Household agricultural activities and child growth: evidence from rural Timor-Leste

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Abstract

Childhood under-nutrition and malnutrition are prevalent in low and middle-income countries. Where it is the primary source of food production, consumption, and cash income, agriculture has a close relationship with health and nutrition in these emerging economies. Although Timor-Leste achieved lower middle-income status in 2011, national economic growth has not delivered anticipated nutritional dividends. Seeking to redress a lack of research that clearly demonstrates how agriculture impacts on nutrition in Timor-Leste, we investigated the links between household agricultural activities and children's physical growth in two agro-ecologically varying field sites: lowland Natarbora and mountainous Ossu. Children in both sites were below World Health Organization standards in height, weight, and body mass index. Coastal children recorded better growth than upland children. Livestock production was linked to poorer growth in the upland, but not coastal communities, which may be linked to specific differences in husbandry practices. In both communities, access to a plantation was positively associated with children's (0–10 years) weight-for-age. As simple agricultural indicators do not fully explain growth outcomes, a livelihood security approach is proposed to better understand how households address food and nutritional needs in relation to broader livelihood concerns.

Keywords *rural Timor-Leste; child growth; agriculture; nutrition; anthropometry; development*

Introduction

Childhood nutrition has become a high priority for policy and interventions in post-conflict Timor-Leste. The 2014 Timor-Leste National Food and Nutrition Security Policy (NFNSP) identified agricultural interventions as a major plank for delivering better nutritional outcomes for children. However, the links between specific components of agriculture and their effects on childhood nutrition in Timor-Leste remain unexplored. Globally, evidence is mixed on the pathways between agricultural interventions and nutritional improvements (Turner *et al*., 2013). Agricultural interventions that increase production and cash income do not necessarily result in improved child nutrition (Berti *et al*., 2003; DeWalt, 1993), in part because they may increase women's farm workload, with resulting reductions in time and effort as caregivers (Kent & MacRae, 2010). Because women promote good nutrition within the household and community, focusing solely on increasing farm productivity further risks privileging better-off, market-oriented smallholder farmers

(mostly men) at the expense of the poorest (usually women) (Kent & MacRae, 2010).

The trickle-down effects of national economic growth—as measured, for example, by gross domestic product—on child growth are similarly varied (Alderman *et al*., 2006; Ecker *et al*., 2012). Furthermore, improving household food security does not necessarily result in nutrition security if dietary intake lacks diversity and micronutrients (Gillespie *et al*., 2012; Sinharoy *et al*., 2015). Access to natural resources and land holding size can be predictors of rural food and nutrition security, but in turn these may be influenced by situated power relations and broader political-economic conditions (Merten & Haller, 2008; Rammohan & Pritchard, 2014). In light of these differing findings, there is a need to further investigate the links between agriculture and nutrition (Turner *et al*., 2013).

This paper pursues this objective in the eastern highlands of Ossu and central south coast of Natarbora, Timor-Leste. Consistent with the literature described above, we find little statistical association between household agricultural indicators and child growth measures in either community. Household differences in agricultural practices seem to exert little demonstrable effect on the nutritional status of children ~~living in given households~~. We explain this result by emphasising the limitations of framing the agriculture–nutrition relationship in terms of simple agricultural indicators alone, and instead call for a more integrated approach using a livelihood framework that positions agriculture within the wider spectrum of people's lives.

Nutrition and agriculture in post-conflict Timor-Leste

Timor-Leste's population of 1.1 million is growing at 2.4 per cent annually (World Bank, 2016). The national rates of childhood under-nutrition and malnutrition are high by international standards with 58 per cent of children under five years of age stunted (low height-for-age), 19 per cent wasted (low weight-for-height), and 45 per cent underweight (low weight-for-age) (Timor-Leste ~~DHS~~, 2010). In economic terms, the country had an estimated gross domestic product (GDP) per capita of US$4,000 in 2011, but this was mainly derived from oil and gas revenues (Lopes, 2013). Non-oil GDP per capita was only US$935 (Lopes, 2013). Sixty per cent of the population earn less than US$1 a day (World Food Programme, 2015). Timor-Leste's government has prioritised primary health care and hospital services to its population (Asante *et al*., 2014) and, in support of this strategy, has rolled out community health centres and targeted health promotion programmes that include disease prevention and dietary supplements in rural municipalities (Ministry of Health, 2011). Despite these significant health investments, improvements in anthropometric indicators of child growth in Timor-Leste have stalled in recent years. At the same time, Timor-Leste remains food-insecure and a net importer of food (Andersen *et al*., 2013). Poor soil fertility, steep relief, seasonal climate impacts, water insecurity, and inadequate crop storage systems have hindered domestic agricultural production (Da Costa *et al*., 2013). On average, farming households have access to one to two hectares of land, which is insufficient on its own to ensure household food security (Da Costa *et al*., 2013). Rural households are hampered by limited access to markets to sell their produce because of poor road infrastructure.

Following global trends that give expression to the complex interrelationships between social and environmental determinants of agriculture, health, and nutrition, the Timor-Leste government formulated the NFNSP in 2014. This policy sets an ambitious target for all East Timorese to become 'free from hunger and malnutrition' by 2030 (Democratic Republic of Timor-Leste, 2014, p.5). The NFNSP identifies agricultural systems as critical to achieving this ambition. The policy calls for: (1) smallholder production to be increased through mechanisation; (2) locally nutritious crop varieties to be grown; (3) investment in post-harvest technology, storage and methods for hygienic and safe food production. Furthermore, the policy promotes the development of income-generating opportunities in rural areas to increase economic access to nutritious food (particularly for women, youth, and other marginalised groups), and 'climate smart' agricultural practices and sustainable management of natural resources (Democratic Republic of Timor-Leste, 2014).

The extent to which these initiatives can address food and nutrition insecurity, however, depends on their complementarity with existing human and physical landscapes of Timor-Leste. As discussed below, agricultural development has had a complex history in this young nation.

Timorese subsistence and agricultural change

Seventy per cent of the Timorese population reside in rural areas and are engaged in subsistence and smallholder agriculture. The northern half of the country is much drier than the southern half, with

the latter characterised by extended and heavier rainfall events (Fox, 1988). Swidden agriculture is widely practised across the country. Farmers are generally reliant on rainfall and rarely use fertiliser. Coastal communities typically cultivate irrigated rice. The average rural Timorese household has a small food garden (*kintal* in the national *lingua franca* Tetun) around its residence, where cassava, pumpkin, papaya, banana, chilli, garlic, onion, sweet potato, and other vegetables are grown. Families tend to have access to a larger intercropped vegetable garden (*to'os*) of maize, peanut and beans, and/or a rice field (*natar*) at a further distance from their dwellings. Households may have access to family groves (*plantasaun/ai hahoris*) of fruit, such as mango, jackfruit, and citrus; cash crops such as coffee, tobacco, betel nut, and coconut; as well as timber and non-timber forest products.

Rural Timorese diets are primarily plant-based. The main staple crops are maize, rice, cassava, sweet potato, banana, and taro. Animal protein makes up a small proportion of the dietary intake because livestock are raised mostly for ritual exchange purposes and as a source of household savings (Andersen *et al.,* 2011). Hunting for birds, wild pigs, deer, and small marsupials in the forests and woodlands ~~also~~ contributes to rural diets (McWilliam, 2003), ~~as do fish~~, prawns, and other food sources caught in river streams, flooded rice paddies, and the sea.

Seasonal food shortages, particularly in the rural areas, are characterised by two phases: the first period (*tempu aihan menus*) is marked by diminished household food supply, and this results in reduced meals per day and diets dominated by root crops such as cassava, sweet potato, taro, and arrowroot (Da Costa *et al*., 2013). The second phase, commonly termed the "hungry season" (*tempu rai hamlaha*), coincides with the extended rains that mark the period between planting and first harvest. During this latter period, staple food stocks are depleted and families draw on a range of coping strategies: skipping meals, consuming seeds reserved for the next season, selling livestock and other assets, borrowing money and taking food loans, foraging for wild food, and drawing on kin and wider social networks to supplement resources (Da Costa *et al*., 2013; Erskine, 2015).

Historically, the Timorese engaged in hunting, foraging, fishing, and horticulture. Through inter-island trade within those living in the Indonesian archipelago and New Guinea, and taking advantage of the arrival of Chinese traders on Timor as early as the fifteenth century, Job's tears—a tall grain-bearing perennial, rice, millet, mung bean, pigeon pea, sesame, and sorghum were among the first crops to be introduced and cultivated (Fox, 2003). Because the characteristic clay soils on Timor ~~Island~~ do not readily support agriculture, local populations practised shifting cultivation in the mountains and hills in limestone and marine-rich areas of mixed soils and alluvial terraces. The island's geology also localises water availability, which historically encouraged the Timorese to live in scattered settlements (Fox, 1988). To varying degrees, multi-local livelihoods are still prevalent as coping strategies in times of environmental uncertainty and political adversity, as witnessed throughout the country's turbulent history (Pannell, 2011; Thu, 2012).

The Portuguese were first attracted to Timor by sandalwood prospects in the sixteenth century, but significant change to Timorese subsistence agriculture occurred only with the establishment of a plantation economy in the early twentieth century (Gunn, 1999). This period also marked the colonial push to develop maize and rice into export crops, which was motivated by tax collection rather than improving indigenous people's welfare (Shepherd & Palmer, 2015). Adopting new agricultural techniques, maize and rice were grown intensively in state-controlled fields in every district (now known as municipalities). Low fertility soils forced farmers to shorten fallow periods and clear more land by burning already-diminished natural forested areas (caused by timber extraction and land clearing for state plantations). With a rapidly increasing island population, the clearing of forest land for swidden maize gardens expanded well beyond state control, exacerbating deforestation and environmental degradation (Fox, 1988).

In the 1960s, the Portuguese introduced the use of fertiliser, high-yielding rice varieties, and improved irrigation systems (Fox, 2003). Viqueque district in particular became a major rice growing region. According to Metzner (1977, p.272), widespread land degradation was evident by this time leading to the conclusion that local agricultural systems were 'little developed' to maintain the balance between humans and their environment. Metzner notes that the traditional scattered settlement pattern was also seen as a hindrance to agricultural technology transfer.

From 1975 to 1999, the Indonesian administration similarly perceived Timorese farming practices as needing modernisation. Internment of a large proportion of the population in the early years of occupation~~,~~ gave rise to famine in 1977–78 (Commission for Reception, Truth and

Reconciliation in East Timor, 2005). After establishing security across the territory, forced resettlement served as a key military strategy to improve the seemingly deficient living conditions of the rural Timorese constituency—as well as a means of population control. Many internment camps were transformed into new resettlement villages as part of a broader development programme. Improvements in land transportation increased the mobility of goods and services, connecting agricultural areas to markets and linking population settlements to administrative centres.

In the 1980s and 1990s, Indonesia embarked on a plan to develop export-oriented wet rice cultivation through the introduction of high-yield varieties, new irrigation facilities, and tractors. Optimal yields proved elusive because of geological and weather conditions, and the general lack of labour posed hurdles to bringing additional land into cultivation (Fox, 2001, p.165). By the late 1990s, new major irrigated rice production centres had opened up on both the north and south coasts. To provide necessary labour, mountainous populations were forcibly resettled onto the northern coastal lowlands (Fox, 2001). *Timor-Timur* (as Timor-Leste was then known) increasingly became a destination for state-sponsored transmigration of landless Balinese and East Javanese farmers to bring what are referred to as sophisticated agricultural skills to the East Timorese; the focus on rice resulted in the neglect of the subsistence cultivation of maize, cassava, and other staple food crops (Taylor, 1999). Following the referendum for national independence in August 1999, Indonesian security forces and their supporters destroyed much of the physical infrastructure, livestock, and cultivation fields as they withdrew from the territory. Local people who fled from the looming violence also abandoned their fields for varying lengths of time; this resulted in upwards of 80 per cent of the population experiencing malnourishment (Commission for Reception, Truth and Reconciliation in East Timor, 2005).

Colonial regimes and their development schemes have therefore shaped both the types of Timorese staple foods grown and farming practices, and transformed settlement patterns and natural environments. Paradoxically, the existing swidden system, now considered environmentally destructive, emerged from earlier Portuguese agricultural 'development' (Shepherd & Palmer, 2015). Such historical interventions are reflected in contemporary local food perceptions. Rice is considered a modern, urban, and prestigious food worthy of being served to guests on socially significant occasions. Conversely, although the nutritional quality of maize exceeds that of rice, that grain is perceived as a rural peasant food best consumed by household members (Fidalgo Castro, 2013).

Following independence, improved staple crop varieties are being introduced to increase household food production and income, while better quality storage systems are designed to reduce post-harvest loss and stabilise food supply (Seeds of Life, 2013). However, reducing hunger and improving nutrition require adequate food of nutritious composition—including necessary micronutrients. In the absence of robust evidence demonstrating the links between agriculture and nutrition, we examine the relationships of household agricultural activities and children's growth in two ecologically varying field sites in rural Timor-Leste.

Study sites and methods

Our ongoing project on children's growth in rural Timor-Leste began in 2009 in Ossu and expanded into Natarbora in 2012. Each year, household socio-economic characteristics and the broader social and environmental settings are documented. Our inter-disciplinary team includes researchers and students in human biology, behavioural ecology, and human geography.

Our study areas are located in two distinct agro-ecological zones: four localities in the south-eastern uplands of the Ossu administrative post in Viqueque municipality, between 600 m and 1,000 m above sea level, and three localities in Natarbora administrative post in Manatuto municipality with elevations of 0 to 50 m above sea level (Figure 1). Both field sites receive similar annual rainfall, with monthly rainfall peaking between 230 mm and 250 mm. Natarbora is drier in the dry season and has two wet seasons whereas Ossu is wetter but has only one reliable rainy season. The differences in seasonal rainfall pattern, ground water availability, topography, and soil conditions (and indeed, in the impact of colonial legacies) influence the crop diversity and agricultural systems between the two field sites (Seeds of Life, 2014a; 2014b).

Participating Ossu households are of Makassae and Kai Rui ethno-linguistic groups. Social membership is traced through the male line and sons primarily inherit land and property. Households in Natarbora are predominantly Tetun-Terik language speakers who base their social identity and membership on maternal descent. Resource transfer appeared to be more egalitarian for children of both

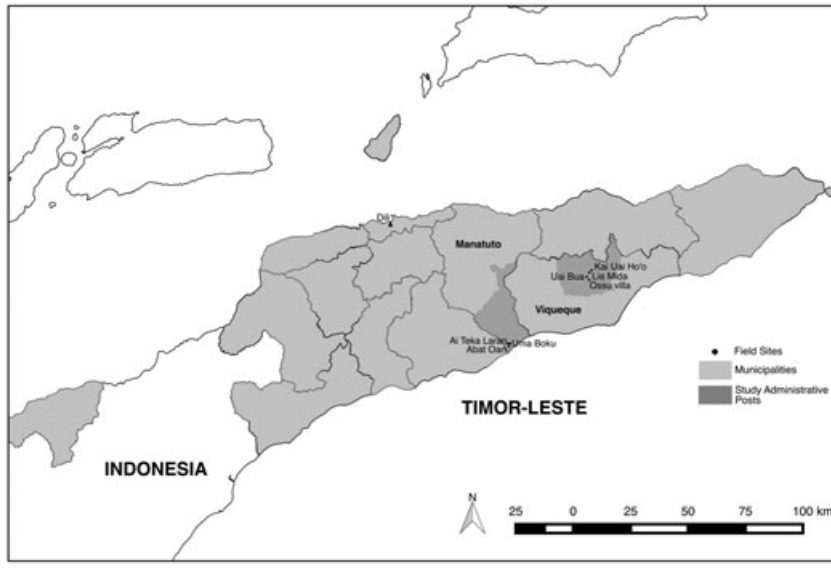

Figure 1 Map of Timor-Leste showing ~~field sites in~~ Natarbora and Ossu Administrative Posts in Manatuto and Viqueque Municipalities

sexes in Natarbora. In the 2010 census, the population in Ossu was 6,220 while in Natarbora it was 2,799 (~~NSD-TL,~~ National Statistics Directorate Timor-Leste and ~~UNFPA,~~ United Nations Fund Population, 2011). To date, firewood remains the main source of cooking fuel ~~and~~ increasing ownership of kettles and rice cookers is potentially reducing household labour for food preparation. During the study period, Ossu households had water access via roadside taps, pipes, and hoses connected to natural springs or, for households residing in Ossu villa, the local dam. Water availability was occasionally low during extended dry seasons, forcing families to fetch water directly from the dam, springs, and rivers. Drinking water was readily available throughout the year in Natarbora, with households relying on hand pumps, and open and closed wells to access ground water.

From August to October 2013, the Natarbora sample of 110 households and 102 Ossu households were surveyed (Table 1). Household socioeconomic status was assessed in terms of livelihood activities, income sources, and resources. Indicators of family resources included housing construction materials, electricity connection, electrical appliances, toilet facilities, land types, and crop production (rice fields, gardens, and plantations), as well as livestock numbers and diversity. Household access to water, health, and education services was also documented.

A total of 609 children (309 boys, 300 girls) were measured in the two field sites. Researchers and trained local research assistants measured each child's height, weight, and mid-upper-arm circumference (MUAC). These growth parameters were standardised using accepted World Health Organization techniques to calculate each child's position relative to international standards for age and sex. Standardised height is an indicator of a child's long-term nutritional status. *Z* weight-for-age is

Table 1 Number or percentage of households in Natarbora and Ossu engaged in agricultural activities and off-farm cash income in 2013

Variable categories	Natarbora	Ossu
Households surveyed	110	102
Mean number of adults (>18 years) per household	3.3	2.5
Mean number of children per household	3.7	4.2
Per cent of households		
Making rice paddy	31.5	31.4
Making garden	72.5	68.6
With plantations	58.2	12.6
Raising animals	93.5	77.7
Raising cattle and/or buffalo	57.8	36.7
Raising pig(s)	63.9	63.3
Raising chickens	92.6	67.3
With salary income[1]	31.8	21.6
With wage labour income	16.3	18.9
With trading income	15.4	35.1

[1]Some households participated in more than one type of income.

an indicator of short-term nutritional status for children under 10 years of age. *Z* body mass index (BMI) (standardised kg/m^2) is an indicator of short-term nutritional status for the full age range of children aged 0 to 19 years. *Z* MUAC is also an indicator of short-term nutritional status but standards are only available for children under five years.

We undertook two statistical analyses of these data. The average of standardised measures of all children in the household produced a 'household' average for each growth measure. Household means for growth parameters were tested for association with various measures of agricultural production and resource access in the two communities. Non-parametric Mann–Whitney tests compared household mean child growth (z height-for-age, z weight-for-age, z BMI, z MUAC, and z head circumference) relative to having a garden, a rice paddy, plantation, livestock, and access to cash income during 2013. This work yielded a gross estimate of bivariate relationships in each community.

Subsequently, mixed linear modelling was used to assess agricultural practices on two measures of short-term nutrition—z weight-for-age and z BMI. We looked at the correlations of a multitude of characteristics of rural farming households with z weight-for-age and z BMI to identify those with a bivariate correlation of $P \leq 0.1$. We selected those with correlation $P \leq 0.1$ and entered them into a backward stepping linear mixed model. Thus, the first mixed model included all those variables with some correlation ($P \leq 0.1$), the results of the mixed model were examined, and the variable with the lowest association (the highest P value) was removed and the model was re-run with the remaining variables. This process was repeated until the remaining variables were all significant and/or the measure of the efficiency of the model (Aikake's Information Criterion) no longer improved. We used this method separately for the two communities.

In Natarbora, we followed up on anthropometric measurements by carrying out semi-structured interviews for a sample of 14 households with children of varying growth outcomes, ~~and~~ recorded distance to gardens and rice fields, and the current land areas under cultivation. Land ownership and access, crop varieties, labour roles, and crop sales were discussed with each family. The boundaries of cultivation fields were mapped, and total cultivation areas calculated using the open source geographical information system QGIS®.

Results and discussion

Table 1 provides background contextual data from our survey. The average household sizes were similar in both sites, but Ossu households included a higher number of children. Households in both sites were heavily dependent on food crops for household consumption within seasonal cropping patterns. Natarbora households produced two crops a year, the first between April and July (maize, peanuts, cassava, and bananas), and the second between August and November (maize, peanuts, cassava, rice, sweet potato, and mung beans). Ossu households produced one crop a year: maize and peanuts harvested between March and April, and sweet potato, cassava, beans, rice, and arrowroot harvested between July and November.

Wet rice ~~cultivation~~ was also ~~grown extensively (~~among approximately 31 per cent of households~~), largely connected to recent historical transformations in both sites~~. Many participating families had been forcibly displaced during the Indonesian occupation, and had had to rebuild livelihoods where they resettled. Abat Oan village in Natarbora was an Indonesian transmigration site in the 1990s; populations drawn from nearby upland villages were resettled on the coast to open up wet rice cultivation. Each household was allocated 0.25 hectares of land for residence and 0.75 hectares of cultivation area. Residents in neighbouring Uma Boku village were similarly resettled onto the plains where they had historically farmed. Many households, including those in Uma Boku, stated that they no longer cultivated rice because they had insufficient money to buy petrol for tractors, or to repair damaged irrigation and infrastructure, or that they had inadequate labour. Several mentioned not having water buffalo for preparing the field *and* being unable to afford petrol for the tractors that have replaced buffalo in cultivation practices. In Ossu, some participating families moved during the Indonesian occupation to live closer to the main roads and town centre, increasing the distance between their residences and gardens, rice fields, and family groves in origin settlements. In Uai Bua, a number of families continued to cultivate rice and other food crops in their ancestral village of Lia Ruka—several hours' walk from their home. Many households in central Ossu villa had abandoned their original cultivation plots and plantations to earn a living through small business and wage income.

The reliance on traditional cultivation in these sites is underlined by the fact that, among households, fewer than 63.5 per cent in Natarbora and 68 per cent in Ossu indicated they earned cash income (Table 1). In part, the relative difference in participating in off-farm activities between these sites is explainable by the fact that Ossu is located along a major north-south road that is accessible year round, while Natarbora sits at the intersection of roads that have lower levels of travel and are often flooded during the rainy season. However, the key point to note is the relatively low extent of non-agricultural activities in these sites: they remain embedded within a dominant farm-based economy.

In these predominantly agricultural sites, there are obvious questions about how child growth is influenced by the type of agriculture practised, or the capacity for households to complement farm-based activities with non-farm cash incomes. However, our bivariate analyses revealed a lack of direct association between simple measures of household agricultural enterprise and indices of household 'mean' child growth in both communities (Table S1). Findings from the Mann–Whitney test indicated a limited range of associations. These included:

1. 0 to 10-year-old children in families with a plantation had significantly better weight-for-age in Natarbora;
2. ~~children in~~ Ossu households engaged in the irregular employment market had poorer standardised weight-for-age (Table S2);
3. children living in households that raised animals showed poor growth in all measures (a very surprising result); and
4. ownership of a garden plot had a positive association with child growth for 0–5 year olds, as measured by MUAC.

Investigating these data in more detail using linear mixed modelling mostly confirmed findings from the bivariate analyses. Linear mixed modelling uses individual children as subjects and ~~hence~~ controls statistically for the fact that they cluster in households. Older children and boys showed poorer *z* BMI than younger children and girls (Tables 2 and 3). ~~Plantation ownership was positively associated with~~ child growth (on the basis of *z* weight-for-age of 0 to 10-year-old children in both communities; Tables 4 and 5). In Ossu, children living in households that raised animals demonstrated much poorer *z* weight-for-age than children in families not raising animals (Table 4). A closer look at the various types of animals indicated that water buffalo and cattle ownership contributed to this difference but not pigs or chickens. By comparison, longitudinal assessment of child growth in Natarbora suggested that households that raised pigs were associated with better BMI and households with more than 10 cattle were associated with poorer height (Spencer *et al.*, 2016). The fact that raising livestock is a long-term investment may explain the associated negative impact on long-term nutritional status (that is, height). Although working a garden was not a significant independent predictor of child

Table 2 Linear mixed model of *z* BMI with estimated marginal means and variable associations for children under 19 years of age in Ossu households. Household number was entered as a random variable to control for the fact that multiple children are measured in any given household[1]

Variable categories (reference)	Marginal mean *z* BMI	*b*	*t*	P
Age group				
0 to 2 years	0.308	0.783	2.281	0.023
2+ to 5 years	0.442	0.917	4.242	<0.001
5+ to 10 years	−0.464	0.011	0.065	0.949
10+ to 15 years	−0.853	−0.378[2]	−2.143	0.033
(>15 years)	−0.475			
Sex of child				
Girls	−0.041	−0.335	−3.222	0.001
(Boys)	−0.376			
Household raises animals				
None	−0.002	0.412	2.218	0.030
(Yes)	−0.414			

[1]The original model also included a plantation and number of children in the household; these were eliminated by the statistical procedure as not contributing significantly to the explanation of variation in *z* BMI.
[2]The beta value for the reference category is not included as it is redundant.

Table 3 Linear mixed model of *z* BMI with estimated marginal means and variable associations for children under 19 years of age in Natarbora households. Household number was entered as a random variable to control for the fact that multiple children are measured in any given household[1]

Variable categories (reference)	Marginal mean *z* BMI	*b*	*t*	P
Age group				
0 to 2 years	−0.424	0.474	1.821	0.07
2+ to 5 years	−0.487	0.411	1.824	0.069
5+ to 10 years	−1.044	−0.146	−0.702	0.483
10+ to 15 years	−1.246	−0.348[2]	−1.672	0.096
(>15 years)	−0.898			
Household making a garden				
No	−0.869	−0.099[2]	−0.618	0.539
(Yes)	−0.770			

[1]This analysis includes 335 children in 95 households. Only age group and making a garden showed bivariate correlation with *z* BMI and making a garden was retained in the model because eliminating it resulted in the AIC value increasing by over 100 units (indicating a substantially poorer explanatory model).
[2]The beta value for the reference category is not included as it is redundant.

growth, its inclusion in the mixed model was highly important to the model's efficiency (as determined using Aikake's information criteria) and therefore retained as a variable (Table 3).

Children in Ossu and Natarbora reflected the low national standardised growth measures of height, weight, and BMI (cf. Timor-Leste ~~DHS~~, 2010). Older children were worse off than younger ones across all sampled localities. Girls' measures were generally better than boys' relative to international standards—significantly so in Ossu. Children in Natarbora showed substantially better growth measures than did children in the Ossu area, which may be because of environmental conditions. Natarbora and Ossu share similar annual rainfall amounts, but Natarbora has a bimodal rainfall pattern, is generally warmer and flatter, and has better water availability, which generates two crop cycles a year compared to one in Ossu. The flat topography may require less labour to prepare cultivation fields than upland gardens and terraced rice paddies in mountainous Ossu. For Ossu children, reaching school, fetching water and firewood, and helping in agricultural activities, may require more work than on the coast. Furthermore, seasonally lower temperatures in the mountains may be associated with different exposure to illness—especially respiratory infection. Cross-culturally, highland Ecuadorian children were found to be shorter and lighter than their lowland counterparts, which may be a combination of altitudinal influences, poor quality soil that affects food production, and higher calorie energy requirement because of the terrain (Katuli *et al.,* 2013).

More surprising, our analyses revealed that owning animals—especially water buffalo and cattle—was associated with poorer child growth. Previous research conducted in Ossu did not find a relationship between indicators of agricultural practice and child growth (Reghupathy *et al.*,

Table 4 Linear mixed model of *z* weight-for-age with estimated marginal means and variable associations for children 0–10 years of age in Ossu households. Household number was entered as a random variable to control for the fact that multiple children are measured in any given household[1]

Variable categories (reference)	Marginal mean *z* weight-for-age	*b*	*t*	P
Have plantation?				
No	−1.782	−0.530[2]	−1.946	0.056
(Yes)	−1.252			
Household raises animals				
None	−1.035	0.963	3.867	< 0.001
(Yes)	−1.998			

[1]No individual or household composition variables were correlated with *z* weight-for-age. $N = 168$ children age 0–10 years in 63 households.
[2]The beta value for the reference category is not included as it is redundant.

Table 5 Linear mixed model of *z* weight-for-age with estimated marginal means and variable associations for children 0–10 years of age in Natarbora households. Household number was entered as a random variable to control for the fact that multiple children are measured in any given household[1]

Variable categories (reference)	Marginal mean *z* weight-for-age	*b*	*t*	P
Age group				
0 to 2 years	−0.452	0.561	3.323	0.003 (overall)
2+ to 5 years	−0.644	0.368[2]	2.340	0.001
(5+ to 10 years)	−1.013			0.020
Household has plantation[3]				
No	−0.865	−0.237[2]	−1.682	0.094
(Yes)	−0.627			

[1]$N = 222$ children aged 0–10 years in 104 households. The original model also included fostering status of the household, raising animals, and sex of the child; these were removed through the statistical process.
[2]The beta value for the reference category is not included as it is redundant.
[3]Plantation is retained in the model because its elimination resulted in the information content of the model (AIC value) increasing and because it has a $P < 0.1$.

2012). In that case, livestock was indexed using a 'market value' dollar equivalent and, because livestock is rarely sold, that was unlikely to have provided a culturally relevant index. In 2013, poorer children's growth in Ossu households practising animal husbandry may be related to the fact that livestock are herded, penned or tied up; it may require more human work to bring food to the animals or to herd them periodically to graze in new areas. By contrast, Natarbora livestock is allowed to roam freely; the consistently negative association of livestock with children's growth in the Ossu area was not mirrored in Natarbora. This result does make it clear, however, that the broad scale indicators of agricultural participation that used are not so general as to preclude important information on child growth and agriculture. Access to family plantations is associated with better weight-for-age in young children in both communities, suggesting that plantations may provide a resource that requires minimal work effort relative to rice production or garden maintenance. Such access appears to be associated with a greater difference in growth in Ossu than in Natarbora. The follow-up qualitative interviews in Natarbora revealed that betel-nut from family plantations was an off-farm income source for several households during the dry season, fetching between US$10–$20 per 100 *fitun* bunch (each stick in a *fitun* had 20 to 22 dried betel nut). Clearly, further exploration of the actual production activities and income streams from plantations is warranted.

Although the qualitative interviews highlighted the diverse livelihood strategies drawn by Natarbora households, no obvious direct positive impact on child growth arose from a household's ability to cultivate more food or diversity of crops, or to purchase better-quality food through cash income (Table S3). Our use of the 2013 post-harvest cross-sectional data in this article has limited our ability to assess how child nutritional status changes over time. However, our longitudinal research in Ossu has demonstrated that although children lost weight following the extended wet season in 2010, they showed recovery by 2012 and 2013 (Judge *et al*., 2012). Simple agricultural variables may therefore be insufficient to understand the full range of factors shaping child well-being.

Food and nutritional insecurity may be better understood as a subset of livelihood security (Frankenberger & McCaston, 1998). Households may choose to prioritise meeting other basic needs over securing food and nutrition, or they may endure hunger in the short-term in order to preserve their resources to meet broader livelihood goals in the future (Maxwell, 1996). A livelihoods approach may give insight into household strategies used to meet basic needs and respond to environmental uncertainty, seasonal food shortage, and irregular income which, in turn, have a bearing on child nutritional outcomes (Frankenberger & McCaston, 1998). 'Objective' measurements such as child anthropometry, caloric intake, or income sources—which are easier to quantify—are conventionally favoured in assessing food and nutrition security (Maxwell, 1996).

'Subjective' indicators, such as the perspectives of the food insecure, their nutritional knowledge, cultural acceptability of food, livelihood needs, and aspirations are harder to assess and less used. Variations in cultural beliefs and practices can shed additional light on local food uses. For

example, the exchange of food and livestock is a critical aspect of strengthening marital ties among the Makassae people (Forman, 1980). Our respondents in Ossu, who are Makassae and Kai Rui speakers, stated that marital gift exchange can involve elaborate transfers of livestock between the transacting families, whereas more modest forms of gift transaction occur among the Tetun-Terik residents in Natarbora (associated with more common sale of livestock). Sensorial preferences (for example, smell, taste, and texture), lineage-related food taboos, and food prohibitions during pregnancy may also explain why specific nutritious foods are not eaten by particular social groups (Fidalgo Castro, 2013). From an interdisciplinary perspective then, both objective measurements (outcomes) and subjective perspectives (mechanisms) are significant to identify a wider possible range of agricultural-related factors affecting child nutritional status.

Conclusion

Food and nutrition security is a wicked problem that traverses multiple scales, ranging from the individual and household to the broader biophysical, social, political, and economic environment; further, there are complex inter-connections with agriculture, poverty, gender, and even climate change (Pritchard, 2016). Children's growth must similarly be understood as multi-dimensional. In this paper, referring to two differing communities in rural Timor-Leste, we have assessed the possible links between household agricultural practices, and child growth—as a proxy for nutrition. Although children on the coastal plain fared better overall than upland children, we found that local variation in growth was little-explained by household agricultural indices. Opportunities for household diversification into the cash economy similarly did not have evident benefit to children's growth. Of the household-level agricultural indices drawn here, only animal husbandry explained significant independent variation in child growth, and that in only the mountain community (though plantations and gardening were important in the multivariate modelling). As would be expected, there were fewer explanatory insights for variation in the community where children are less disadvantaged than where their growth is poorer. Clearly, a multivariate approach yields more insights than the simple bivariate approach. While it is possible that low variation in our samples would mask influences on growth, and accounting for the fact that most individuals are characterised by negative standardised measures, previous research has indicated that some household composition variables are relevant to some growth measures.

Increasingly, multi-sectoral 'nutrition-sensitive' development projects are adopted in Timor-Leste to address the complex nature of food and nutrition insecurity. These include school feeding programmes that provide nutritious meals to students (World Food Programme, 2013), community-based cooking demonstrations for breastfeeding and pregnant women (HealthNet, 2014), the promotion of high-carotene and high-protein crop varieties (Seeds of Life, 2012), and education about safe water, hygiene, and sanitation practices (Department of Foreign Affairs and Trade, 2014). However, there has been no evaluation of the nutritional impacts of these interventions to date or their effectiveness as compared to 'nutrition-specific' interventions—for example, the Ministry of Health's distribution of fortified food blends. As practitioners are cautioned by Dangour *et al.* (2012), even when national data are available on agricultural and nutrition-related indicators, they are usually not based on the same sample populations, and analyses consequently produce fragmented and incomparable information. These research gaps and methodological shortcomings must be addressed promptly to avoid repeating similar development interventions of the colonial past that brought far-reaching social and environmental impacts.

It is unlikely that researchers of distinct disciplines will, by themselves, be able comprehensively to examine the entire evidence chain linking agriculture and nutrition, and the global evidence suggests few studies to date have attempted to develop integrated research designs and methodologies (Turner *et al*., 2013). A livelihood security approach might be a useful framework to investigate whether households prioritise food and nutritional needs in relation to meeting other immediate subsistence needs. As lower and middle-income populations such as those in Timor-Leste undergo rapid socio-economic change, household demographics, livelihoods, incomes, expenditures, and aspirations will shift. This change will invariably reshape intra-household dietary intake, food allocation practices, and nutritional outcomes. With this dynamism comes the urgency for researchers to bridge disciplinary divides and develop the agriculture-nutrition evidence base further which, in turn, will better inform development programmes and policy making.

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Supporting information

Additional supporting information may be found in the online version of this article at the publisher's web-site:

Table S1. Bivariate relationships of household resource access and mean household child growth measures in Natarbora. Summary of results of bivariate Mann-Whitney test of relationship. NS = $P \geq 0.05$.
Table S2. Household resource access and mean household child growth measures in Ossu. Summary of results of bivariate non-parametric (Mann-Whitney) tests of relationship.
Table S3. Summary of qualitative interviews with 14 Natarbora households: household mean child growth measures, land areas under cultivation, crop diversity and off-farm income in 2013. Names were changed to preserve anonymity.