household survey in 2008.

To obtain a better understanding of the income impacts of intercropping we conducted a follow up fieldwork trip to six of the villages within the three townships in our research site in January 2014. (The time-lag issue can be a result of subjective interpretation bias by respondents. The descriptive questions in the 2014 interview were carefully designed and asked by professionally-trained evaluators in order to reduce the impact of this.) They were selected as the crop-tree intercropping program had been widely adopted since late 2004. In-depth interviews with key informants were undertaken to explore the lessons that could be learnt for future policy implementation and to understand farmers' initial rationales for (non)participation in the crop-tree intercropping program. The rich information obtained from these interviews is used in anecdotal analysis in Section 4.4.

4. Empirical Evidence

4.1. Basic Model

The main objective of our analysis is to assess the income impact of intercropping. As we discussed above, intercropping influences participants' labor and land inputs between farming and off-farm activities, thus this analysis focuses on farming income, off-farm income and gross income. We assume that households' income is the function of participation in the intercropping program and other control variables. The income model is specified as:

$$Y_i(S) = F^s(X_i) + \varepsilon_i^s \quad S = 0, 1 \tag{1}$$

$$S_i = G(W_i) + \mu_i \tag{2}$$

$Y_i(S)$ denotes three income types for household i that participates in intercropping S. S_i concerns participation in the program (=1 yes; =0 otherwise). Y_i^1 and Y_i^0 represent the income derived from these two possible participation statuses. X_i is a vector of explanatory variables. W_i represents a subset of X_i, which may influence the adoption of intercropping. ε_i and μ_i are error terms.

4.2. Estimation Strategy

Our study is to examine the impact of a non-experimental participation program. Usually, participants in intercropping program are not randomly assigned but are selected on the basis of some household or village characteristics [15,73]. The primary challenge we faced was to address the confounding bias in our observational data [43,74]. Theoretically, to obtain unbiased estimation, information on both the pre-program status and the post-program status for each participant and non-participant would be required. However, such information was impossible to obtain in non-randomized program design, like our study case [41]. The main challenge in assessment analysis is to find a comparable control group that has the same characteristics as the treatment group [42,43].

The recently developed propensity score matching (PSM) technique provides researchers with a valid way to address this fundamental data-missing problem. As mentioned above, PSM generates two statistically similar or identical groups of units (namely the treatment group and the control group) [44]. The difference in outcomes between these two groups can then be attributed to a program [42]. Available analyses based on both large sample theory and small sample theory have demonstrated that the PSM is able to remove the observation bias in program impact assessment analysis [43,75]. This method is considered a straightforward way to draw plausible causal effects [76,77], and is widely applied in the literature on assessing the effects of program [78,79]. (The PSM method is applied in order to critically judge the success of the child and family service program and the impact of the microfinance program on savings and income respectively. Please refer to Barth et al. and De Silva for detail [78,79].)

The basic idea method for using the PSM involves selecting a group of non-participants (as the control group) whose pretreatment characteristics are similar to those participants (as the treatment group). This allows for differences in outcomes (that is the income in our case) between these two groups to be ascribed to the effects of program [41]. To make the comparison more meaningful, participants and non-participants are sub-classified according to the propensity score in order to make the characteristics of the two groups similar [75]. (Propensity score refers to the likelihood of participating in a program, which is calculated based on observed covariates [74].) Balancing assessment is conducted to further confirm the real presence of similarities and the matching algorithm test shows how close the similarities are [73]. The formula of the PSM estimation can be written as:

$$\tau_i = \mathrm{P} * \left[\mathrm{E}\left(\mathrm{Y}^1 \middle| \mathrm{S}=1\right) - \mathrm{E}\left(\mathrm{Y}^0 \middle| \mathrm{S}=1\right)\right] + (1-\mathrm{P}) * \left[\mathrm{E}\left(\mathrm{Y}^1 \middle| \mathrm{S}=0\right) - \mathrm{E}\left(\mathrm{Y}^0 \middle| \mathrm{S}=0\right)\right] \quad (3)$$

τ_i is the average treatment effect across all farmers. S and P denote the policy participation status and participation likelihood respectively. Y^1 and Y^0 are the impacts of program participation and non-participation respectively. The counterfactual effects $\mathrm{E}\left(\mathrm{Y}^0 \middle| \mathrm{S}=1\right)$ and $\mathrm{E}\left(\mathrm{Y}^1 \middle| \mathrm{S}=0\right)$ are unobservable, but can be substituted by proper parameters via the matching approach.

According to Caliendo and Kopeinig, and Lanza et al., an unbiased estimation in the PSM application involves four main steps [41,44]: (1) estimate the propensity score by a logistic regression model for binary treatment; (2) use matching to adjust for the confounding values; (3) balance the assessment; and (4) estimate the effect (for a more detailed introduction on the use of the PSM, see Abadie et al., and Caliendo and Kopeinig [41,80]).

It is worth noting that the most frequently estimated effect in program impact evaluation is the average treatment effect on the treated group (ATT) as this focuses explicitly on the effect of the treatment on the outcomes experienced by the treated group [41,44]. Thus, this parameter can be interpreted as the gross benefit of program implementation. It can also be used to compare with the program to establish a positive or negative benefit cost ratio [43]. We focused on the ATT parameter, which, in our case, measures the difference between incomes of the two matched groups (the program

participating group and the non-participating group). The estimation for the ATT can be stylized as (X is the confounder in propensity score model in step 1):

$$\tau_{ATT}^{PSM} = \mathrm{E}_{(\mathrm{P(X)|F=1})}\{\mathrm{E}[(\mathrm{Y}(1)|\mathrm{F}=1, P(\mathrm{X}))] - \mathrm{E}[(\mathrm{Y}(0)|\mathrm{F}=0, \mathrm{P}(\mathrm{X}))]\} \quad (4)$$

In the use of PSM estimation, households who participated in the program were assigned as the treated group, with the remaining households as the control group. We acknowledge that the income differences observed between participants and non-participants may not just be the result of program participation. Assuming that two underlying assumptions (the conditional dependence and common support) hold true, the ATT estimation procedure was run as follows: first we estimated the likelihood of program participation (Equation (2)) by using the probit regression (see results in Table A1 in Appendix A) to obtain the propensity score for each household. (Two assumptions should be satisfied to obtain unbiased estimation on the ATT. The first assumption is the conditional independence, namely given a set of covariates X, Y(0), Y(1) and S are independent: (Y(0), Y(1)$\perp$S | X). This implies that the variables introduced should satisfy the "balancing" condition. The second assumption is the common support condition, namely 0 < Pr (D = 1 | X) < 1, which implies that the "matching" test should be satisfied.) (As our specific concern is the average treatment effect, for brevity, we do not discuss the probit regression results, but only report them in Table A2 in Appendix A) Second, following Villano et al., we match the treated group with the control group by applying three matching strategies with common support: (1) nearest neighbor with replacement; (2) radius within 0.05; and (3) kernel (bandwidth = 0.06) [81]. Lastly, the ATT (Equation (4)) is estimated by using the matching results. The evaluation of the estimation quality test on the use of the PSM was conducted through the matching quality test and the balancing quality test (see results in Tables A3 and A4 respectively in Appendix A).

4.3. Variable Definition and Descriptive Statistics

A crucial practical issue is the selection of observed covariates in the application of the PSM [75]. In principle, variables that theoretically facilitate the prediction of being selected into the treatment groups and that are related to the outcome should be included, but those that are influenced by the treatment should be excluded [41,82]. In addition, the instrumental variables that are related to the treatment but not related to the outcome should be excluded [83]. Based on the empirical literature on smallholders' technology adoption and the evaluation of program impacts [21,22,30], we introduced variables that are jointly related to intercropping participation and income into the propensity score model (Equation (2)) as covariates, including three groups of characteristic variables: village, household and land.

At the village level, experience of land adjustment within the village (an indicator of land tenure security) and the distance from village to town center (as indicator of access to markets and information) are both included [60]. The predicted impact of land adjustment is mixed. On the one hand, insecure land tenure can motivate farmers to engage in intercropping in order to protect their land use rights [18]. On the other hand, insecure land tenure can discourage farmers from investing in intercropping [51]. In order to reduce the estimation bias caused by the possibly existed endogeneity of land tenure security, only the village level tenure security variable was introduced. Market access is found to be positively correlated with intercropping adoption [84]. Meanwhile it is also relevant to income, since market access is crucial in deriving incomes from fruit and farming. Thus, it is expected to have a positive effect.

At the household level, the characteristics of human capital, the amount of available agricultural labor in a family, and ethnic background are introduced. Human capital is considered to be the most important factor in influencing rural households' wealth accumulation strategies and their likelihood to adopt innovations adoption [22]. We introduce household age, square of household age and education as indicators of human capital. The effects of these may be mixed: younger farmers may display a stronger tendency to take risks but older farmers may be more experienced in field

management [15]. The amount of agricultural labor within a family, as well as family size, both influence labor force availability [21], and may positively influence decision about labor allocations and how to generate income [15]. China's central government operates favorable policies towards ethnic minorities, for instance in education and infrastructural investments [85]; thus we introduced the ethnic characteristic on the assumption that the likelihood of program participation and the income impact of intercropping would differ between Han Chinese and the Uyghur ethnic minority.

Natural resources, particularly land and irrigation water, are acknowledged to be two fundamental inputs in agricultural production [22,86]. We introduce soil fertility, land endowment and access to irrigation as indicators of land characteristics. Soil fertility and irrigation are key determinants for good harvests and are thus predicted to be positively correlated with program adoption and income generation [11]. The effect of land endowment is mixed. On the one hand, smallholder households could be more concerned about governmental subsidies and be more likely to participate in state programs [15]. On the other hand, farmers with more cultivated land may be more willing to set aside part of their land for intercropping in order to benefit from a diversified cropping system. To detect the unobservable effects from outside the village, we also introduced two township dummies. The variable definitions and descriptive statistics are presented in Table 2.

Table 2. Variable definition and descriptive statistics.

Variables	Definition	Mean (S.D.)			Diff. (I-II)
Treatment Variable		Combined	Participant (I)	Non-Participant (II)	
Participation	Intercropping adoption (=1 yes; =0 otherwise)	/	/	/	/
Village Characteristics					
Distance	Distance from village to township centre (km)	9.20 (7.07)	7.69 (5.75)	12.28 (8.40)	−4.59 ***
Land reallocation	Past land reallocation experience(=1 yes; 0 = no)	0.43 (0.43)	0.53 (0.50)	0.24 (0.04)	0.28 ***
Household Characteristics					
Age	Age of household head (years)	47.81 (14.43)	48.67 (14.02)	46.06 (15.14)	2.61 *
Age square	Head age squared	2493.05	2563.94	2348.82	215.12 *
		−1469.93	−1430.06	−1544.15	
Education	Household head's level of education (years)	5.747 (3.14)	5.59 (3.17)	6.06 (3.05)	−0.47 *
Family size	Number of person in the household	4.74 (1.53)	4.84 (1.53)	4.54 (1.52)	0.30 **
Agricultural labor	Share of agricultural laborers as a share of total family laborers	0.65 (0.23)	0.66 (0.23)	0.64 (0.23)	0.02
Uyghur	Uyghur ethnicity household	0.88 (0.33)	0.91 (0.28)	0.80 (0.40)	0.11 ***
	(=1 yes; =0 otherwise)				
Land Characteristics					
Soil quality	The quality of soil (=1 high; =0 otherwise)	0.44 (0.50)	0.54 (0.50)	0.24 (0.43)	0.30 ***
Land area	Area of cultivation land per capita (mu/capita)	4.21 (5.89)	4.22 (5.49)	4.19 (6.65)	0.03
Irrigation	Enough irrigation (=1 yes; =0 otherwise)	0.27 (0.44)	0.29 (0.45)	0.23 (0.42)	0.06

Table 2. *Cont.*

Variables	Definition	Mean (S.D.)			Diff. (I-II)
Treatment Variable		Combined	Participant (I)	Non-Participant (II)	
Township Dummies					
Dum1	=1 If location is in Horiqol; =0 otherwise	0.28 (0.45)	0.38 (0.49)	0.09 (0.28)	0.29
Dum2	=1 If location is in Bex'erik; =0 otherwise	0.23 (0.42)	0.26 (0.44)	0.16 (0.37)	0.10 ***
Obs.		352	236	116	/

Note: *, **, and ***, respectively, represent 10%, 5% and 1% statistical significance levels; Source: own household survey in 2008.

4.4. Estimation Result and Interpretation

Table 3 reports the estimated the income effect of intercropping by applying three matching techniques. It is notable that the three matching methods produced nearly consistent estimation results for each income type (the tests relevant to the use of the PSM estimation are reported in Tables A2 and A3 in Appendix A) and that the adoption of intercropping had a negative effect on all three types of income.

Table 3. Estimation results of the impact of crop-tree intercropping on participants' incomes.

Matching Algorithm	Farming Income	Off-Farm Income	Gross Income
Nearest Matching	−17932.89 ***	−515.72	−23600.92 ***
Radius Matching	−22330.35 ***	−970.09	−30556.11 ***
Kernel Matching	−17209.00 ***	−657.35	−22139.11 ***

Note: Covariates included are log (distance), land reallocation, age, log(age square), education, Uyghur, family size, log(share of agricultural labor), log(per capita land), soil quality, irrigation and two township dummies; *** represents 1% statistical significance level; Source: own household survey in 2008.

For farming income, the result obtained from the nearest neighbor technique showed that participants experienced an income loss amounting to 17,932.89 Yuan ($p < 0.01$). Similar results were obtained from both radius and kernel based approaches, but the estimated negative income effect obtained from the radius technique was far greater (estimate = 22,330.35 Yuan, $p < 0.01$).

While the estimated off farm income effect was not significant, participants still experienced a declined income trend from this source. This is another shortcoming in the program since off farm income is considered to be income source with the highest potential for alleviating rural poverty as discussed above in Section 2 [23].

In terms of gross income, the evidence showed that participants experienced a dramatic loss of income from program participation (estimates = −23,600.92, −30,556.11 and −22,139.11 Yuan respectively, $p < 0.01$). In other words, the households who participated intercropping program were significantly worse off in terms their income improvement than if they had not participated. This finding implies difference in gross income between participants and non-participants, which confirms our previous speculation that the program was poorly targeted.

Intercropping programs have been widely acknowledged as a sustainable agricultural practice and have been advocated in many developing countries as a way of improving incomes and tackling environmental degradation [14,15]. However, our estimation results demonstrate that, in our case study, intercropping had negative impacts on participants' incomes. This leads us to ask why this program failed to improve participants' incomes. The anecdotal evidence unearthed on a return visit to the region showed some of the reasons why participants' incomes derived from farming and off-farm activities were negatively influenced by participating in the intercropping program (see Box 1 below). (The stories contained in Box 1 are reported because they provide a more comprehensive understanding

of how participation in the intercropping system influenced people's incomes. Due to the sensitive subject of rural poverty in ethnic region, we kept the name of case village anonymous (named as L)).

Box 1. Visit to L village, Horiqol township, Awati county, 7 January 2014.

The village is located in the southeast of the township. The village cadre (Uyghur, male, aged 56) told us that there are eight natural villages, with 550 households and a population of 2370. There are limited off-farm employment opportunities available within this region. Only around 30 villagers in total have small business outside of the township, and the rest mostly makes a living from cotton. This village was called "the homeland of apricots" before 2005. However, most apricots were replaced by jujube, particularly between 2008 and 2009. In 2010, the township government proposed to plant 3500 mu fruit and nut trees in this village, consisting of 1000 mu of jujube, 1200 mu of pears and 1300 mu of walnuts. The villagers we interviewed listed several reasons for the failure of the intercropping program to improve their incomes.

First, the subsidy was low and hard to obtain. Usually provided in cash by the county government (90 Yuan/mu, delivered directly to participants), the subsidy was only available during the first three years and only for jujube planters. There was a precondition of a survival rate of at least 80% of the young trees: a very hard target to meet. In addition, the subsidy was too low to cover the massive costs involved in fruit planting.

Second, the current insecure land tenure system does not guarantee a long-term income from fruit harvesting. Around 85% of interviewed villagers believe that the second round of 30-year land contract under the HRS started in 1997 will expire in several years (about 10 years left). However, the life cycle of fruit trees is much longer: jujube produces fruit for at least 15–20 years and walnut for at least 30 years. This means that future fruit harvests may be lost if the contract period is not extended. This discouraged many farmers from participating. The negative impact of insecure land tenure on field management was also a cause of concern. There is a condition that all fruit fieldwork (including weeding, loosening-up the parcel, pesticide applications etc.) has to be conducted under the supervision of a local government official. A local official claimed that it was because the arable land is contracted from government (either from village committee or from the township's government) and is owned by government. Under this tenure system, field management is done collectively, with the local government offering physical support, such as fertilizer and pesticides, and the village cadres organizing villagers to do the field management work. Around 90% of smallholder farmers interpret that as meaning that they are not allowed to reap the fruits of their own labors, but instead, are pushed to work for the government. This gives rise to much *Toulan* (free-rider behavior). At the same time, the participants were unwilling to pour investments to their trees and, as a result, the fruit harvests were poor.

In addition, the design of the program created serious competition between crop and tree species for water, sunshine and fertilizers, leading to a dramatic decline in crop outputs. An Uyghur farmer, who cultivates 19 mu land (of which, 4 mu is walnut intercropped with cotton; 6 mu walnut with wheat; 4 mu sole walnut; and the reaming 5 mu being jujube mixed with cotton), did comparisons of the output from fields with and without intercropping: he calculated that cotton production in the intercropped fields suffered a 30% decline. The suffered decrease for maize and winter wheat is around 55% and 20%, respectively.

Furthermore, the program has exacerbated problems of access to irrigation water. On the supply side, households who are intercropping are only allocated the same amount (based on their cultivation land) of water as before. However, demand for water has increased dramatically, as fruit trees consume more water than crops. One experienced villager claimed that jujube consumes the most, followed by walnut and pear. Water demand from cotton is almost the same as jujube, with wheat and other crops consuming relatively less.

Finally, intercropping is labor-intensive. For instance, in the busy weeding and pesticide application period, the workload on an intercropped filed is around 30 man days: two to three times that on a non-intercropped field. Thus, participation in the intercropping program inhibits the rural labor force from taking up off-farm economic activities.

Note: Source: fieldwork notes from Aksu, January 2014.

Anecdotal observations such as those above illustrated how people's income generation strategies were influenced by the introduction of intercropping in rural Xinjiang. The Uyghur farmers have long been highly dependent on cotton production, which generally does not pay very well. Intercropping was introduced as a way to improve these farmers' prospects, yet our evidence shows that there were considerable negative unexpected outcomes of the program.

A range of factors led to participants experiencing a decline in their incomes. These included: nutrient competition between the different species in the combined cropping system; the aggravation

of the existing irrigation scarcity, the low level of subsidies available; and the labor-intensive nature of intercropping.

The situation was made worse by the land tenure insecurity that exists under the HRS. As discussed before, despite several rounds of tenure reforms in China, farmers still perceive the probability of losing land as very real under the current land tenure framework [65]. It is not unreasonable that farmers are distrustful of the current legal tenure arrangements, especially as the current contract is perceived to be expired in 2027. Taking these factors together, it is not surprising that participants' incomes experienced a dramatic decline.

5. Conclusions

While there has been a notable increase in incomes in rural Xinjiang over the past decade, they remain far below the national average level [11]. To address the high incidence of poverty, the XJUAR government proposed implementing a diversified crop-tree intercropping system in late 2004. This analysis has attempted to examine the impact of the intercropping program on participants' incomes. It applies the propensity score matching approach to a 352-household survey dataset. It also uses anecdotal observations to further explore the underlying reasons behind the income effect that we estimated.

One striking finding is that the income impact of the intercropping program on all types of income was negative (but not statistically significant for off-farm income). This finding indicates that smallholders who participated in the program suffered significantly losses in both their farming and gross incomes. This is consistent with the finding by Uchida et al., who demonstrated that the SLCP participants in Gansu and Sichuan experienced a net income loss [28]. Despite a lack of statistically significant evidence on the impact that the program had on off farm income, we did observe a decline in participation in off farm activities among program participants. This is also a cause for concern as off-farm activities are the main channel for escaping poverty in rural China [28].

Given the predominant role that farming (particularly cultivating cotton) plays in smallholders' livelihood strategies, it was somewhat of a shock to find that, rather than improving farm incomes, the program actually damaged them. This finding leads us to question how effectively the program was implemented and the level of commitment that smallholders showed in it. However, it is unlikely that the government will abandon the intercropping program for three main reasons. First, it is very difficult to restrain farming on arable land in Xinjiang province, as was done in the SLCP (which also aimed to improve environmental services) because cotton production provides a substantial share of farming households' net incomes [11], and because Xinjiang is a strategic and crucial grain and cotton production base in China [67]. Second, crop-tree intercropping can change the traditional mono-cropping system and lead to diversified income generation sources. Third, intercropping can simultaneously safeguard food and cotton production and generate some environmental benefits.

However, besides the intrinsic shortcomings in the program design and implementation (such as targeting inefficiency), a number of other factors meant that many participants experienced a decline in incomes. There was a significant decline in crop yields, increased demand for scarce water resources, increased demand for labor due to the labor-intensive nature of intercropping, and insecure land tenure. Participants find themselves trapped in a dilemma: they can neither quit intercropping nor pour more investment into their fruit trees for two crucial reasons. If they quit now, the initial and substantial investments they have made in tree planting would have to be written off. Second, local officials have considerable power in implementing policy, particularly over land tenure (and particularly in this politically-sensitive ethnic minority region) [55,65], and this power of land allocation may dissuade many smallholders from quitting the scheme for fear of losing their land.

To offset the substantial negative effect that this program has had on participants and to achieve a win-win outcome by meeting both environmental and developmental goals, we recommend implementing a number of counter measures. First, the local government should, as a matter of urgency, improve subsidy levels and extend the subsidy period. A payment for environmental service

approach could be a useful policy instrument as it has the potential to induce land users' incentives to improve their natural resource management, while also helping to alleviate poverty and has been widely used to finance natural resource conservation programs in many places around the world [87,88]. Second, as the subsidy will inevitably be terminated at some point in the future, it would be helpful to carry out effective rural land tenure reforms to enhance small-scale farmers' land tenure security. Third, although there has been a rapid expansion of fruit tree planting, it is unclear where the market for these fruits is [11]. Thus, governments should assist farm households to build and access local, and more extended, markets and even extend these markets to outside Xinjiang province, in order to create new income generating sources. Finally, more off-farm opportunities and trainings should be created and provided.

We are aware that our analysis has some limitedness. First, it only focuses on the income impact. A comprehensive assessment of the long-run sustainability of the intercropping system that includes the socioeconomic and ecological impacts in an integrated framework would useful extend the scope of this research. Second, the empirical study is based on small-scale 2008 cross-sectional data, and anecdotal discussions, based on the 2014 interview data. There may well be a time-lag between these two datasets, and results obtained from a larger-scale panel data would probably be more reliable.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Important events in crop-tree intercropping development in Xinjiang since 2004.

Year	Program/Titles	Description
2004	"Decision to accelerate agricultural reform and introduce intercropping system" (Source: http://lyj.loulan.gov.cn/zhengcefagui/2011-02-21/24432.html (accessed 29 August 2014).)	• Increase the contribution that income from fruit income makes to farmers' overall income and for fruit farming to be the predominant farming income source by 2010; • Total output of fruits to exceed 15 million metric tons by 2010 and 20 million metric tons by 2020; • Develop a two-year plan of to plant 10 million mu in a "fruit belt" around the Tarim basin (1 hectare = 15 mu); • Extend the cultivation period to 50–70 years for wasteland that is intercropped with trees; • Exempt irrigation fees for land intercropped with trees.
2005	"Opinions on accelerating the development of the fruit industry's characteristics" (Source: http://xzzf.forestry.gov.cn/portal/zfs/s/3290/content-489517.html (accessed 29 August 2014).)	• Confirm fruit production as the key intercropping development strategy; • Carry out forest land reforms by issuing forest land certificates and encouraging wasteland transfers; • Confirm the policies mentioned in 2004.

Table A1. *Cont.*

Year	Program/Titles	Description
2006–2010	"6311" program (Source: http://news.ts.cn/content/2009-06/25/content_4313131.htm (accessed 30 August 2014).)	• Expand the areas of almonds, apricot, walnut and other fruit species to 0.6 million mu, 0.3 million mu, and I million and one million mu respectively by 2010.
2008–2010	"Fruit management efficiency improvement" campaign (Source: authors' calculations based on statements from the Annual Three-Level Caucuses (2008–2010). http://www.docin.com/p-376996106.html (accessed 30 August 2014); http://wrdlq.blog.hexun.com/29094531_d.html (accessed 20 June 2014); http://zt.xjsy.gov.cn/ggkf/nr.jsp?urltype=news.NewsContentUrl&wbnewsid=74789&wbtreeid=13138 (accessed 20 June 2014).)	• Intensify the use of both arable land and irrigation water; • Expand the intercropped area under the slogan of "stabilize grain, reduce cotton and extend fruit"; • Improve farmers' gross income to 8–10 thousand Yuan per capita, with fruit being the main source by 2010.
2013	"No fruit expansion from 2013 onwards" (Source: http://news.ts.cn/content/2013-03/01/content_7850860.htm (accessed 30 August 2014).)	• Devote a hundred million Yuan fund for developing the fruit industry; • Stop the expansion of area planted to fruit trees.

Table A2. Probit regression results for households participating in the intercropping program.

Variables	Dependent Variable: Dummy Participation	
	Coef.	Robust S.D.
Log(Distance)	−0.39	0.03 ***
Land reallocation	−1.04	0.32 ***
Age	−0.06	0.03 **
Log(Age square)	0.89	1.16 **
Education	0.02	0.03
Family size	0.03	0.05
Log(Agricultural labor)	0.01	0.58
Uyghur	0.56	0.25 **
Soil quality	0.83	0.11 ***
Log (Land area)	0.04	0.13
Irrigation	−0.11	0.05 **
Dum1	1.27	0.21 ***
Dum2	0.78	0.20 **
Pseudo R2	0.1535	
Log pseudolikelihood	−188.87753	
Wald chi2(9)	60.30	
P > chi2	0.0000	
Obs.	352	

Note: ** and *** represent 5% and 1% statistical significance level, respectively; Source: own household survey in 2008.

Table A3. The matching quality test.

Matching Algorithm	Indicators					
	Pseudo R2		*p* > chi2		Mean Standardized Bias	
	Unmatched	Matched	Unmatched	Matched	Unmatched	Matched
Nearest neighbor	0.153	0.007	0.000	0.896	24.60	4.10
Radius	0.153	0.007	0.000	0.862	24.60	3.70
Kernel	0.153	0.010	0.000	0.707	24.60	7.50

Note: The matching quality tests reported indicate that the estimation satisfies the underlying common support assumption.

Table A4. Balancing test using nearest neighbor matching.

Confounders	Mean				*T*-Test	
					T-Value	
	Unmatched		Matched		Unmatched	Matched
	Control	Treated	Control	Treated		
Log (Distance)	2.31	1.93	1.96	1.94	−4.63	−0.40
Land reallocation	0.24	0.52	0.60	0.53	5.24	−1.54
Age	46.06	48.67	47.57	48.63	1.60	0.83
Log(Age square)	7.55	7.68	7.65	7.68	1.85	0.65
Education	6.06	5.59	5.72	5.61	−1.31	−0.39
Family size	4.54	4.84	4.75	4.79	1.74	0.29
Log(agricultural labor)	0.49	0.49	0.50	0.49	0.53	−0.32
Uyghur	0.80	0.92	0.94	0.91	3.09	−0.92
Soil quality	0.24	0.54	0.52	0.53	5.56	0.12
Log (Land area)	1.06	1.14	1.18	1.14	1.01	−0.58
Irrigation	0.23	0.28	0.28	0.29	1.10	0.13
Dum1	0.09	0.38	0.36	0.37	6.05	0.27
Dum2	0.16	0.26	0.27	0.27	2.08	−0.02

Note: Results obtained by using radius and Kernel matching are similar and, for the sake of brevity, are not reported here (results are available on request from the authors); *T*-test demonstrated that the balance for all confounders was sufficient, meaning that the bias from confounders has been removed and that the underlying "balancing" assumption is satisfied; Source: own household survey in 2008.

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