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Advancing the Sustainable Development Goals through participatory research: long-term impacts of farmer participation on sustainable land use and livelihoods in Honduras

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Abstract

Background This study describes a long-term farmer innovation project (local farmer research committees (Spanish acronym: CIALs)) in a remote hillside region of Honduras that has succeeded in intensifying land use under annual food crops towards sustainable food and agroforestry production. The findings add to evidence of what actually happens in long term participatory development and also suggest how some of the Sustainable Development Goals are being met in practice. The objectives of this study were (1) to compare the characteristics of the CIAL program members to non-members; (2) to examine how the CIAL program contributed to changes in sustainable land use practices among small-scale farmers in the hillsides of rural Honduras; and (3) to describe how the changes facilitated through farmer participation within the CIAL program connect to broader efforts to achieve Sustainable Development Goals related to poverty alleviation, food security, and sustainable land management. Data for the study were drawn from two household surveys (2013 and 2017) conducted in the three rural municipalities of Yorito, Sulaco, and Victoria, Honduras. Survey data were complemented by ongoing, long-term ethnographic research and engagement.

Results Comparisons were made between old CIAL members (5 or more years of membership), new CIAL members (less than 5 years of membership), and non-members (no participation in CIALs). In 2013, benefits of CIAL membership appeared primarily concentrated among CIAL members. Of note, 88.2% of old CIAL members and 73.6% of new CIAL members reported that their income had improved because of CIAL membership. CIAL members were also more likely to invest in household resources and agricultural activities as well as hold savings than non-members. Over time, participatory bean breeding conducted through the CIALs has made improved bean seed available to all three study groups, which has translated into improved bean yields across households. Furthermore, data suggest that sustainable agricultural practices have scaled across study locations.

Conclusions Farmer participatory research and plant breeding have succeeded in increasing yields of maize and beans, helping to alleviate food insecurity among hillside farmers, as well as providing a source of income, primarily through bean sales. Furthermore, land previously held under extensive food cultivation has been converted to coffee production, mostly in conjunction with agroforestry, supporting additional income and savings. Scaling this

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initiative to small scale farmers through distribution of improved maize and bean seed is underway across Honduras. The experience from the Honduran hillsides provides evidence of the impacts of long-term participatory development and, simultaneously, of a possible route towards achievement of some of the Sustainable Development Goals.

Keywords Participatory plant breeding, Farmer-led innovation, Sustainable land management, Scaling, Central America

Background

Meeting individual country targets for the Sustainable Development Goals (SDGs) by 2030 will almost certainly call for scaling successful development projects. The vision to take pilot projects to scale has long been a priority for international development agencies and non-governmental organizations (NGOs), as well as international development research centres (e.g., the International Development Research Centre (IDRC) and the Consultative Group on International Agricultural Research (CGIAR)) [1–4], whose mandate supports scaling of successful research in low- and middle-income countries. Reduction of core and long-term funding to international and local organizations in favour of short-term project funding over the past three decades, however, has complicated this goal given that effective monitoring and evaluation typically extends well beyond the short cycle of most projects, pilot or otherwise [1, 5]. In addition, since most of the individual SDGs involve interactions amongst goals to achieve overall country targets [6–9], meeting targets is frequently complicated by limited understanding of how such complex interactions occur over time and place [6, 8].

With the global challenges of achieving food security and addressing rural poverty in a sustainable way, scaling sustainable land use interventions is especially important. Key to successfully implementing sustainable land use practices is ensuring that such practices contribute to household incomes and food security; have an available market for products and cost-effective operations; support capacity building throughout the supply chain; and maintain multi-stakeholder partnerships, collaboration, and a participatory process [10–12]. A participatory process, in which farmers lead and are involved with the various facets of developing and scaling up interventions, is central to designing locally appropriate and flexible land use practices [10, 12]. Indeed, scaling should be morally justified by the full participation of individuals affected by an intervention and in determination of what constitutes success within it (4). It is also important to consider the different spatial scales at which stakeholders involved in land use practices operate, and in so doing identify potential trade-offs involved in adopting specific practices at these scales [10]. In addition, building the capacity of producers, consumers, governments, and private companies is crucial to ensuring that a market exists for products produced using sustainable land use practices, as well as building the capacity of national and international leaders to create policies that support the SDGs [11].

To engage with this complexity, and importantly, with the role of participation in the scaling process, this study looks at a specific case of bringing a community-based agricultural intervention (local farmer research committees (Spanish acronym: CIALs)), which has unfolded in rural Honduras over a period of more than 25 years, to scale, reporting on how and why it happened.[1] A key component of this scaling effort has been alleviating poverty (SDG #1) and achieving food security (SDG #2) alongside sustainable land use (SDG #15) in the search for sustainability amongst small scale farmers in the hillsides of Honduras. The objectives of this study were (1) to compare the characteristics of the CIAL program members to non-members; (2) to examine how the CIAL program contributed to changes in sustainable land management use among small-scale farmers in the hillsides of rural Honduras; and (3) to describe how the changes facilitated through farmer participation within the CIAL program connect to broader efforts to achieve Sustainable Development Goals related to poverty alleviation, food security, and sustainable land management. The study responds to calls for evidence of what actually happens in development practice [13, 14], particularly in the field of participatory development where claims are often inconsistent with what is supported by research [15].

Study context: participatory plant breeding to address food insecurity amid climate change

The study took place in the municipalities of Yorito, Sulaco, and Victoria in the department of Yoro in northern Honduras where the Honduran non-profit, research foundation, La Fundación para la Investigación Participativa con Agricultores de Honduras (FIPAH), has had a presence since the late 1990s. In 2003, these three municipalities were ranked in a World Food Program

[1] The program described has been supported since 2000, to the present, by Canadian NGO SeedChange, formerly USC Canada, backed with funding from the Canadian Government, and between 1995-2000 by the International Development Research Centre, Ottawa.

report amongst those municipalities having "very high vulnerability by access to food" [16]. Such vulnerability was associated with indicators of isolation and low road density, low income, low educational levels, high dependency ratios, high percentage of women-headed households, and low percentage of land in permanent crops. More recently, climate change has been projected to significantly reduce levels of basic grains in the coming years in the region adding to food insecurity [17, 18]. The effect of climate change on food insecurity is likely to be particularly acute in the case of physically isolated communities where seasonal food scarcities are aggravated under adverse growing conditions due to price fixing by local merchants who control narrow markets.

FIPAH evolved from a program of participatory agricultural research based on the concept of CIALs (developed at the International Centre for Tropical Agriculture (CIAT)), and has sought to work with farmers in the three Yoro municipalities around food security. From the start of the CIAL initiative in Honduras in 1993, the overwhelming interest of communities has been in maize and beans research, emphasizing the precarity of access to food. When yield improvements from early experiments with formal-sector varieties failed to materialize across hillside communities, the focus switched to participatory plant breeding (PPB) and varietal selection of maize and beans with the goal of adapting materials to the conditions of local farmers [19–21]. Most of the PPB research supported by FIPAH has taken place with farmers in the three Yoro municipalities. Through partnerships with national (the Pan American Agricultural School, El Zamorano; Honduran Government agricultural research agency, DICTA) and international (The Maize and Wheat Improvement Centre, CIMMYT) institutions, FIPAH supported CIALs have contributed to 12 new bean varieties and seven maize varieties since 2005 [22, 23].[2]

Until recently, CIAL-produced seed has been limited to localized distribution due to national seed policy. However, shortages of agricultural inputs during disruptions caused by tropical storms (Iota and Eta) and the COVID-19 pandemic, including seed, have resulted in a de facto opening of the seed market. Promoted by national, as well as international programs that aim to resuscitate small farmer production systems in the wake of these disturbances, this opening relies on the national seed certification laboratory (CERTISEM) to validate the quality of locally produced seed. In the case of beans, the recently formed National Bean Chain (initiated in 2017), which was designed to increase production and to foster value along the chain, has also provided an opportunity to market CIAL seed. By pushing for regionally approved, commercial bean seed, (similar to quality declared seed), participants in the National Bean Chain have sought to reduce the requirements for certification, opening the way for CIAL seed to be sold in regional markets. In addition, the quality of CIAL seed is upheld by inspections carried out by CIAL seed committees using their own quality control mechanism, which serves to facilitate dissemination of trusted seed through social networks and seed purchase at the regional and municipal levels. It should be noted that the respect for CIAL member knowledge, which underpins quality control and accountability, emanates from CIAL organization, and the social learning and empowerment that is contingent upon research and innovation. CIAL members, particularly its seed producers, are respected agricultural leaders in the communities, and maintaining the excellence of CIAL seed supply is recognized as essential both to local domestic provisioning and to commercial bean sales. Finally, it is important to mention that in regions of the country where FIPAH lacks a presence, it has nevertheless been able to distribute appropriate PPB seed to farmers through a variety of local organizations utilizing triadic comparison of technologies (tricot) [22]. This method permits each farmer participant to rank three different seed genotypes (including advanced lines, PPB, and formally released varieties) on their own farm according to different traits, and, by synthesizing data from large numbers of farmers, to predict preferred genotypes for different geographical and environmental regions [24]. These various mechanisms are starting to replace a centralized strategy, previously underpinned by national level seed trials prior to national seed release, with ones that are decentralized and flexible [25]. Together, they are supporting the scaling out of CIAL-produced seed across Honduras.

Methods

This study was grounded in a long-term partnership between FIPAH staff members and Canadian researchers (i.e., the research team). Insights from this long-term partnership, alongside nearly three decades of ethnographic research in the study locations, provided a rich foundation for the design, implementation, and interpretation of the two household surveys described below. The study was conducted between 2013 and 2017 in the three rural municipalities of Yorito, Sulaco, and Victoria. Additional data from ongoing research by FIPAH up to

[2] In total, the Honduran CIALs have contributed to 18 new bean varieties and 12 new maize varieties. Additional varieties were produced by CIALs supported by the Program for Rural Reconstruction in conjunction with Zamorano.

2019 were included to support the interpretation of study findings.[3]

Initial household survey in 2013

In 2013, a household survey was developed and administered by members of the research team with input and support from local facilitators working with FIPAH. The survey was designed to assess the use of maize and bean varieties developed by CIAL members through participatory plant breeding (PPB) across the three study locations. The survey was also designed to assess the contributions of CIAL membership to agricultural output. Survey questions included a combination of closed-ended and open-ended questions.

The survey was administered to households representing three distinct groups within these municipalities: old CIAL members (five or more years of membership at the time of survey administration), new CIAL members (less than 5 years of membership at the time of survey administration), and non-members (no participation in CIALs at the time of survey administration). Given that it takes most CIAL members a few years to understand and practice the methodology [26], the research team hypothesized that impacts of CIAL participation would be most evident among old CIAL members, while impacts would be less evident among new CIAL members. Non-members provided a counterfactual sample. While the research team originally planned to draw the counterfactual sample from non-CIAL communities, following consultation with local facilitators from FIPAH, it was deemed more appropriate to sample non-member households from communities with an existing CIAL. This sampling approach was more appropriate because communities without CIALs are distinct and not comparable to communities with CIALs by virtue of the fact that they have not elected to have a CIAL [26, 27].

Selection of households to be surveyed was done randomly, both for CIAL and non-CIAL members. To support participant recruitment, FIPAH provided lists of old and new CIAL members within the study locations, while local government health centres made available lists of households within each community to facilitate the selection of non-member respondents. In communities where the health centre was unable to provide a list of local households, FIPAH's farmer facilitators generated this list based on pre-existing knowledge of communities included in the study. Households were assigned numbers and numbers/households were randomly selected using a random number generator. Anticipating the possible absence of selected household heads at the time of the survey, or their inability or unwillingness to answer the survey questions, the randomization process included three options followed in sequence: (1) survey responses provided by household head; (2) survey responses provided by another family member; or (3) the surveyor proceeded to the next household, as dictated by the initial randomized selection. A similar process was followed when occupants of a survey household were absent. Selected CIAL members were contacted by the local facilitator in advance of the survey and nearly all participated. Non-members were more likely to be absent at the time of the survey because they were not organized in advance.

Follow-up survey in 2017

In 2017, the research team designed a follow-up study to explore changes in crop production strategies and sustainable land use practices since the initial household survey in 2013. In particular, this household survey was designed to explore the role of coffee production and management in household savings and livelihood strategizing. Overall, different survey questions were asked during the 2017 follow-up survey to reflect changes across study communities related to crop production. The research team randomly selected a subset of households that were surveyed in 2013 for participation in this follow-up survey. The same household member that participated in the initial survey was invited to participate in the follow-up survey. If that household member was unavailable or unable to participate in the survey, the surveyor proceeded to next household in the subset, as per the procedure described above. CIAL membership categories were maintained between the 2013 and 2017 surveys (i.e., a new CIAL member in 2013 was considered a new CIAL member in 2017).

Statistical analyses

Household survey data from 2013 to 2017 were entered and managed in Microsoft Excel® and analyzed using Stata® 13. Initial descriptive analyses of proportions, means, and medians were conducted using Pearson's chi-squared tests (to evaluate differences between proportion), one-way ANOVA (to evaluate differences between means), and Kruskal–Wallis *H* tests (to evaluated differences between medians), respectively. Tukey's pairwise comparison was used to conduct post-hoc analyses of significant differences found through one-way ANOVA. The Wilcoxon rank sum test was used to conduct post-hoc analyses of significant differences found through the Kruskal–Wallis *H* test.

[3] Between 2015-2020, FIPAH received funding from SeedChange and Global Affairs Canada for scaling up existing development work in the dry corridor of Honduras. Some data from this project, where indicated, were used in the Discussion to further interpret findings from the surveys.

Table 1 Respondent and household characteristics by CIAL membership category in Sulaco, Victoria, and Yorito municipalities from surveys administered in 2013 ($n=220$)

	Old CIAL member ($n=68$)	New CIAL member ($n=68$)	Non-CIAL member ($n=84$)	p value[a]
Respondent characteristics				
Female (%)	30 (44.12%)	30 (44.12%)	8 (9.52%)	< 0.001
Mean age in years (SD)	49.49 (13.17)	41.07 (12.66)	46.36 (17.01)	0.0036
Literacy (%)	53 (77.94%)	46 (67.65%)	52 (61.90%)	0.104
Completed primary education (%)	30 (44.12%)	19 (27.94%)	22 (26.19%)	0.041
Household characteristics				
Mean number of household members (SD)	5.43 (2.01)	5.87 (2.52)	4.69 (2.11)	0.0046
Mean number of household members 7–12 years of age (SD)	0.69 (0.87)	0.90 (1.06)	0.56 (0.91)	0.097
Mean number of household members 13–17 years of age (SD)	1.18 (1.18)	1.12 (1.32)	0.73 (0.93)	0.029
Mean number of household members 18–75 years of age (SD)	2.79 (1.40)	2.56 (1.20)	2.36 (1.18)	0.111
Mean number of household members > 75 years of age (SD)	0.07 (0.36)	0.10 (0.55)	0.06 (0.36)	0.813
Mean number of household members currently in school (SD)	1.50 (1.23)	2.00 (1.62)	1.25 (1.80)	0.016
Mean number of household members currently engaged in agriculture (SD)	1.88 (1.43)	1.54 (1.16)	1.28 (1.01)	0.011
Mean number of household members currently engaged in domestic work (SD)	1.31 (1.03)	1.31 (0.95)	1.14 (0.82)	0.438
Mean number of household members currently engaged in salaried work outside agriculture (SD)	0.09 (0.29)	0.07 (0.36)	0.10 (0.37)	0.934
Mean number of household members currently engaged in salaried agricultural day labour (*trabajo de jornal*) (SD)	1.09 (1.25)	1.04 (1.11)	0.93 (1.23)	0.696
Internal or international migrant member (%)[b]	13 (19.70%) ($n=66$)	12 (19.35%) ($n=62$)	15 (18.99%) ($n=79$)	0.994
Receive remittances from internal or international migration of household member (%)[b]	10 (15.38%) ($n=65$)	8 (12.70%) ($n=63$)	15 (18.99%) ($n=79$)	0.611

[a] p values are for Pearson's chi-square for proportions and one-way analyses of variance (ANOVA) for means

[b] Some respondents chose not to answer this question on behalf of their household

SD: standard deviation

Concurrent ethnographic investigation

In addition to the long-standing partnership and history of ethnographic research that provided a critical foundation for this work, ongoing ethnographic investigations were conducted over the 5-year study period. These investigations occurred through multiple field visits to the study communities and communications with study participants. Communications were oriented towards understanding how local farmers responded to, and made decisions about, seed selection and crop production practices in the context of seasonality, climate change, resource availability, and market trends. Findings from these investigations were used to interpret the results from the two household surveys.

Results

Findings from the initial household survey (2013)

Characteristics of survey respondents and their households

In total, individuals from 220 households participated in the 2013 survey across the study locations ($n=68$ old CIAL members; $n=68$ new CIAL members; $n=84$ non-members). Of note, old and new CIAL member respondents were more likely to be female compared to non-member respondents. Low participation of female respondents from the non-member group in this study reflects the cultural tendency for local women to be excluded from leadership and innovation in agriculture. As earlier studies have shown [26, 27], the Honduran CIALs encourage the participation of women. Female CIAL members, who comprised 44% of CIAL

membership ($n=30$ old CIAL members; $n=30$ new CIAL members) across the study locations, are accustomed to actively participating in meetings, agricultural activities and program evaluations (see Table 1).

The mean age of new CIAL members was 41.1 years (SD = 12.7), which was younger than the mean age of old CIAL members (49.5 years; SD = 13.2; $p<0.001$). New CIAL members entered the program both through the formation of new CIAL groups, as well as through existing groups. The latter was particularly evident for spouses and adult children of CIAL members. New groups were typically found in communities at mid–low elevations, while CIALs at higher elevations tended to be older and more established. This distinction is associated with an early emphasis by FIPAH on supporting the formation of CIALs in upland communities. Since government research has tended to focus on improving maize and bean germplasm for lower altitudes, particularly in the more productive foothills, upper-level communities have traditionally lacked germplasm adapted to their conditions.

A higher proportion of old CIAL members (44.1%; $n=30$) had completed primary education than both new members (27.9%; $n=19$) and non-members (26.2%; $n=22$). This was true of both men and women old CIAL members.

Both old and new CIAL households had, on average, more than five members, which was higher than the average number of household members in non-member households. Differences were also evident between old CIAL and non-member households in terms of the average number of household members in the 13–17-year age group, as well as the average number of household members employed in agriculture. These findings suggest that old CIAL households use agricultural production as an opportunity to employ family labour, particularly taking advantage of their teen demographic (i.e., 13–17 years). A similar trend was evident in the retention of older children and higher use of family labour for agriculture in new CIAL households compared to non-member households. In addition, given the high proportion of female CIAL members, it is more likely that women would be incorporated into agricultural activities in CIAL households than non-member households, further increasing the availability of household labour. The productive use of family labour in CIAL households may explain their lower levels of outmigration, despite a greater number of household members. Indeed, while outmigration is a commonly practiced livelihood diversification strategy in the study communities [28–30], there was no difference in the number of migrant members nor the proportion of households that received remittances across CIAL membership categories.

CIAL membership advantages: savings and investment in agriculture

In 2013, 88.2% ($n=60$) of old CIAL members and 73.6% ($n=50$) of new CIAL members reported that their income had improved because of CIAL membership. While non-members may have seen increases in their household income for some of the same reasons as CIAL members, such as adoption of new bean and maize varieties developed by the CIALs, they had not sought to save and invest household resources in agricultural activities to the same degree as members. To illustrate this point, Table 2 shows that in 2013, new CIAL members were significantly more likely to have savings than non-member households, despite having fewer assets and younger families with more school-aged children. Old CIAL members were also significantly more likely to

Table 2 Household agricultural assets and investments by CIAL membership category in Sulaco, Victoria, and Yorito municipalities from surveys administered in 2013 ($n=220$)

	Old CIAL member ($n=68$)	New CIAL member ($n=68$)	Non-CIAL member ($n=84$)	*p* value[a]
Household savings (%)[b]	30 (44.12%)	26 (38.24%)	4 (5.33%) ($n=75$)	< 0.001
Land ownership with full title (%)	19 (27.94%)	14 (20.59%)	22 (26.19%)	0.582
Land ownership via usufruct or right to use (%)	31 (45.59%)	28 (41.18%)	37 (44.05%)	0.870
Inherited land (%)	18 (26.47%)	13 (19.12%)	10 (11.90%)	0.072
Median amount of land (mz; range)	2.5 mz (0–22 mz)	1.5 mz (0–7.5 mz)	2 mz (0–50 mz)	0.01
Median value of agricultural equipment (range)	2715 Lps (175–24,580 Lps)	1496 Lps (0–25,620 Lps)	2420 Lps (65–44,490 Lps)	0.005
Income from coffee cultivation	40 (58.82%)	18 (26.47%)	38 (45.24%)	0.001

[a] *p* values are for Pearson's chi-square for proportions and Kruskal–Wallis *H* test for medians

[b] Not all non-CIAL member respondents provided an answer for this question

SD: standard deviation

Lps: Honduran Lempiras

mz: manzanas (unit of land)

Table 3 Relative importance (rank) of different crop types as a source of household savings by CIAL membership category in Sulaco, Victoria, and Yorito municipalities from surveys administered in 2017 ($n=81$)

	Old CIAL member ($n=25$)[a]	New CIAL member ($n=33$)[a]	Non-CIAL member ($n=23$)[a]
Beans (spring) (mean rank; SD)[b]	1.4 (0.5) ($n=23$)	2.12 (1.02) ($n=28$)	2.09 (1.47) ($n=23$)
Beans (fall) (mean rank; SD)[b]	2.32 (1.38) ($n=23$)	1.63 (1.39) ($n=23$)	1.88 (1.14) ($n=18$)
Maize (mean rank; SD)[b]	3.16 (1.07) ($n=24$)	2.70 (1.31) ($n=30$)	2.26 (1.10) ($n=21$)
Coffee (mean rank; SD)[b]	1.8 (1.35) ($n=21$)	1.64 (1.08) ($n=31$)	1.83 (1.44) ($n=13$)

[a] Not all households surveyed cultivated each crop (e.g., 21 of 25 old CIAL members cultivated coffee at the time of survey administration)

[b] Lower rank means greater importance as a source of household savings

SD: standard deviation

have household savings. These findings can be attributed to the structure of the CIALs themselves, as well as the *futurista* attitudes[4] that motivate their members [26]. For CIAL members, saving is a means to upward mobility. Their teams function not only as agricultural research committees, but also as savings groups and sources of credit. Members typically make small monthly contributions, creating a pool of funds that can be loaned out for larger purchases or emergencies. Importantly, CIAL groups develop a substantial stock of social capital over time, allowing members to trust one another with their savings and to mutually benefit from this form of collaboration [31]. The development of social capital is particularly evident in older CIALs, some of which have more than 20 years of experience of group saving.

In terms of the economic characteristics among participating households, new CIAL households reported less access to land than both old CIAL households and non-member households (see Table 2). New CIAL households also reported lower levels of investment in agricultural equipment (measured by the cumulative value of key agricultural equipment) than the other two groups. A smaller percentage of new CIAL households had income from permanent crops. Indeed, while 43.6% of all respondents ($n=96$) received income from coffee in 2013, this proportion was unevenly spread amongst the three groups, with coffee cultivators representing 58.8% ($n=40$) of old CIAL members, 45.2% ($n=38$) of non-CIAL members, and a mere 26.5% ($n=18$) of new CIAL members. Taken together, these findings suggest fundamental wealth differences between new CIAL households and the other two groups at the start of this study.

Findings from the follow-up survey (2017)

In total, individuals from 81 households participated in the 2017 follow-up survey across the study locations ($n=25$ old CIAL members; $n=33$ new CIAL members; $n=23$ non-members). Savings were assessed across all three groups by examining priority crops for participating households. Notably, a higher proportion of respondents from all three groups were engaged in coffee cultivation in 2017 compared to 2013: of the 81 survey respondents from 2017, 80.3% ($n=65$) indicated that they were cultivating coffee. The biggest expansion over the period occurred amongst new CIAL members with 93.9% ($n=31$) reporting coffee cultivation, followed by old CIAL members (84.0%; $n=21$) and non-CIAL members (56.5%; $n=13$).

The rate of change in coffee cultivation amongst CIAL members, may be attributed, in part, to a small project that encouraged women's participation in agroforestry (2013–2015), and to follow-up programming (2015–2020).[5] Before this project was implemented, however, farmers indicated that they were already using savings from beans to invest in permanent agroforestry crops, primarily in coffee.

For all three groups, savings were most likely to come from beans and coffee, while maize was ranked lowest as a source of savings (Table 3). Maize is primarily planted by hillside farmers for home use, rather than for sale. Beans are planted separately from maize by local hillside farmers and revenue on a per unit basis is comparatively higher. The coffee harvest, on the other hand, has long been a key source of household income for rural households, particularly from January to April. While in the past, it was common for people to migrate outside their municipalities to pick coffee as day labourers, increasingly, local farmers, are able to pick coffee from their own

[4] CIAL members define themselves as *futuristas,* contrasting themselves to those they dub as *conformistas.* They characterize the latter as being resistant to change as they conform to their lot in life, while CIAL members aspire to improvements in wellbeing by seeking to actively bring about change in their lives.

[5] PROLINNOVA supported FIPAH in a small agroforestry project with funding from the CGIAR program: Climate Change, Agriculture and Food Security (CCAFS) between 2013-2015. Between 2015 and 2020, USC Canada (now SeedChange) continued the program designed to increase women's access to agroforestry.

trees, as well as work as hired labour on neighbouring properties, illustrating the expansion of coffee cultivation within the study communities.

Old CIAL members ranked bean sales more highly than coffee as a source of savings. Interestingly, they indicated that sales from *primera* beans (spring) were their primary savings mechanism while, more predictably, the other two groups ranked savings from the *postrera* planting (fall) of beans more highly. Most of the beans produced in Honduras are planted in the *postrera* cycle due to more favourable climatic conditions in this growing season. However, seasonal gluts at the fall harvest can lead to low market prices that only farmers with post-harvest storage facilities and adequate savings can ride out this season. While commercial bean production in the *primera* cycle can help farmers evade market saturation, a delay in spring rains can lead to seed loss, as can high temperatures and humidity that are typical of the rainy season. Thus, farmers have traditionally planted smaller bean crops of faster maturing seed in the spring, with the primary purpose of alleviating seasonal hunger (*los junios*), and for providing fresh seed in time for the fall planting. CIAL members who prioritize savings from the *primera* planting, are more likely to sell PPB seed and beans, or store them in post-harvest facilities.

Recognizing the advantages of spring planting, old CIAL members have intensified production in the *primera* cycle, investing household resources in this growing season in order to raise overall household earnings and savings. Collaborative family labour provides old CIAL households with more than double the number of *primera* season workdays than the other two groups [32],[6] suggesting that old CIAL members draw on their relatively abundant supply of labour from older teenage children, as well as from women. In comparison to new CIAL members, old CIAL members may be advantaged by the location of their land, which is more likely to be at higher elevations, and is therefore less affected by the heat and humidity that threatens bean crops planted in the spring. They also have bean varieties adapted to upland spring planting. Furthermore, old CIAL members are more likely to plant on steeply sloped land than non-members from the same communities [32]. While sloped land is vulnerable to erosion and reduced soil fertility, rapid runoff can also reduce humidity in the *primera* season, which may contribute to more successful bean production. With effective erosion management strategies employed through CIAL training, and greater access to credit than non-member households, old CIAL members are uniquely positioned to be successful in *primera* bean production. Thus, the findings also illustrated ways in which CIAL members engage in agricultural innovation differently from non-members.

Evidence of scaling: agroecological practices and sustainable land use

Participatory bean breeding conducted through the CIALs has made improved bean seed available to all three study groups [21]. In other words, CIAL-developed seed has been *scaled out* beyond CIAL members. This finding aligns with other studies demonstrating that PPB seed produced by CIALs in Yorito, Sulaco, and Victoria was used by hillside farmers in communities across Honduras [25]. Having *scaled-up* through institutional partnership with national plant breeders at Zamorano (the Pan American Agricultural School), seed varieties that were initially developed by CIALs in the study locations have been further adapted to offer broad-spectrum resilience to hillside growing conditions, and higher productivity than local (criollo) varieties [21, 23]. In the context of this study, adoption of PPB seed was comparably high among CIAL members and non-members during the *postrera* bean planting.[7]

In the 2013 survey, both categories of CIAL members reported more thorough engagement in sustainable land use practices than non-members. Differences between old CIAL members and non-members were statistically significant in all categories of organic and agroecological practices (see Table 4). This finding is consistent with cultivation practices promoted by FIPAH amongst CIAL members. However, new CIAL members showed significantly higher engagement in the application of organic fertilizer, organic insecticide, and mulch, erosion control through live barriers and trees within the plot, and practices of intercropping, crop rotations, and minimum tillage than non-members. In the 2017 follow-up study that focused on coffee production, there were few appreciable differences in agricultural practices between the three groups. Nevertheless, new members were the least likely to practice burning of secondary vegetation in the preparation of coffee plots, and the most likely to engage in diverse tree cropping (coffee, fruit, shade trees)

[6] Old CIAL members used 198 days of family labour/ha versus 91 and 99 days of family labour/ha for new and non-members, respectively. Days of paid labour between the groups was almost the same (32-36 days/ha). Overall, 89% of family labour amongst non-CIAL members was provided by male family members, compared to 55% for old CIAL members, and 46% for new CIAL members, demonstrating the important role played by CIAL women in agriculture.

[7] Lower use of PPB seed by non-CIAL members in the *primera* planting is most likely the result of restricted access to credit, combined with low savings. CIAL seed growers provide fresh PPB seed on credit to CIAL members, but not to non-members. In the *postrera* season, high quality PPB grain for planting is readily available through CIAL members from the *primera* cycle. Inadequate storage capacity limits many farmers from storing grain over the period between fall and the next year's spring planting.

Table 4 Agricultural practices by CIAL membership category in Sulaco, Victoria, and Yorito municipalities from surveys administered in 2013 ($n=218$)

	Old CIAL member ($n=68$)	New CIAL member ($n=66$)[+]	Non-CIAL member ($n=84$)	p value*
Use of organic fertilizers (%)	33 (48.53%)	16 (24.24%)	8 (9.52%)	<0.001[a,b,c]
Mulch (%)	57 (83.82%)	54 (81.82%)	50 (59.52%)	0.001[a,b]
No slash and burn agriculture (%)	55 (80.88%)	46 (69.70%)	51 (60.71%)	0.027[a]
Use of organic insecticides (%)	33 (48.53%)	19 (28.79%)	5 (5.95%)	<0.001[a,b,c]
Living barriers (grasses) (%)	42 (61.76%)	20 (30.30%)	13 (15.66%)	<0.001[a,b,c]
Rock barriers (%)	28 (41.18%)	17 (25.76%)	19 (22.62%)	0.033[a]
Trees within plot (%)	48 (70.59%)	36 (54.55%)	26 (30.95%)	<0.001[a,b]
Live fence (%)	43 (63.24%)	30 (45.45%)	26 (30.95%)	<0.001[a,c]
Intercropping (%)	52 (76.47%)	40 (60.61%)	35 (41.67%)	<0.001[a,b,c]
Crop rotations (%)	46 (67.65%)	50 (75.76%)	37 (44.05%)	<0.001[a,b]
No tillage (%)	64 (94.12%)	48 (72.73%)	59 (70.24%)	0.001[a,c]
Minimal tillage (%)	17 (25.00%)	21 (31.82%)	5 (5.95%)	<0.001[a,b]
Grain storage (%)	64 (94.12%)	53 (80.30%)	57 (67.86%)	<0.001[a,c]
Seed saving (%)	51 (75.00%)	30 (45.45%)	41 (48.81%)	0.001[a,c]

[+] Two new CIAL members did not respond to these questions

* p values are for Pearson's chi-square for proportions

[a] Old CIAL member versus non-CIAL member different to $p<0.05$ with Pearson chi-square test

[b] New CIAL member versus non-CIAL member different to $p<0.05$ with Pearson chi-square test

[c] Old CIAL member versus new CIAL member different to $p<0.05$ with Pearson chi-square test

compared to the other two groups, particularly compared to non-members.

Of note, in 2013, old CIAL members reported a higher use of chemical inputs, such as mineral fertilizer, fungicides and insecticides, than non-members in *primera* bean cultivation.[8] This trend is related to the greater importance placed on *primera* beans compared to the other two groups, in conjunction with high seasonal humidity. In 2017, use of chemical inputs was comparable across groups, although CIAL members reported slightly higher use of chemical inputs for coffee and bean production. In general, the percentage of coffee cultivators reporting the use of specific organic and agroecological practices in 2017 was below 50% of those sampled. However, coffee rust makes avoidance of any chemical inputs highly risky. And all government released varieties are susceptible to fungus, leading to increased use of fungicides. Moreover, most farmers sell their coffee to merchants who do not reward them for organic production, instead mixing beans from different producers regardless of inputs used. Unless farmers have access to organic and/or fair-trade markets where the premium paid for specialty coffee offsets the risk of disease due to non-chemical usage, most farmers are unlikely to avoid all chemical inputs, even if aware of the health and environmental benefits of doing so. At the time of the follow-up study, only a handful of the women farmers were incorporated into a local organic cooperative. By 2019, there were 29 members. With international prices for direct sales of organic coffee in 2018 as high as 300% above local prices, these women are highly incentivized to adhere to a strict regimen of organic inputs [33].

Importantly, none of the three groups sought to acquire new land for coffee production in the period between surveys (2013–2017). Instead, increases in coffee cultivation occurred on *existing* household land. Paired with reduced engagement in the traditional practice of burning off secondary vegetation on fallow land, this finding suggests that farmers across all three groups had intensified their agricultural production strategies.

Discussion

Intensifying agriculture

Agricultural intensification can be linked to the adaptation of maize and bean varieties through PPB to farmers' hillside growing conditions. Whereas average bean yields in 1999 were recorded as 626 kg/ha in spring, and 417 kg/ha in fall, in four upland Yorito communities [17], in an evaluation study conducted by FIPAH in 2019 (30) among a sample of CIAL members ($n=41$), yields averaged over the spring and fall cycles, were 913.4 kg/ha., representing a 75% local yield increase. This stands in

[8] Old CIAL members used 62 kg/ha of fertilizer compared to 4 kg/ha and 15 kg/ha for new CIAL and non-members, respectively, in the *primera* bean cycle. Similarly, old CIAL members used 1.13 lit/ha of fungicides and insecticides versus .45lit/ha and .73lit/ha for new and non-members respectively.

contrast to 2020 study projections for Yoro, based on climate change modelling, which show a reduction of 24%, that are amongst the largest predicted declines of the country's departments. The 2020 study projects Yorito as a climate hotspot where bean production is likely to be particularly, negatively affected [17]. The yield increase is the result of improved bean germplasm, which includes materials selected for drought tolerance, and cultivation practices developed through farmer-supported participatory research. Maize productivity in 2019 among sampled CIAL members ($n=41$) increased from 1229 kg/ha to 1666.3 kg/ha between 2015 and 2019, an increase of 35.6% over a 5-year period when improved maize varieties from PPB became accessible to local farmers [33]. Such productivity increases in basic grains, in conjunction with decreased fallowing and burning, allow for increased use of existing land for agroforestry, particularly for coffee and, more recently, also for avocado production. In other words, the productivity increases in basic grains contributed to intensified agricultural land use.

Participatory innovation that raises productivity on annual crop land, helping to reduce food insecurity and to increase farmers' savings and income, may also function to shift farming towards more sustainable land use practices. In the case study, farmers—both CIAL and non-CIAL—are investing in agroforestry on *existing* land that was previously employed in extensive food production, typically under slash and burn management. CIAL members have led this shift as they have supplied improved seed to non-CIAL participants and adopted more ecological cropping practices. The apparent contradiction between higher adoption of ecological practices by CIAL farmers in 2013, compared to non CIAL farmers, and higher use of inorganic inputs (e.g., fungicides, urea), particularly by old CIAL members associated with cultivation in the off-season, can best be understood in terms of risk-taking behaviour, where there is no premium given for chemical-free production. Arguably, judicious use of inorganic inputs through a regime of integrated pest and soil management, is not incompatible with sustainable land management [34–36]. At the same time, new CIAL members, who have the least amount of land and capital, were the most likely to pursue a range of ecological practices in 2013, and more diverse tree cropping in 2017, perhaps suggesting that these farmers seek to minimize out-of-pocket expenses while maximizing self-provisioning through diversified agroforestry (e.g., fruit trees, spices, plantains, fuelwood, and medicinal shrubs, *in addition* to coffee and recently, also to avocados) on their plots. Finally, and as demonstrated in other contexts, the risks of small-scale farming are also offset through the development of social capital [37–39]. The widespread use of CIAL membership for accessing savings and loans provides members with a fallback in the case of family crises, reducing pressure to sell land or becoming indebted to money lenders.

Scaling

The literature on scaling development interventions points to the role of innovation and learning in sustainable development and land use, discussing a number of pathways to successful scaling (e.g., local participation, capacity building, policy and institutional change, organizational engagement, financial investment, technological innovation, etc.) [8, 11, 40, 41]. It is argued that within development interventions, innovation, learning, and scaling-up are separate, but linked components [42]. For example, through farmer field schools, knowledge on sustainable practices and technological innovations can be shared to build the capacity of smallholder farmers in bringing agricultural interventions to scale [43–46]. The current study provides a concrete case of how sharing knowledge between family and neighbours, in other words, through farmer-to-farmer extension, has facilitated scaling to take place.

Scaling-out new seed *beyond* Yorito, Sulaco and Victoria, the three municipalities in which it was developed by CIALs, necessarily demands changes to national regulations that govern seed management. Prior to 2020, the national government resisted seed legislative change [25]. Nevertheless, recent supply chain disruptions, coupled with national and international pressure, have pushed sectors of the national government towards greater flexibility in seed distribution. Key actors in the National Bean Chain, including those in the private sector, Zamorano (the Pan American Agricultural School), FIPAH, and CIAL Associations (ASOCIAL), have made greater seed decentralization a central demand, helping to drive the scaling process. Even before this opening occurred, however, FIPAH had succeeded in scaling out PPB seed testing beyond the Yoro CIALs, to a variety of organizations, such as credit and women's groups, to involve 270 rural groups located in 194 communities, across five of the country's departments [33].

Including women and youth

New technology is only one aspect of innovation demonstrated in the Yoro case, however. The use of family labour, particularly of adolescent and women's labour, to flexibly meet the increased labour demands of the *primera* bean cycle is also part of leaning into risk-taking. In Honduras, crop agriculture has traditionally been regarded as a male undertaking [27, 47, 48], and CIAL women members, initially faced local criticism, often from other women, for participation in the CIALs. CIAL

women had long felt excluded from agricultural projects due to cultural norms, which were particularly harmful for women in women-headed households. Nowadays, however, there is more acceptance and indeed often deep respect for women CIAL members, recognizing the knowledge they have acquired through agricultural research and innovation. CIAL women members are more likely than non-members to engage in joint decision-making about agriculture at the household level, including decisions affecting their children's labour in agriculture [27]. A *futurista* perspective, characteristic of CIAL members regarding innovation possibilities, means they are more likely to encourage the participation of their children in a local agricultural enterprise, such as *primera* beans, instead of pushing their children towards an uncertain future through out-migration. This observation raises a note of caution regarding scaling. While new seed technology may easily be scaled out beyond the CIALs, scaling out a shift of gender roles and youth engagement, may not be so readily accomplished [29, 30, 49–51].

Investing in coffee and other tree crops

Notwithstanding differential access to family labour, all CIAL/non-CIAL groups have sought to increase their investment in coffee in the five-year period between surveys. This shift is most apparent amongst new CIAL members. Whereas in 2013, only a low percentage (26.47%) of new CIAL members derived income from the sale of coffee, by 2017, 93% indicated that they were cultivating coffee, a crop they ranked almost equally with *postrera* beans as their most important source of household savings. This group also has access to the least amount of land on average of the three groups. Since the data suggest that expansion of coffee has taken place on *existing* land, rather than on newly acquired land, this indicates that intensification of agriculture, along with sustainable land management practices, have been particularly important for the poorest CIAL category. Notably, this group employs the widest range of ecological practices, including more diverse tree crops, perhaps because of greater attention to self-provisioning than the other groups and greater risk aversion. However, it is also true that poor, risk averse subsistence farmers would be unlikely to jeopardize their food security for a cash crop, such as coffee, known for its price volatility [52, 53]. Rather, the switch to coffee, and to other tree crops, is indicative of a growing confidence in food security that the new maize and bean varieties, coupled with improved agricultural practices, has provided to local users. This situation can be contrasted with that described by the 2003 World Food Program report, which characterized the municipalities of Yorito, Sulaco and Victoria as having "very high vulnerability by access to food" that was associated, among other things, with the low percentage of land used for permanent crops [16].

The shift to permanent crops, mostly under agroforestry systems involving coffee and, recently, also avocados, is a shift towards more sustainable agriculture for the Honduran hillsides. Diverse agroforestry systems, however, require close attention to spatial management to allow varied plant species access to differential amounts of sunlight and shade. This is particularly the case with the plots of small farmers where diversity for self-provisioning, as well as for sale, is paramount. Notwithstanding their small size, these plots deliver ecological benefits at the landscape level through the provision of biological corridors, erosion and water regulation, amongst other ecological services [54, 55]. Organic agriculture, free of synthetic inputs, however, requires markets that reward farmers for the risks associated with these practices. The increase in women's membership in a local organic coffee cooperative, following the rise of international prices for direct sales of organic coffee, reflects this reality (30). Since women and young people are involved in the shift to permanent crops, it is also a shift that enhances equity and social justice. As hitherto excluded groups become recognized as experts, men—both husbands and fathers—are increasingly willing to allocate some level of power to women and youth. This has resulted in women acquiring decision-making power that has been extended to the management of agroforestry plots and to the sale of produce from those plots, most recently through women's cooperatives, while some young people have been given rights to plots of family land with the explicit goal of developing shade coffee and other tree crops on them. Since land is traditionally inherited only upon the death of the owner, typically the male household head, this departure from tradition opens the way to encouraging young people to farm locally. In both cases, the shift represents confidence in the agricultural knowledge and experience acquired through CIAL membership.

Linking to the Sustainable Development Goals

Multiple attempts have been made to organize the 17 SDGs into manageable categories [9, 56]. One suggested route describes five primary groupings, based on compatibility, or alignment, between groups [57]. These five groupings include: (1) multiple poverty dimensions (SDGs 1–5); (2) development infrastructure (SDGs 6–9); (3) fairness (SDGs 10–12); (4) ecological infrastructure (SDGs 13–15); and institutions (SDGS 16–17). In this configuration, *sustainable land use* is argued to perform an 'integrative function', linking nonmaterial dimensions of the SDGs, such as rights and governance, to the material dimensions such as goods and services provision [57,

58]. The results of the Yoro study demonstrate how this may play out in practice. Namely, how innovation in seed supply and improved land management can lead to more sustainable land use, freeing up land for permanent tree cropping. This strategy has particularly benefitted the poorest participating families, as well as breaking down some of the gender barriers and inheritance patterns affecting women and youth. In other words, sustainable land use developed through participatory research has performed an 'integrative function', linking different categories of SDGs. Scaling up this experience more broadly in Honduras and the region is the next step.

Limitations

This study has several limitations. First, there were challenges in recruiting non-CIAL members to participate in this study due to their previous limited interaction with FIPAH. In addition, non-CIAL women, in particular, were frequently unable to answer survey questions which may have reflected their limited engagement with agriculture and sustainable land management practices more broadly. This tendency led to a bias towards non-CIAL men in the responses among non-members. Second, data from the 2017 study are presented as counts as the overall sample size ($n=81$) was too small to test for statistical significance in savings and sustainable land use practices between old CIAL, new CIAL, and non-member groups. Despite this limitation, our research team's longstanding and ongoing ethnographic work and engagement with farmers in the Honduran hillsides provided insights for potential differences observed across membership groups. Finally, different events and changes (e.g., COVID-19 pandemic, climatic variability, political change) that have occurred since this study was conducted have necessarily shaped the smallholder livelihoods across Honduras. Further research is needed to assess the degree to which these events and changes have shaped smallholder livelihoods and well-being, as well as sustainable land use practices.

Conclusions

Meeting the SDGs by 2030 almost certainly requires scaling sustainable land use practices. But, as it was argued at the outset, scaling also needs to be morally justified, through participation, for doing so. As we have demonstrated, putting small farmers, including importantly women farmers, at the centre of decision-making has empowered them to innovate, finding solutions for sustainable livelihoods and land uses that have also helped to shift social relations in the process. Meeting the SDGs requires transformations that are not just technical but also social in nature, changes that help to shift power towards the most marginalized. There is evidence that this has occurred over the past 25 years in the CIAL communities of Yorito, Sulaco and Victoria.

Scaling the experiences beyond the localities described above demands changes in government legislation to support some level of seed decentralization. It also requires technical support to accompany the new seeds, as has been available to Yoro farmers in the three municipalities described here. While existing organizations can become vehicles for the introduction of the new technology, empowerment of marginalized groups requires strong organizations that are equipped to support these efforts. As the study has shown, marginalized actors earned respect by acquiring skills they were traditionally denied access to. Organizations involved in scaling sustainable land uses must have at their disposal skilled practitioners, especially farmers familiar with the new technology, including women and youth, who can act as role models for others.

The case study on shifting land use in Yoro highlights the role that sustainable resource management may play in linking different categories of the SDGs. Specifically, it demonstrates how sustainable and ecological land use practices achieved through participatory research with small farmers link the non-material dimensions of the SDGs that support rights (e.g., poverty alleviation, equity, and fairness) with the material dimensions of markets, goods, and services. And it is this linkage that provides the moral justification for scaling this model in Honduras and beyond.

Overall, farmer-led participatory research and plant breeding have succeeded in increasing yields of maize and beans, helping to improve rural livelihoods through alleviating food insecurity and enhancing farmer incomes. In addition, land previously held under extensive food cultivation has been converted to coffee production, which has supported additional income and savings. Importantly, the distribution of improved maize and been seed is ongoing across Honduras, contributing to the scaling of this initiative. The experience from the Honduran hillsides provides evidence of the impacts of long-term participatory development and, simultaneously, of a possible route towards achievement of some of the SDGs.

Recommendations

To incentivize small farmers to engage in seed development, policy must support the decentralization of seed markets, allowing for regional seed certification to permit commercialization of what amounts to 'quality declared seed'. Disruptions in seed supply during successive tropical storms and the COVID-19 pandemic have brought about *de facto* changes in seed decentralization. Legislative change is the next step. The National Bean

Chain, which brings together the private sector, producer organizations, and some government departments, is firmly behind this decentralization effort and requires policy makers to engage in further strengthening.

Practitioners should seek ways to support the development of cooperatives and other producer organizations for the sale of commercial crops. Such organizations are critical for moving farmers' products up the value chain, cutting out local middlemen and ensuring higher returns for producers. This is particularly the case with organic production where a guarantee of higher returns per unit is necessary to offset lower anticipated yields and typically higher labour inputs. Without such guarantees, farmers lack the financial incentive to reduce chemical usage in agriculture. Women farmers may benefit from women's cooperatives where there is added value to be gained in some international markets for products sourced from women, particularly for organic products such as coffee.

Future research should focus on bringing together researchers at the CGIAR with local non-profit research organizations, such as FIPAH, that work day-to-day with farmers. Cutting edge research techniques can be most effectively utilized through such partnerships. In the case of tricot (triadic comparison of technologies), by allowing farmer participants to individually rank different seed genotypes (including advanced lines, PPB, and formally released varieties) on their own farms according to different traits, and, by synthesizing data from large numbers of farmers to predict preferred genotypes, scaling up appropriate seed for different geographical and environmental regions can readily occur. Such nimbleness is simply not possible under a centralized seed regime. Joint research between formal sector researchers and those working with small farmers, such as FIPAH, supports the nimbleness that is vital to addressing food security, particularly in the context of a rapidly changing environment.

Abbreviations

ANOVA	Analysis of variance
ASOCIAL	Association of local farmer research committees
CERTISEM	Departamento de Certificación de Semillas
CGIAR	Consultative Group on International Agricultural Research
CIALs	Local farmer research committees
CIAT	International Centre for Tropical Agriculture
CIMMYT	Maize and Wheat Improvement Centre
DICTA	Dirección de Ciencia y Tecnología Agropecuaria
FIPAH	Fundación para la Investigación Participativa con Agricultores de Honduras (Foundation for Participatory Research with Honduran Farmers)
IDRC	International Development Research Centre
NGOs	Non-governmental organizations
PPB	Participatory plant breeding
PROLINNOVA	Promoting local innovation in ecological agriculture and natural resource management
SDGs	Sustainable Development Goals

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Author contributions
Conceptualization: MG, SH, SK, JJ, PO, WD. Methodology: MG, SH, SK, JJ, PO, WD. Analysis: MG, SH, SK, SW, WD. Writing—original draft: MG, SH, SW, WD. Writing—review and editing: MG, SH, SK, JJ, PO, SW, WD. All authors read and approved the final manuscript.

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Availability of data and materials
Datasets generated and analyzed during this study are not publicly available due to the personal information contained within the data. However, an anonymized version of the dataset is available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was review and approved by the Research Ethics Board at the University of Guelph, Canada (REB # 16-12-661). Prior to data collection, informed consent was obtained from all participants.

Consent for publication
Not applicable.

Competing interests
MG, JJ, and PO have received or currently receive remuneration from La Fundación para la Investigación Participativa con Agricultores de Honduras (FIPAH). They have the academic freedom to publish both positive and negative results. SH, SK, SW, and WD have no competing interests to declare.

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