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Demonstration gardens improve agricultural production, food security and preschool child diets in subsistence farming communities in Panama

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Abstract
Objectives: To explore impacts of a demonstration garden-based agricultural intervention on agricultural knowledge, practices and production, food security and preschool child diet diversity of subsistence farming households.
Design: Observational study of households new to the intervention or participating for 1 or 5 years. Variables measured were agricultural techniques learned from the intervention and used, agricultural production, household food insecurity (FIS) and child diet diversity (DDS), over one agricultural cycle (during land preparation, growing and harvest months).
Setting: Fifteen rural subsistence farming communities in Panama.
Participants: Households participating in intervention (*n* 237) with minimum one preschool child.
Results: After 1 year, participants had more learned and applied techniques, more staple crops produced and lower FIS and higher DDS during land preparation and growing months compared with those new to the intervention. After 5 years, participants grew more maize, chickens and types of crops and had higher DDS during growing months and, where demonstration gardens persisted, used more learned techniques and children ate more vitamin A-rich foods. Variables associated with DDS varied seasonally: during land preparation, higher DDS was associated with higher household durable asset-based wealth; during growing months, with greater diversity of vegetables planted and lower FIS; during harvest, with older caregivers, caregivers working less in agriculture, more diverse crops and receiving food from demonstration gardens.
Conclusions: The intervention improved food production, food security and diets. Sustained demonstration gardens were important for continued use of new agricultural techniques and improved diets.

Keywords
Diet diversity
Subsistence agriculture
Panama
Agricultural intervention
Preschool children

Rural poverty and undernutrition remain intractable problems in many developing regions, particularly in subsistence farming contexts characterised by reliance on family labour and small landholdings with little potential for expansion[1]. Intensified subsistence agriculture can help households to ensure their own food and nutrition security[2]. For those that purchase some or most of their food, increased agriculture can increase direct access to food[3] and provide stable access to staples throughout the year[4], decreasing vulnerability to food price shocks[1,5]. Furthermore, diversification of agricultural crops can increase dietary diversity[6–8], resulting in higher-quality diets that are more likely to include animal source foods and fruits and vegetables rich in micronutrients[4,9–11].

Nutrition-sensitive agricultural interventions that increase intensity, diversity and sustainability of subsistence agriculture have been widely promoted[9,12–14]. Such interventions may involve distribution of seeds, vines or seedlings, fertilizers and produce grown in demonstration gardens[4,15–22], training in methods to improve soil fertility such as the use of animal and green manures and compost[23,24], improved animal husbandry practices[4,22,25,26] and education in nutrition and food preparation to encourage introduction of new crops[4,15–20,23,25–27]. Recent reviews have

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demonstrated that agricultural interventions can improve nutritional metrics, particularly dietary diversity[6,28,29], which has been shown to correlate strongly with greater micronutrient adequacy of the diet, leading to better nutritional status in children[30–32]. However, improvements appear to be context specific[33]. Further, questions remain regarding the sustained impacts of interventions over time[28] and whether benefits are equally evident at different phases of the agricultural cycle[33].

Approximately 25 % of preschool children in the province of Veraguas, Panama, experience chronic undernutrition[34]. In the poorest rural subsistence farming communities, approximately half of preschool children are stunted[35]. To address this problem, the Panama Ministry of Health (MoH) in collaboration with the Ministries of Education and Agricultural Development and the Japan International Cooperation Agency (JICA) selected fifteen of the poorest communities in the province where they initiated an agricultural intervention called VERASAN (*Proyecto para el mejoramiento del consumo y la disponibilidad de alimentos en comunidades de la provincia de Veraguas*, 'Project for improved consumption and availability of food in communities in the province of Veraguas')[36]. Prior to beginning the intervention, a number of MoH nutritionists received training from JICA in community development. Planning of the intervention, including workshop and demonstration garden design, was done in collaboration between MoH and JICA, and initially costs were shared, although over time these were taken on completely by MoH. Agriculture extensionists and nutritionists from MoH and the Ministry of Agricultural Development were involved in carrying out the intervention, and teachers from the Ministry of Education who were located in intervention communities were involved in organising community meetings and providing leadership and support for meetings.

VERASAN focused on agricultural training to increase intensity and diversity of production of participating households for home consumption. Trainings took place weekly or every other week in community demonstration gardens, where agriculture extensionists, nutritionists and other support staff taught new techniques and cultivation of diverse crops that households could use in their home plots. New techniques were focused on ameliorating soil with organic fertilizers (including fermented fertilizers), planting techniques to protect against soil erosion, pest control, seed selection and cultivation techniques and caring for domestic animals such as chickens, pigs and small fish ponds. Households typically focus production efforts on staples (rice and maize), so the intervention also encouraged diversification to include a greater variety of vegetables, legumes and tubers local to the region. Participants also received some materials for their home plots, including seeds, seedlings and fertilizers. Each community had a primary school, where most demonstration gardens were located, although in a few cases where space at the school was limited, demonstration gardens were located in a nearby common area. Size of demonstration gardens varied depending on land available, but none exceeded 1 ha. Produce from the gardens primarily went to school lunch programs, but households occasionally received produce for home consumption. Depending on community interest, training meetings also occasionally included topics such as animal husbandry, nutrition for young children and pregnant women, food preparation and hygiene. When this research study began in 2012, the intervention had been active in some communities for 1 or 5 years (since 2011 and 2007, respectively) and had just begun in a third group of communities (February–March 2012; 0-year group). Communities newer to the program were visited weekly, whereas communities with 5 years in the program were visited every other week. In the study year, half of the communities in the 5-year group no longer had demonstration gardens, although they continued to be supported by visits from intervention staff.

This study was requested by the Panama MoH to explore how the VERASAN intervention impacted agricultural knowledge and practices, food production, household food security and preschool child diet diversity. It was part of a larger study to examine impacts on child infection and nutrition dynamics in these communities. We hypothesised that the intervention could ultimately improve child diet diversity through multiple pathways: intensification of agriculture, diversification of production and improved household food security. The objectives were to determine (1) whether years of involvement with the demonstration garden-based agriculture intervention were positively associated with the variables along the progression from increased agricultural knowledge and practices to increased food production to improved household food security and ultimately to preschool child diet diversity, (2) whether improvements were evident in each of three phases of the agricultural cycle (months when agricultural lands were prepared and planted ('land preparation'), staple crops were growing ('growing') and staples were harvested ('harvest')) and (3) whether ongoing presence of intervention demonstration gardens was significant for sustained improvements in production, food security and diet diversity after 5 years in the intervention.

Methodology

Study design

This observational study compared households involved with the VERASAN intervention for 0, 1 or 5 years, and within the 5-year group, those with and without continued community demonstration gardens in the 5th year. The two inclusion criteria for household participation were self-reported involvement of at least one household member in the intervention and at least one child between 6 months and 5 years at the time of recruitment. The study was

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introduced and explained to households during regular community meetings. Written informed consent was obtained from the primary caregiver (89 %) or other responsible adult (11 %) on the first day of data collection, on behalf of the household and the participating child.

Data on household demographics, income and durable household assets for a household wealth index (HWI) were collected at the time of recruitment[37]. Data on agricultural techniques learned and used were collected early in the study as 0-year households began training in the community demonstration gardens. Two sets of food production data were collected, one based on recall from the year prior to the study (2011) when 0-year households had not yet benefitted from the intervention and a second for the year of the study (2012). Data on household food security and child diet diversity for each household were collected during land preparation (February–March 2012), growing months (June–July 2012) and harvest (September–October 2012). Questionnaires were administered by local university students who were trained and supervised by the lead author.

Agricultural practices

Participants were asked whether having an agriculture plot and keeping domestic animals were important for their household's food security and overall health. To understand perceived challenges to agriculture, participants indicated whether production had been diminished by lack of materials (seeds, water, tools, manures, synthetic fertilizers and pesticides), knowledge, land or animal feed or presence of weeds or other pests, poor soil or flooding.

Participants indicated which household members had attended training activities at the demonstration garden, attended other workshops and had other interactions with VERASAN staff during the study year. Participants listed agricultural techniques they had learned in the demonstration garden and techniques they had applied in their home plots (even if not learned from the intervention). They listed foods, seeds, seedlings and fertilizers received from the demonstration garden for use at home and indicated whether they had sold any produce over the last year, and if so, what.

Food production

Household food production in 2011 and 2012 was measured as diversity of crops planted (total crops, grains and starches, legumes and vegetables), quantities of staples planted and harvested (rice, maize, beans, plantain and cassava) and number of domestic animals kept for food, as previously reported[37]. Harvest data were only collected for 2011 because the study ended before the 2012 harvest was complete.

Household food insecurity score

Household food insecurity was measured using an experience-based food security questionnaire adapted for Panama and validated for this population[37] that was administered to each household during land preparation, growing and harvest periods. Food insecurity scores (FIS) ranging from 0 ('food secure') to 42 ('severely food insecure') were calculated for each household in each period[37].

Preschool child diet

Seven-day semi-quantitative FFQ were administered during land preparation, growing and harvest periods to the caregiver of one randomly selected preschool child from each household who was no longer breast-feeding[38]. Using a pre-tested list of foods (see online supplementary material, Supplemental Table 1), caregivers were asked how many times in the last week the child had eaten each food and whether the food had been grown at home or purchased.

Diet composition was compiled by classifying foods into eleven categories, adapted from Arimond *et al.*[39]: (1) grains and starches; (2) legumes; (3) dairy products; (4) eggs; (5) meat and fish; (6) vitamin A-rich green leafy vegetables; (7) orange-fleshed vegetables; (8) vitamin A-rich fruits; (9) vitamin C-rich vegetables; (10) citrus and other vitamin C-rich fruits and (11) other fruits and vegetables. Two additional categories used by Arimond[39] were not included: 'small fish eaten with the bones' which were not part of the local diet; and 'organ meats' which had been included in the 'meat and fish' category when the questionnaire was administered. Fruits and vegetables were divided into vitamin A-rich foods (>60 retinol activity equivalents per 100 g) and vitamin C-rich foods (>9 mg vitamin C per 100 g)[39] (see online supplementary material, Supplemental Table 2). Foods rich in both were categorised as vitamin A-rich foods only. Composite foods, such as *empanada de maíz* (maize pastry stuffed with tuna or meat), *sancocho* (clear broth soup containing cassava, maize and chicken or beef) and *guacho* (stew of rice and beans), were counted by their component categories. A dietary diversity score (DDS) was calculated in each agricultural period as the number of food groups (1 to 11) the child had eaten at least once during the previous 7 d, regardless of quantity.

Statistical analysis

Statistical analyses were performed using SAS version 9.3 (SAS Institute Inc.). Analyses were considered significant at $P < 0{\cdot}05$ except for multiple non-parametric pairwise comparisons of years in the intervention and sampling period, where a Bonferroni correction was applied ($P < 0{\cdot}0167$).

One-way parametric and non-parametric ANOVA and χ^2 tests were used to compare outcome variables by years

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in VERASAN (0 *v.* 1 *v.* 5 years) and ongoing demonstration garden (Y/N, within the 5-year group). Years in VERASAN were tested using parametric Tukey HSD, pairwise non-parametric or χ^2 tests (with Bonferroni correction for multiple comparisons) as appropriate. Data on agricultural methods were compared between the 0-year group and combined 1-year and 5-year groups to reduce multiple pairwise comparisons.

Multivariate models were created for DDS for each agricultural period. DDS was approximately normally distributed, so linear regression models were used. Initial models included caregiver age and education (years), HWI, years in VERASAN (0, 1 or 5), receipt of produce from demonstration gardens (Y/N), caregiver work in household agricultural plots (h/week), sale of produce (Y/N), number of animals raised (chickens, pigs, cattle, goats, turkeys, ducks and pigeons) and FIS. In order to provide the best temporal match between production and diet data, the DDS models for land preparation and growing months included 2011 livestock and planting data, whereas the DDS model for the harvest months included livestock and planting data from 2012. Because of the large number of variables, Spearman rank correlations between individual explanatory variables and DDS with $P > 0{\cdot}30$ were excluded from the models. Variables were removed using a stepwise process until only those with $P < 0{\cdot}10$ remained. Only variables with $P < 0{\cdot}05$ were considered significant.

Results

Study population

In total, 237 households participated in the study, 208 of which entered the study during land preparation. During the growing months, 150 households returned, representing a 28 % dropout rate, and twenty-one new households were recruited, bringing the sample size to 171. During harvest, 165 households previously recruited during land preparation or growing months participated, and an additional eight households were recruited, resulting in a sample size of 173. Further details can be found in Krause *et al.*[37]. Basic population characteristics are summarised in Table 1.

Years of exposure to the VERASAN intervention

Participation in VERASAN training

Neither regular attendance at VERASAN trainings (66·3 % of households) nor attendance by the primary caregiver (27·9 %) differed with years in VERASAN. However, receipt of seeds or seedlings from the demonstration gardens was higher in the 1-year compared with the 5-year group (46·4 % *v.* 22·6 %; $P < 0{\cdot}001$). Caregivers in the 1-year group spent less time in the household agriculture plot compared with the 0-year group (7·2 ± 1·7 h *v.* 16·7 ± 3·9 h; $P = 0{\cdot}007$).

Agricultural challenges

Regardless of years in VERASAN, nearly all participants (94·4 %) strongly agreed that having a household agricultural plot and raising domestic animals for food played an important role in securing enough food. Participants identified a number of challenges to agricultural production. Compared with households new to VERASAN, fewer in the 1-year and 5-year groups reported lack of land (3·6 % *v.* 24·1 %; $P = 0{\cdot}0005$) or lack of knowledge (17·9 % *v.* 37·9 %; $P = 0{\cdot}0201$) as barriers to agricultural production. There was no effect of years in VERASAN on the proportion of households who reported pests (23·1 %), lack of pesticides (25·4 %) and lack of tools (23·7 %) as barriers.

Agricultural practices

Households applied 10·3 ± 0·6 methods learned in the demonstration gardens (listed in Tables 1 and 2). Over 50 % of households raised seedlings, practiced seed selection of vegetables and tubers, transplanted seedlings, planted directly, prepared soil for planting and raised chickens. The 1-year group had learned more agricultural methods (Fig. 1(a)) and applied more new methods at home than the 0-year group (Fig. 1(b)). Several methods were more commonly used in the 1-year and 5-year groups compared with the 0-year group (Table 2): making and applying bocashi (a type of fermented compost)[40,41] and other composted fertilizers, raising seedlings for transplanting, treating tubers, planting in a bed, applying synthetic fertilizer and controlling disease and insect pests.

Plant and animal production

In 2011, the 1-year and 5-year groups planted a greater quantity (rice and beans) and diversity (grains and starches) than the 0-year group, and the 5-year group planted a greater diversity (overall crops, legumes, vegetables) (Table 3). The quantity of cassava planted, however, was lower in the 5-year group than the 1-year group. The only difference in the 2011 harvest data was that those in the 5-year group harvested more rice than 1-year and 0-year groups. In 2012, the 1-year and 5-year groups planted more rice and a greater diversity of grains and starches but planted less cassava than the 0-year group. The 5-year group also kept fewer pigeons than the 1-year and 0-year groups and planted more maize and kept more chickens than the 0-year group (Table 3).

Sale of produce

The percentage of households selling produce did not differ with years in VERASAN. However, the 1-year and 5-year groups sold a wider range of produce (beans and tomatoes and more rarely rice, pigeon peas, sweet peppers, pumpkins and sugar cane) than those in the 0-year group which primarily sold maize (data not shown).

Food security

FIS during the land preparation and growing seasons was lower in the 1-year and 5-year groups compared with the

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Table 1 Descriptive population characteristics, including demographic data, household participation in agriculture and agricultural techniques used by households

	Mean %	SE %		%	95 % CI
Participants			Agricultural techniques used*, cont.		
Primary caregiver age (year)	33·1	0·4	Fungus control %	13·4	8·3, 18·5
Education of primary caregiver (year)	5·0	0·2	Seed selection – vegetables %	65·1	58·0, 72·2
People in household (HH) (*n*)	6·3	0·1	Seed selection – tubers %	51·2	43·7, 58·7
Preschool children (*n*)	1·53	0·05	Seed saving – vegetables %	22·7	16·4, 29·0
Age of index preschool child at recruitment (mo)	40·4	1·1	Cultivar association – vegetables %	19·2	13·3, 25·1
Index child female (%)			Cultivar association – tubers %	18·0	12·3, 23·7
%	50·8				
95 % CI	44·5, 57·2				
Household agricultural plot			Stakes for vines %	40·1	32·8, 47·4
Area of land farmed (ha)	0·92	0·05	Transplant trees %	11·6	6·8, 16·4
Agricultural plot owned (%)			Germination in a sack %	13·4	8·3, 18·5
%	88·3				
95 % CI	83·7, 92·9				
HH members work in agricultural plot (*n*)	1·9	0·1	Direct planting %	58·7	51·3, 66·1
Caregiver works in agricultural plot (%)	57·3	50·7, 64·0	Hilling of planting beds %	41·3	33·9, 48·7
Household sold produce (%)	10·3	6·2, 14·4	Stone crop barrier %	22·7	16·4, 29·0
Agricultural techniques used*			Raise chickens free range around the house %	76·7	70·4, 83·0
Agriculture methods used (*n*)	10·3	0·6	Keep chickens in cages %	10·5	5·9, 15·1
Collect animal manure for fertilizer (%)	13·4	8·3, 18·5	Prepare synthetic pesticides %	20·9	14·8, 27·0
Apply animal manure (%)	18·6	12·8, 24·4	Apply synthetic pesticides %	14·5	9·2, 19·8

HH, household.
*The following methods were used by <10 % of households: Make and apply organic manure (lumbriculture manure and green manures composed of *Canavalia* sp. or *Mucuna* sp.), make garlic-based organic insect repellent, make pepper-based organic insect repellent, apply organic insect repellent, apply synthetic herbicide, apply synthetic fungicide, collect seeds from trees, tree nursery, tree grafting, wooden frame around planting beds, land terracing, use an A level, fatten chickens, fish cultivation.

Table 2 Association of years in VERASAN and ongoing demonstration garden on percent of households using new agricultural techniques* in their household agricultural plot in 2012

		Years in VERASAN				Demonstration garden in the 5-year group		
		0	1	5	*P*†	Yes	No	*P*
n		31	54	85		48	37	
Fertilizers	Make *bocashi*‡	10	29	36	0·0086	48	22	0·0125
	Apply *bocashi*‡	6	27	36	0·0033	48	22	0·0125
	Composting	3	23	22	0·0127	29	14	0·0859
	Apply compost	3	21	21	0·0179	27	14	0·1290
	Apply synthetic fertilizer	0	13	15	0·0257	10	22	0·1547
Pesticides	Disease control	29	52	47	0·0439	46	49	0·7965
	Insect control	6	32	28	0·0070	35	19	0·0939
Seed selection, collection and growing	Raise seedlings	42	68	74	0·0015	83	62	0·0271
	Transplant vegetables	42	52	54	0·2563	71	32	0·0004
	Treatment of tubers before planting	0	18	13	0·0218	13	14	0·8902
Soil conservation and planting techniques	Soil preparation for planting	45	50	61	0·2411	71	49	0·0375
	Plant in a bed	10	29	29	0·0250	31	27	0·6718
	Living crop barrier	19	23	16	0·9790	25	5	0·0157

*Only variables that differed by years in VERASAN and/or presence of a demonstration garden are reported here; data for other variables are shown in Table 1.
†Statistical test for difference between '1 year' and '5 years' combined compared with '0 years'.
‡*Bocashi* is a fermented, organic fertilizer composed of green materials, ash, dried bean or corn husks, manure and molasses[40,41].

0-year group, but no differences in FIS were detected among years in VERASAN during harvest (Fig. 2(a)).

Ongoing presence of demonstration gardens after 5 years

Agricultural practices

Among households in communities where VERASAN demonstration garden were still active during the 5th year, caregivers worked longer in their agricultural plot (12·2 ± 1·8 *v.* 11·1 ± 2·3 h/week, $P < 0·017$) and more households used methods they had learned (Fig. 1(b)) compared with those without a continued demonstration garden. Specifically, more of those with ongoing demonstration gardens made and applied bocashi, planted and raised seedlings, prepared soil for planting, transplanted vegetables and planted living crop barriers (Table 2). Also, more received produce (35·4 % *v.* 8·1 %, $P < 0·003$) and seeds

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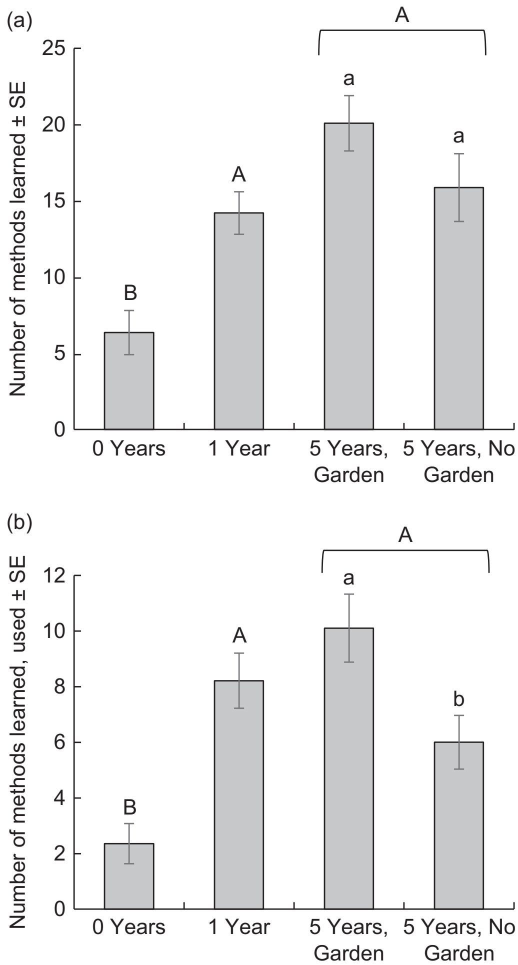

Fig. 1 Number of methods learned through VERASAN (a) and learned and practiced at home (b) by number of years in VERASAN, and for those in VERASAN for 5 years, by presence/absence of a community demonstration garden. Different uppercase letters indicate differences in main effect (years in VERASAN), and different lowercase letters indicate differences between communities with and without a demonstration garden ($P < 0{\cdot}05$)

and seedlings (34·0 % *v.* 8·1 %, $P < 0{\cdot}003$) from demonstration gardens or VERASAN intervention staff (in communities with discontinued demonstration gardens; Table 3).

Plant and animal production

Households in communities with continued demonstration gardens planted more plantain but less beans in 2011 and kept more pigs in 2011 and 2012 (Table 3).

Food security

FIS did not differ between households with and without demonstration gardens (Fig. 2(a)).

Description of preschool child diet over one agricultural cycle

Dietary data were recorded for preschool children during the three phases of the agricultural cycle (land preparation, growing and harvest) of 2012. Almost all children ate grains and starches and legumes, more than 70 % ate meat or fish and more than 50 % ate eggs. Among fruits and vegetables, few ate leafy green vegetables (<5 %) or orange vegetables (<10 %) but about 50 % ate 'other fruits and vegetables'.

Preschool child DDS was higher in the growing season than land preparation or harvest ($F_{2,479} = 8{\cdot}06$, $P = 0{\cdot}0004$; Table 4). During the growing season, diets contained more dairy products, vitamin A-rich fruits and citrus and other vitamin C-rich fruits, although during harvest diets contained more vitamin C-rich vegetables (cabbage, peas, broad beans) and tomatoes (Table 4). Other food groups were unaffected by season.

The cassava and maize eaten by children were grown entirely at home. Rice was grown at home and also purchased, especially during harvest. Home-grown beans were more commonly eaten during harvest. About half of the chicken eaten by children had been raised at home regardless of agricultural season (data not shown).

Child diet and household involvement in the VERASAN intervention

Years in VERASAN

Among food crops grown at home, only use of home-grown rice differed by years in VERASAN. During land preparation and growing months, more children in the 5-year group ate home-grown rice: during land preparation, 89 % of the 5-year group ate home-grown rice compared with 45 % and 58 % in the 0-year and 1-year groups, respectively (both $P < 0{\cdot}0001$); and during the growing months, 75 % in the 5-year group compared with 50 % and 46 % in the 0-year group ($P = 0{\cdot}04$) and 1-year group ($P = 0{\cdot}0003$), respectively. During harvest, very little of the rice consumed was grown at home (none in the 0-year and 1-year groups, 14 % in the 5-year group).

DDS was higher during land preparation and growing months in the 1-year group compared with the 0-year group (Fig. 2(b)). However, years in VERASAN had minimal impact on child diet (Table 5) as the only difference was detected during land preparation, when those in the 1-year group ate more dairy products than the 5-year group.

Ongoing demonstration gardens after 5 years

Ongoing presence of a demonstration garden was associated with higher intake of vitamin A-rich orange-fleshed vegetables during land preparation and higher intake of vitamin A-rich fruits and vegetables but fewer eggs during the growing months (Table 5).

Determinants of preschool child diet diversity over one agricultural cycle

Preschool child DDS was associated with distinct sets of variables in the three agricultural periods (land preparation, growing and harvest months; Table 6). During land

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Table 3 Association of years in VERASAN and ongoing presence of a demonstration garden with household agricultural production during the previous (2011) and current year (2012)* %

	Years in VERASAN							Demonstration garden in the 5-year group				
	0		1		5			Yes		No		
Agricultural production	Mean	SE	Mean	SE	Mean	SE	*P*†	Mean	SE	Mean	SE	*P*
Previous year (2011)												
n	30		56		84			47		37		
Diversity of crops grown												
All types (*n*)	10·3	0·9^{b}	13·2	0·8^{ab}	13·1	0·6^{a}	0·042	13·2	0·9	13·0	0·8	0·969
Grains and starches (*n* types)	4·1	0·3^{b}	5·3	0·2^{a}	5·2	0·2^{a}	0·002	5·3	0·2	5·0	0·3	0·197
Legumes (*n* types)	1·4	0·2^{b}	1·8	0·1^{ab}	1·8	0·1^{a}	0·029	1·8	0·1	1·9	0·1	0·839
Vegetables (*n* types)	2·0	0·3^{b}	3·2	0·3^{ab}	3·3	0·3^{a}	0·030	3·1	0·3	3·5	0·4	0·414
Quantity of staple crops planted												
Rice (lbs)	14·9	2·0^{b}	20·9	1·6^{a}	21·8	1·4^{a}	0·028	21·9	2·0	21·5	1·8	0·793
Beans (lbs)	1·2	0·5^{b}	5·8	0·9^{a}	3·2	0·6^{b}	<0·001	3·1	0·7	3·3	0·9	0·609
Cassava (units)	62·0	14·3^{ab}	108·7	17·1^{a}	58·0	6·8^{b}	0·015	60·2	7·3	54·9	12·9	0·146
Quantity of staple crops harvested												
Rice (lbs)	341	98^{b}	647	92^{a,b}	675	71^{a}	0·040	699	113	642	63	0·205
Maize (lbs)	341	98	370	63	351	40	0·977	325	57	389	55	0·084
Beans (lbs)	43	18	99	20	58	10	0·047‡	39	11	87	19	0·037
Plantain (units)	80·5	63·6	16·9	3·6	10·9	1·5	0·084	12·8	2·0	8·1	2·5	0·025
Livestock												
Pigs‖ (%)	12·1		21·4		20·8		0·513	29·8		7·3		0·006
Current year (2012)												
n	33		51		95			56		39		
Diversity of crops grown												
Grains and starches (*n* types)	4·3	0·3^{b}	4·9	0·3^{a}	5·1	0·2^{a}	0·004	5·2	0·3	5·2	0·2	0·139
Quantity of staple crops planted												
Rice (lbs)	10·5	2·0^{b}	18·1	1·4^{a}	22·6	1·9^{a}	<0·001	25·8	2·9	18·5	1·3	0·121
Maize (lbs)	6·3	1·0^{b}	8·2	0·8^{ab}	10·1	0·8^{a}	0·013	10·3	1·2	9·9	0·1	0·739
Livestock												
Pigs§ (%)	6·3		17·9		9·4		0·179	16·7		0·0		0·009
Chickens (%)	81·3^{b}		94·6^{ab}		96·5^{a}		0·013	95·8		97·3		0·717
Turkeys (%)	12·5		8·9		1·2		0·031‡	2·1		0·0		0·508
Pigeons (%)	31·3^{a}		26·8^{a}		11·8^{b}		0·022	12·5		10·8		0·811

*Only variables that differed by year in VERASAN and/or presence of a demonstration garden are included. Pooled data for all production variables have been previously reported[37].
†Different letters indicate differences in main effect (years in VERASAN) at $P < 0.05$ corrected for multiple pairwise comparisons (corrected $P < 0.0167$).
‡*Post hoc* tests did not reveal significant differences.
§Usually only one pig per household.

preparation, DDS was higher in households with higher HWI. During the growing months, DDS was higher in households that had planted more types of vegetables and lower in households with greater food insecurity. During the harvest months, DDS was higher in households that had planted a greater diversity of crops, had received produce from the demonstration garden, for children with older caregivers, and lower if the primary caregiver spent more time working in the household agricultural plot. Years of involvement in VERASAN was positively associated with DDS during harvest, although it did not reach the threshold of statistical significance ($P = 0.051$).

Discussion

This study provides evidence that participation in an agricultural intervention based on community demonstration gardens can improve agricultural knowledge and production and, through this, improve household food security and preschool child dietary diversity during leaner seasons of the year. After 1 year in the intervention, participants had learned and applied more agricultural techniques, rice production was higher and household food security and preschool child dietary diversity were improved. After 5 years in the intervention, more children were eating home-grown rice, and households were growing a greater diversity of staple crops. Importantly, increases in agricultural production happened without households increasing the size of their landholdings, indicating successful intensification of practices. Community demonstration gardens were a central component of this intervention, and continuing the gardens into the 5th year of the intervention appeared to impact sustainability of gains made by the intervention as households in communities with gardens used more of the agricultural knowledge learned through the

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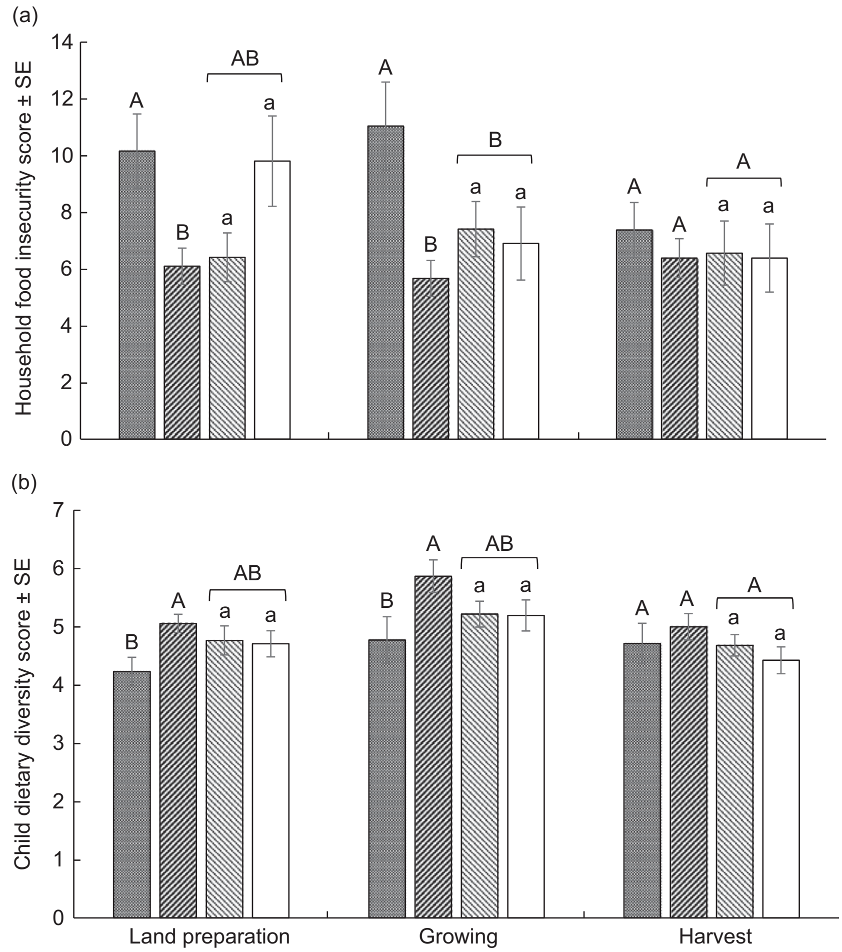

Fig. 2 Household food insecurity score (a) and child diet diversity score (b) during land preparation, growing season and harvest, by number of years of participation in VERASAN, and within the group of communities in VERASAN for 5 years, between those with and those without a demonstration garden. Different uppercase letters indicate differences in main effect (years in VERASAN), and different lowercase letters indicate differences between communities with and without a demonstration garden ($P < 0.05$). ▩, 0 year; ▨, 1 year; ▧, 5 years, Garden; □, 5 years, No Garden

Table 4 Comparison of diet composition and diversity of index preschool children in land preparation (*n* 180), growing season (*n* 150) and harvest (*n* 152) periods of 2012

Food group	Land preparation	Growing	Harvest	P^*
Diet diversity score (Avg ± SE)				
Average	4·72	5·35	4·74	0·0004
SE	$0·11^{b}$	$0·14^{a}$	$0·12^{b}$	
Grains and starches (%)	99	100	99	0·3440
Legumes (%)	97	95	95	0·6748
Meat and fish (%)	71	77	70	0·3577
Eggs (%)	58	54	55	0·7787
Dairy products (%)	34^{ab}	39^{a}	25^{b}	0·0273
Leafy green vegetables (%)	4	1	2	0·0799
Orange-fleshed vegetables (%)	6	9	8	0·4173
Vitamin A-rich fruits (%)	5^{b}	28^{a}	1^{b}	<0·0001
Vitamin C-rich vegetables (%)	17^{ab}	11^{b}	26^{a}	0·0031
Citrus and other vitamin C-rich fruits (%)	34^{b}	66^{a}	41^{b}	<0·0001
Other vegetables and fruits (%)	47	54	52	0·3824

*Different letters indicate differences in main effect (sampling season) at $P < 0.05$ corrected for multiple pairwise comparisons (corrected $P < 0.0167$).

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Table 5 Comparison of diet composition and diversity of index preschool children by years of exposure to VERASAN and ongoing presence of a demonstration garden, during both the land preparation and growing seasons*

	Years in VERASAN				Demonstration garden		
Food group	0	1	5	*P*†	Yes	No	*P*
Land preparation							
n	39	53	88		47	41	
All animal source foods	79·5	96·2	88·6	0·0411‡	89·4	87·8	0·8184
Dairy products	35·9[ab]	54·7[a]	20·5[b]	0·0002	25·5	14·6	0·2061
Vitamin A-rich orange fleshed vegetables	2·6	7·5	5·7	0·5861	10·6	0·0	0·0315
Growing season							
n	22	46	82		46	36	
All animal source foods	77·3	95·7	92·7	0·0339‡	89·1	97·2	0·1626
Eggs	36·4	60·9	54·9	0·1609	43·5	69·4	0·0190
All vitamin A-rich fruits and vegetables	36·4	41·3	28·0	0·2957	39·1	13·9	0·0116
Vitamin A-rich fruits	27·3	37·0	23·2	0·2485	37·5	5·6	0·0008

*No food groups differed in consumption by years in VERASAN or presence of a community garden during the harvest season. Only food groups that differed are included in the table.
†Different letters indicate differences in main effect (years in VERASAN) at $P < 0.05$ corrected for multiple pairwise comparisons (corrected $P < 0.0167$).
‡*Post hoc* tests did not reveal significant differences.

Table 6 Final multiple regression models* for diet diversity score of index preschool children during land preparation (*n* 155), growing season (*n* 115) and harvest (*n* 149)

	Land preparation		Growing season		Harvest	
Variables	β	*P*	β	*P*	β	*P*
Overall model	$R^2 = 0.09$	0·0004	$R^2 = 0.15$	<0·0001	$R^2 = 0.24$	<0·0001
Caregiver age (years)	NS		0·030	0·0802	0·0258	0·0361
Caregiver education (years)	0·094	0·0506	NS		NS	
Caregiver works in household plot (h/week)	NS		NS		−0·0163	0·0250
Household wealth index	0·558	0·0004	NS		NS	
FIS†	NS		−0·061	0·0067	−0·0310	0·0577
Diversity of crops planted (*n*)	NS		NS		0·0885	0·0001
Diversity of vegetables planted (*n*)‡	NS		0·213	0·0101	NS	
Household sells produce (Y/N)	NS		NS		0·5981	0·0731
Household received food from demonstration garden (Y/N)	NS		NS		0·5319	0·0290
Involvement in VERASAN (years)	NS		NS		0·2997	0·0510

FIS, food insecurity score.
*Initial variables entered in models but not retained: quantity of staples planted (rice, maize, beans, pigeon peas, cassava and plantains) and number of animals (chickens, pigs, cattle, goats, turkeys, ducks and pigeons).
†FIS ranges from 0 (food secure) to 42 (most food insecure).
‡The growing season model included number of types of vegetables planted during the previous year.

demonstration gardens and planted more micronutrient-rich fruits and vegetables.

Through demonstration gardens, the intervention promoted ecologically appropriate agricultural methods to help households intensify production on existing landholdings. These included methods to preserve soil fertility and prevent erosion, such as the use of various organic fertilizers and planting techniques[24,42,43]. Several lines of evidence showed that VERASAN successfully transferred this knowledge to participants. First, after 1 year, families were less likely to report lack of knowledge as a barrier to agriculture. Second, in this same time period, families learned and applied more of the methods in their home plots. Other researchers have noted that subsistence farmers take up agricultural techniques they deem to be useful[23], reinforcing our conclusion that VERASAN was successful in matching training to needs of participants. Third, half of the newly applied techniques involved making or applying composts and fertilizers. This is particularly relevant in this region, where the combination of slash-and-burn agriculture and the tropical climate can lead to rapid loss of soil fertility[44]. Fourth, the higher production of staple crops (particularly rice) suggests that incorporation of fertilizers for improving soil fertility increased the ability to produce food, as has been suggested by other studies in the region[43]. Finally, households in the intervention for 5 years had higher production in agricultural plots of similar size as 0-year and 1-year groups. Together, these demonstrate intensification of production with time in the intervention.

Another goal of the intervention was to encourage participants to diversify the types of foods grown at home, and we observed a greater diversity of starchy crops grown after 1 year and more maize grown after 5 years, although production of other food groups was not different. We also observed a shift in animal production with longer exposure to VERASAN, from keeping pigeons (considered a poorer food source) to chickens and pigs. However, households grew on average only a quarter of all crops and livestock types observed in this study, demonstrating additional capacity for greater agricultural diversity even after 5 years. This raises questions about the capacity of demonstration garden-based interventions such as this one to increase the range of crops that households are growing. Previous interventions have successfully expanded the range of crops grown and consumed by subsistence households; however, these interventions tended to focus on a limited range of crops, such as vitamin A-rich fruits and vegetables[15–20] or improved varieties of staples such as maize[45] rather than the full range of intensification and diversification activities in the VERASAN intervention. In comparing the relatively greater successes of VERASAN in helping households to intensify production of staples rather than increase diversity of nutrient-dense crops, it may be that the successful uptake of new crops requires different or more focused types of interventions, or that in the context of these communities a longer intervention timeline is required.

The ultimate goal of the intervention, as stated in its name, was to 'improve consumption and availability of food' through increased consumption of home-grown foods as a means of lowering food insecurity and increasing diet diversity. We observed that after 1 year, households grew more rice, and after 5 years, children were more likely to eat home-grown rice. As previously noted[37], higher rice production in these communities was associated with lower food insecurity throughout the agricultural cycle of 2012. Improvements to household food security through increasing agricultural knowledge have been observed in other contexts, such as in a study of small-scale farmers in Tanzania[46]. Training in the demonstration gardens was also aimed at improving diet diversity through diversification of agriculture, as demonstrated in recent reviews[6,28,33]. When examining years in the intervention as a cumulative measure of its impact, we observed that after 1 year, households had greater food security and dietary diversity during the lean land preparation and growing months, which are seasons when households in this region typically rely on staples stored from the previous year's harvest and purchased foods. The relationship between VERASAN participation and diet diversity may be due in part to direct benefits in the form of food received by households from the demonstration gardens, as shown by a positive association between DDS and receiving food in the harvest DDS multiple regression model. In this model, there was also a positive association with years in VERASAN that bordered on statistical significance ($P = 0{\cdot}051$), suggesting that other aspects of the intervention not measured in this study may have also contributed to improved child diets, such as increased nutrition knowledge of caregivers[7,28] through nutrition and hygiene workshops or one-on-one support from intervention staff. Together, these data suggest that multiple aspects of the VERASAN intervention may have positively impacted household food security and child diets.

Community demonstration gardens were a central component of this agricultural intervention and were key in introducing new, locally relevant techniques and crops through weekly trainings. This was anticipated to be important for communities early in the intervention that were still in the early stages of learning the techniques promoted in the demonstration gardens. However, interestingly, we observed that the sustaining of community demonstration gardens into the 5th year of the intervention also had an effect on agricultural practices in households' own plots. Half of the communities in the 5-year group no longer had a functioning demonstration garden in the year of the study (although intervention workers continued to visit the communities regularly). Anecdotally, the difference between communities with and without demonstration gardens sustained into the 5th year appeared to be related to the ownership that community members had felt over their community garden in previous years. The continuation of demonstration gardens was associated with ongoing use of new agricultural techniques and higher production of plantain, keeping of pigs and consumption of vitamin A-rich foods. There was also a borderline positive impact on DDS during the harvest. These findings highlight the significance of the demonstration gardens for the sustained success in later years of the intervention.

A unique aspect of this study was that households were followed over an entire agricultural cycle, highlighting potential seasonal influences on the relationship between production variables and dietary diversity that may be important in designing future agricultural interventions[33]. First, none of the production variables emerged in the regression model for diet diversity during land preparation. Instead, diet diversity was positively associated with HWI, consistent with our previous report of better food security during land preparation in households with a higher wealth index[37]. Other researchers have observed that even in resource-poor subsistence farming contexts, families still purchase some foods[47], and the relationship between higher wealth index and diet and food security in our study population may demonstrate this. On the other hand, as our wealth index is composed of durable assets, including cattle, horses, tools, and infrastructure for cooking, this may also indicate that households with these assets were better able to prepare for the lean months. Second, during the harvest, preferred starchy options (which are lower in micronutrients such as vitamin A) were readily available, and the total diversity of crops planted was positively associated with diet diversity. However, preschool children less frequently ate fruits and vegetables, and average DDS was lower than during the growing months. Also, 1-year exposure to VERASAN was associated with greater weekly

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consumption of animal source foods during land preparation and growing months but had no impact on child diets during harvest. The less diverse diet during harvest could reflect choices of households to sell or store produce and rely on staples to satisfy children's appetites. Third, average DDS was highest during the growing months, even though this is a lean period when food stores from the previous year have been depleted and most crops planted that year are not yet ready to harvest. Multiple regression analysis revealed that child diet diversity during the growing period was higher in households that had planted a greater diversity of vegetables, presumably because some locally grown vegetables are harvested continuously. Higher DDS was also associated with greater consumption of vitamin A- and C-rich fruits such as mangoes and citrus fruits, which were in season during this period. Previous studies have shown that children are more likely to consume foods, particularly those rich in vitamin A, if their production is promoted[15–19]. Thus, fruits and vegetables contributed to child diet diversity during this lean time.

The pathways to diversifying diets of preschool children in subsistence farming contexts are complex, and although the focus of our study was on the demonstration garden-based agriculture training central to the VERASAN intervention, other household and caregiver variables measured also shed light on nutrition dynamics in these communities. The literature shows that better income and market connectivity and improved ability of caregivers to care for their children also influence diet diversity[9]. Given that our study communities were largely isolated from markets through geographic distance and lacked transportation and income, we expected that agricultural diversity would be the dominant factor contributing to child diet diversity[28]; however, as noted above, household wealth and asset ownership and not agricultural variables were associated with child diet diversity during land preparation. Childcare practices can also play an important role in determining the diets of young children[48], and we observed a negative association between hours that caregivers worked in the agricultural plot and DDS during harvest. These findings highlight the role of non-agricultural factors in children's diet diversity and the importance of considering gender roles within agricultural interventions for subsistence contexts that depend on family labour, as women often have multiple roles as agriculture workers and caregivers[13,48].

This study had some limitations. First, it did not include a true control group. This is a common concern in evaluation of such interventions[19,23,49–52]. Second, the VERASAN intervention also incorporated health and nutrition education, which is known to have an important impact on child nutrition[7,9] but was not directly measured in this study. Third, the observational nature of this study only allows us to demonstrate associations between involvement of varying lengths in VERASAN and outcome measures.

Our study provides an example of successful intensification of household subsistence-level agriculture, through an intervention focused on demonstration gardens. Our results indicate that the expanded knowledge of context-relevant agricultural methods increased household agricultural practices and production and improved household food security and preschool child diets. Furthermore, our results illustrate the benefit of continued support of households through ongoing community-based demonstration gardens, which can help households retain the learning that leads to increased production and improved diets. The multivariate models for child dietary diversity demonstrate the multidimensional nature of the drivers of diet quality for children, including agricultural production and household food security, as well as household and caregiver characteristics, such as household wealth and produce sales, caregiver age and education and caregiver involvement in household agriculture, suggesting that socioeconomic and gender dimensions need to be considered by interventions. Finally, by following households over one agricultural cycle, possible seasonal relationships among agricultural and nutritional variables have emerged, suggesting that agricultural interventions will be most successful when they are sensitive to seasonal changes in food availability.

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all procedures involving human subjects were approved by the Internal Review Board of the Faculty of Medicine of McGill University in Canada and the National Research Bioethics Committee of Gorgas Commemorative Institute for the Study of Health in Panama. All subjects provided written informed consent.

Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980020002918

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