Engagement in Agriculture Protects Against Food Insecurity and Malnutrition in Peri-Urban Nepal

Corrina Moucheraud,[1] Ram K Chandyo,[2,3] Sigrun Henjum,[4] Tor A Strand,[2,5] Manjeswori Ulak,[6] Wafaie W Fawzi,[7,8,9] Lindsey M Locks,[7] Patrick Webb,[10] and Andrew L Thorne-Lyman[7,11]

[1]Department of Health Policy and Management, University of California Fielding School of Public Health, Los Angeles, California; [2]Center for International Health, University of Bergen, Bergen, Norway; [3]Department of Community Medicine, Kathmandu Medical College, Kathmandu, Nepal; [4]Oslo and Akershus University College of Applied Science, Oslo, Norway; [5]Innlandet Hospital Trust, Lillehammer, Norway; [6]Department of Child Health, Institute of Medicine, Kathmandu, Nepal; Departments of [7]Nutrition, [8]Global Health and Population, and [9]Epidemiology, Harvard T.H. Chan School of Public Health, Boston, Massachusetts; [10]Friedman School of Nutrition Science and Policy, Tufts University, Boston, Massachusetts; and [11]Center for Human Nutrition, Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland

ABSTRACT

Background: Urbanization is occurring rapidly in many low- and middle-income countries, which may affect households' livelihoods, diet, and food security and nutritional outcomes.

Objective: The main objective of our study was to explore whether agricultural activity among a peri-urban population in Nepal was associated with better or worse food household security, household and maternal dietary diversity, and nutritional outcomes for children and women.

Methods: A cross-sectional survey was administered to 344 mother–child pairs in Bhaktapur district, Nepal, including data on household agricultural practices, livestock ownership, food security, dietary diversity and expenditures, anthropometric measurements of children (aged 5–6 y), maternal body mass index (BMI), and maternal anemia. Multivariable adjusted odds ratios (AORs) and unadjusted odds ratios were calculated using logistic regression.

Results: Our findings suggest that in this sample, cultivation of land was associated with lower odds of child stunting (AOR: 0.55; 95% CI: 0.33, 0.93) and household food insecurity (AOR: 0.33; 95% CI: 0.18, 0.63), but not low (or high) maternal BMI or anemia. Livestock ownership (mostly chickens) was associated with lower food insecurity (AOR: 0.34; 95% CI: 0.16, 0.73) but not with nutrition outcomes. Women in farming households were significantly more likely to eat green leafy vegetables than were women in nonfarming households, and children living in households that grew vegetables had a lower odds of stunting than children in households that cultivated land but did not grow vegetables (AOR: 0.49; 95% CI: 0.25, 0.98).

Conclusions: Our study suggests that households involved in cultivation of land in peri-urban Bhaktapur had lower odds of children's stunting and of food insecurity than noncultivating households, and that vegetable consumption is higher among those households. Given Nepal's rapid urbanization rate, more attention is needed on the potential role of peri-urban agriculture in shaping diets and nutrition. *Curr Dev Nutr* 2019;3:nzy078.

Keywords: urban agriculture, nutrition, food security, dietary diversity, diet

Manuscript received August 14, 2018. Initial review completed August 14, 2018. Revision accepted September 25, 2018. Published online November 1, 2018.

This study was funded by the USAID Feed the Future Security Innovation Lab for Nutrition—Asia (award number AIDOAA-l-10-00005) through a subcontract to the Harvard T.H. Chan School of Public Health and the Johns Hopkins Bloomberg School of Public Health from the Friedman School of Nutrition Science and Policy, Tufts University; and by the GC Rieber Foundation.

Supplemental Tables 1–3 are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/cdn/.

Author disclosures: CM, RKC, SH, TAS, MU, WWF, LML, PW, and ALT-L, no conflicts of interest.

Address correspondence to CM (e-mail: cmoucheraud@ucla.edu).

Abbreviations used: AOR, adjusted odds ratio; DHS, Demographic and Health Survey.

Introduction

The world is increasingly urbanizing: just under half of the population in low- and middle- income countries now lives in urban areas and over a quarter of urban dwellers are involved in agri-food value chains (1, 2). Recent articles have highlighted the important role that agricultural participation can play in shaping dietary patterns and nutritional outcomes (3–5). As the global community and national governments seek to end hunger and poverty under the Sustainable Development Goals agenda (6), it is important to gain an improved understanding of how agriculture in urban and peri-urban areas influences diet and nutritional outcomes. Several recent systematic reviews on urban agriculture and nutrition have noted the limited body of evidence on this topic and highlighted a need for more studies to understand the relations between engagement in urban agriculture and children's nutritional status (7–9).

The Kathmandu valley is one of the most rapidly growing urban areas in South Asia and is home to 17% of Nepal's population (10). Even in Nepal's urban and peri-urban areas, agriculture remains an important contributor to livelihoods and income. For example, the 2011–2012 Living Standards Monitoring Survey in Nepal found that ∽9% of all "agriculture households" were based in urban areas, with 72% of these working their own land (11). Based on our literature search, which included a number of recent reviews on the topic of urban food security and nutrition, we are not aware of any studies that have empirically explored links between agricultural practices and the food security situation, dietary quality, or nutritional status of peri-urban households in Nepal (9, 12).

This paper offers new insights into how participating in peri-urban agricultural activity contributes to women's and children's nutritional status, and their household food security, expenditures, and diet diversity. Data for the study were collected in Bhaktapur, Nepal, a municipality in the Kathmandu valley, ∽15 km from the capital. Over the last decade, Bhaktapur saw the largest annual population growth rate in the country (excluding the capital) and, as of the most recent report in 2011, was the most population-dense district outside Kathmandu (13).

The 2 key research questions examined in this paper are: *1*) Did households that engaged in agricultural activity have better or worse food household security, household or women's dietary diversity, or nutritional outcomes for children and women compared with those who did not? *2*) What were the associations between engagement in specific agricultural practices, including vegetable gardening, production of different types of crops or ownership of animals, and these same outcomes?

Methods

This analysis uses cross-sectional data collected from a survey conducted in Bhaktapur, Nepal. Details on the study design, including sampling frame, participant recruitment, and data-collection methods, have been described elsewhere (14). Briefly, 500 lactating women and their infants participated in a survey in 2008–2009. Four years later (August 2012 to February 2014) the study team located and recontacted the same women for a follow-up survey; a total of 344 women were successfully resurveyed. During the follow-up survey, which was the only source of data for this analysis, women were asked questions about household characteristics including agricultural engagement and a recall of expenditures; data were also collected from mothers and children on anthropometric measures, and blood samples were taken from mothers for the assessment of hemoglobin and anemia.

Women reported on land ownership (owning compared with renting) and crops grown. For each crop, they were asked how much was produced in the past year and whether any was sold. For rice, women reported the number of months for which the rice produced was sufficient for household consumption. All units of measure for land size and agricultural output were converted to standard international metric system units (i.e., *ana* to hectares, *muri* to kilograms). We defined "cultivating households" or "farming households" in this paper as those who reported cultivating any land, irrespective of the source of that land. "Livestock owning households" reported ownership of ≥1 chicken, goat, pig, cow, or buffalo.

Household expenditures were estimated using a 13-item tool with a monthly recall period for different categories of food, electricity, and fuel. Reported expenditures were translated to per capita values, based on the reported number of household members. Staple food expenditure was defined as money spent on rice, wheat, or corn. Local currency (Nepal rupees) was converted to US dollars, using the average exchange rate from 2012 to 2013, and then to current US dollars using inflation rates (15).

Household wealth was calculated using inverse probability weighting (16) based on the WAMI (Water and sanitation, Assets, Maternal education, and Income) index (17) and using the following dichotomous variables: household had a separate kitchen room, household owned a refrigerator, household owned a television, household owned a motorcycle/motorbike, household owned a bicycle, household had piped water, household had an improved floor, and used electricity or propane for cooking [the latter 2 were based on Demographic and Health Survey (DHS) wealth index guidelines (18)]. The availability of each of these characteristics at the household level was calculated (all binary variables) and was divided by the proportion of the sample with a "yes" for each. These per-item values were then summed together into a total score, and households were classified into quartiles according to these summed scores.

The Household Food Insecurity Access Scale (19) was used to assess household food security. In addition, 24-h recall data collected at 2 points in time from children's mothers were recoded into dichotomous yes/no consumption variables according to the 10 food groups used to compile the Minimum Dietary Diversity for Women score (20), with score summed for each day and averaged across the 2 points in time. Anthropometric measures were taken from the children who had participated in the original study, by trained enumerators using standardized equipment: at the time of the survey, these children were aged 5–6 y (mean: 5.1 y). The WHO Child Growth Reference for school-aged children was used to calculate *z* scores (21). Women's BMIs were calculated using their measured height (in meters) and weight (in kilograms) using the formula [weight/(height^2)] and expressed as kg/m^2. Women's hemoglobin concentrations were assessed using a sample drawn from a fingerstick and analyzed using Hemocue 201+. Anemia was defined by hemoglobin <12.3 g/dL, reflecting an upwards adjustment of 0.3 g/dL for altitude. Women's anthropometric measures, both anemia and BMI, were calculated only for nonpregnant women.

Data were analyzed using Stata version 14. Differences between groups were analyzed using *t* tests for continuous variables (except for tests of differences between monthly expenditures—because these were not normally distributed, Wilcoxon rank-sum tests were used), and ORs were used to express the results of logistical regression analyses.

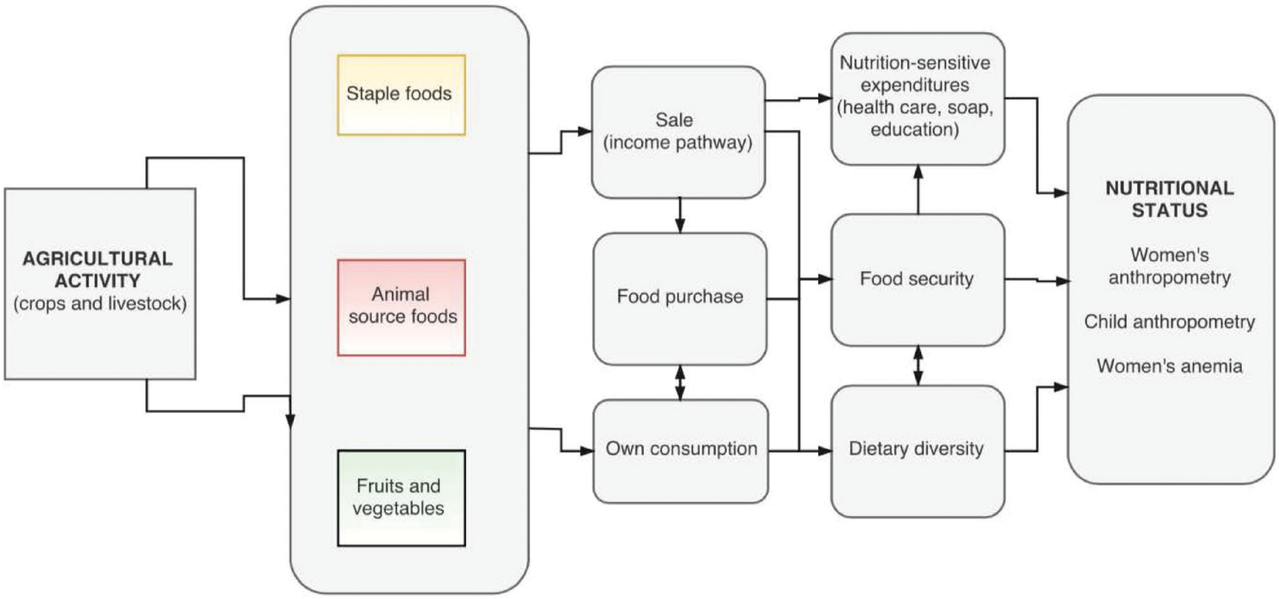

FIGURE 1 Conceptual framework for the analysis.

We used a theory-driven approach to guide our analysis and covariate selection, drawing on the framework presented in **Figure 1**, with models including measures of socioeconomic status (maternal and paternal education, maternal and paternal employment status, household wealth score), demographic factors (maternal age, child birth order, child sex), and other factors (months of exclusive breastfeeding, birth at a health facility).

Ethical clearance was given by the Institute of Medicine at Tribhuvan University in Nepal, by the Norwegian Regional Committee for Medical and Health Research Ethics (REK VEST), and by the Institutional Review Board at the Harvard T.H. Chan School of Public Health.

Results

The study population for this analysis included 344 women and their children; characteristics of these households are shown in **Table 1**. The average household included 5.5 people. Just under one-third of households reported owning livestock (30.5%). All livestock-owning households owned chickens (median of 2 chickens owned), and very few (2.9%) sold the chickens or their eggs. Nearly two-thirds (61.9%) of the households in this sample cultivated some agricultural land. The average plot of agricultural land was ∼0.10 hectares (reported size ranged from 0.003 hectares to 0.71 hectares). Rice and vegetables were the most common crops grown, followed by wheat and maize. Among vegetable growers, households cultivated a mean (and median) of 5 different varieties over the past year. Agriculture was reportedly the main occupation of only 10% of men from farming households and 2.3% of nonfarming households. Among nonfarming households, 57.3% of men relied on daily wage work as a main occupation, and 20.6% were self-employed, compared with farming households, in which 40.9% were daily wage earners and 31.5% relied on self-employment as the main source of income. Among all households, nearly two-thirds of women were reportedly not working ($n = 216$, 64.5%), and 14.0% ($n = 47$) were daily wage earners. In the full sample, 9.6% ($n = 32$) of women were reportedly employed in agriculture; nearly all of these women ($n = 27$) resided in households that reported participating in agriculture.

Less than one-quarter of households growing any crop reported selling it. Three-quarters of the households grew rice (72.8%), and on average, this rice was reportedly sufficient for these households' consumption for 7.4 mo of the year. Most commonly, households grew several crops, usually ≥1 staple food plus vegetables (82 households reported growing 2–3 staple crops plus vegetables) over the previous year.

Table 2 presents anthropometric measurements of women and children. Over one-third of children (39.2%) were classified as stunted (<−2 height-for-age *z* score), and 18.2% of the children were underweight (<−2 weight-for-age *z* score). Approximately 40% of mothers (among women not currently pregnant) were classified as overweight or obese (BMI >25), and very few (2.2%) had a BMI below 18.5. About one-third of women (32.9%) had mild or moderate anemia (hemoglobin <123 g/L).

Characteristics of children and households are also disaggregated by farming status and livestock-ownership in Table 2. Farming households had a lower prevalence of child stunting and underweight, and of maternal underweight, overweight, and anemia, compared with nonfarming households. Households without livestock appeared to have slightly higher rates of maternal overweight and lower rates of child underweight.

The relations between agricultural participation and child nutritional outcomes were explored through logistic regression models (**Table 3**). The odds of stunting among children from farming households were approximately half of that among children from nonfarming households in multivariable adjusted regression models [adjusted odds ratio (AOR): 0.55; 95% CI: 0.33, 0.93], and a similar

TABLE 1 Sample characteristics (n = 344)[1]

Household size, persons	5.5 ± 2.5
Livestock ownership, %	30.5
Households that owned livestock (n = 107), %	
Owned chickens	100
Owned ducks	6.7
Owned buffalo	1.0
Owned pigs	1.0
Household farmed, %	61.9
Farming households (n = 213)	
Owned land, %	83.3
Plot size, hectares	0.10 (0.003, 0.71)
Crops grown in previous year	
Rice, %	72.8
Sold any rice, %	7.9
Reported mean number of months of rice sufficiency	7.4
Wheat, %	40.9
Sold any wheat, %	16.5
Maize, %	27.7
Sold any maize, %	17.2
Vegetable(s), %	62.4
Sold any vegetables, %	24.8
Households that grew vegetables (n = 133), %	
Grew potatoes	54.6
Grew green leafy vegetables	97.0
Grew eggplant	25.0
Grew tomatoes	13.6
Grew cabbage	32.6
Grew cauliflower	39.4
Grew onion	31.8
Grew pumpkin	27.3
Grew yams	40.9
Grew garlic	91.7
Grew green beans	45.9
Number of different vegetables grown	5 ± 2.7

[1]Values are means ± SDs, percentages, or medians (minimum, maximum) unless otherwise specified.

but nonsignificant trend emerged for underweight (AOR: 0.65; 95% CI: 0.34, 1.27). Livestock ownership was not significantly associated with odds of stunting or underweight. Although no statistically significant associations were observed between stunting or underweight and cultivation of staple crops, cultivation of ≥1 type of vegetable was associated with significantly lower odds of stunting (AOR: 0.49; 95% CI: 0.25, 0.98). Households that grew wheat (AOR: 0.45; 95% CI: 0.23, 0.86) or maize (AOR: 0.39; 95% CI: 0.18, 0.85) were significantly less likely to have a mother who was overweight or obese; beyond these relations, no significant associations between agricultural practices and maternal nutritional outcomes were observed (**Supplemental Table 1**).

Overall, the dietary diversity scores of women (Minimum Dietary Diversity for Women) in farming/nonfarming households and livestock-/nonlivestock-owning households were similar (P values of 0.5 and 0.8, respectively, for t tests of difference in mean dietary diversity scores) but differed in the specific types of food consumed. In both unadjusted and adjusted models, women in farming households were significantly more likely to have consumed dark green leafy vegetables than were women in nonfarming households, whereas in unadjusted models only, women in households with livestock were significantly more likely to have consumed dairy and eggs than were women in households without livestock (these relations were not robust to the inclusion of covariates) (**Supplemental Table 2**). The only significant predictor of dark green leafy vegetable consumption, after adjusting for important covariates about household sociodemographic characteristics, was cultivation of rice (AOR: 2.23; 95% CI: 1.14, 4.37).

Farming households had significantly lower monthly per capita expenditures on all staple foods, vegetables, and other food (**Figure 2**). Summing across these 3 subcategories, total monthly per capita spending on food among agricultural households was $7.75 (range $0–$33.14), whereas among nonagricultural households it was $13.66 (range $0–$50.41). Farming households were much more likely to report zero spending within each subcategory during the preceding month than were nonfarming households (**Supplemental Table 3**).

Roughly 20% of households were classified as moderately or severely food insecure using the Household Food Insecurity Access Scale measure (Table 2; **Figure 3**). Farming households had significantly reduced odds of moderate or severe food insecurity (AOR: 0.33; 95% CI: 0.18, 0.63), as did households with livestock ownership (AOR: 0.34; 95% CI: 0.16, 0.73) (**Table 4**). Farming and livestock-owning households were much less likely to express concern about household food insecurity domains related to food anxiety and intake. Among farming households, those that cultivated above–median size plots of land were significantly less likely to be classified as food-insecure. Households growing rice and maize were also significantly less likely to be food insecure, but no relation was found with wheat or vegetables.

Discussion

To our knowledge, this is only the second article from South Asia, and the first from Nepal, to explore the links between agriculture participation and nutrition outcomes in a peri-urban setting (12). Our findings indicate that farming households in Bhaktapur, a peri-urban area in the Kathmandu Valley of Nepal, had lower odds of both child stunting and food insecurity than did nonfarming households. Further investigation of agricultural practices revealed that land cultivation, but not livestock ownership, was associated with lesser stunting after adjusting for other indicators, including socioeconomic status. We also found indications that participation in agriculture was associated with greater consumption of green leafy vegetables, but that overall dietary diversity was similar for women in agricultural and nonagricultural households. We did not find any significant associations between household farming and adult women's nutritional outcomes.

A number of recent review papers have outlined the complex web of pathways linking participation in agriculture to the nutritional status of women and children (4, 5, 22–25). A common theme in these reviews is the lack of empirical data to ground the understanding of which pathways matter most and under which contexts. Reviews of the contribution of urban agriculture to nutrition and food security come to a similar conclusion: whereas there are largely anecdotal reasons to think that agriculture *could* improve nutrition—through income-related effects, increasing dietary diversity through greater access to fresh foods, buffering food shortage during seasonal food insecurity or times of stress, or increasing women's time with children—few studies

TABLE 2 Agricultural activity, maternal and child nutritional status, and household dietary diversity[1]

		By household farming activity		By household livestock ownership	
	Full sample ($n = 329$)	Farming households ($n = 203$)	Nonfarming households ($n = 126$)	Livestock owners ($n = 99$)	Nonlivestock owners ($n = 230$)
Nutrition and growth outcomes, % per outcome					
Children: stunting (HAZ<−2)	39.2	35.5	45.2	38.4	39.6
Children: underweight (WAZ<−2)	18.2	16.8	20.6	21.2	17.0
Women: underweight[2] (BMI <18.5)	2.2	1.5	3.2	2.1	2.2
Women: overweight or obese[2] (BMI >25)	40.6	39.7	42.1	34.0	43.4
Women: mild or moderate anemia[2] (Hb < 12.3 g/dL)	32.9	32.0	34.7	36.2	31.5
Dietary diversity: women's consumption of individual food items (any consumption over 2-d recall period)					
Grains, white roots and tubers, and plantains, %	100	100	100	100	100
Pulses (beans, peas, and lentils), %	32.8	29.66	38.2	25.7	36.0
Nuts and seeds, %	0.6	0	1.5	0	0.8
Dairy, %	27.9	26.3	30.5	33.3	25.5
Meat, poultry, and fish, %	9.6	8.9	10.7	8.6	10.0
Eggs, %	2.3	2.3	2.3	3.8	1.7
Dark green leafy vegetables, %	39.5	46.0	29.0	41.9	38.5
Other vitamin A-rich fruits and vegetables, %	17.2	13.6	22.9	11.4	19.7
Other vegetables, %	43.6	41.8	46.6	37.1	46.4
Other fruits, %	2.0	1.9	2.3	1.9	2.1
Woman's mean dietary diversity score	4.06	4.02	4.11	4.08	4.05

[1]BMI is in kg/m^2. HAZ, height-for-age *z* score; Hb, hemoglobin; WAZ, weight-for-age *z* score.
[2]Among women who were not reportedly currently pregnant.

have been able to empirically explore any of these pathways (9, 26). Indeed, a recent review identified only 12 studies in urban areas, 4 from Asia and 8 from East Africa, examining food security ($n = 9$), dietary diversity ($n = 3$), nutritional status ($n = 4$), motivation for engagement in agriculture ($n = 7$), and barriers to urban agriculture ($n = 5$) (9).

Despite the different geographical context of our study, and the limitations identified in many of those studies, some of our findings are consistent with the existing literature. We observed strong protective associations between participation in agriculture and child stunting, findings that are concordant with studies from Uganda (27, 28) but not with other cross-sectional studies from Uganda or Malawi (29, 30) We did not observe any associations of this exposure and other indicators of maternal or child nutrition including anemia, an outcome that to our knowledge has not been explored previously in urban or peri-urban

TABLE 3 Relation between agricultural activity and children's nutritional outcomes[1]

	Children: stunting (HAZ<−2)		Children: underweight (WAZ<−2)	
	OR (95% CI), unadjusted model	OR (95% CI), adjusted model[2]	OR (95% CI), unadjusted model	OR (95% CI), adjusted model[2]
Farming households (ref: nonfarming households)	0.67 (0.42, 1.05)	0.55* (0.33, 0.94)	0.77 (0.44, 1.36)	0.65 (0.34, 1.27)
Households that owned livestock (ref: did not own livestock)	0.95 (0.59, 1.54)	0.88 (0.51, 1.50)	1.32 (0.73, 2.38)	1.26 (0.64, 2.49)
Among farming households				
Households that owned land (ref: rented land)	1.89 (0.80, 4.45)	1.78 (0.67, 4.72)	1.59 (0.52, 4.86)	1.51 (0.37, 6.18)
Households with more land (>0.1 hectares) (ref: below-median land size)	1.38 (0.74, 2.58)	1.36 (0.64, 2.88)	2.16 (0.94, 4.95)	1.83 (0.66, 5.05)
Households that, in the last year, grew: (ref: did not grow each crop)				
Rice	0.83 (0.44, 1.56)	0.67 (0.32, 1.39)	0.92 (0.41, 2.08)	0.98 (0.36, 2.65)
Wheat	0.94 (0.52, 1.69)	0.82 (0.41, 1.64)	0.92 (0.43, 1.96)	0.98 (0.39, 2.49)
Maize	1.61 (0.86, 3.04)	1.39 (0.65,2.99)	1.60 (0.73, 3.50)	1.82 (0.65, 5.14)
Vegetable(s)	0.57 (0.31, 1.02)	0.50* (0.25, 0.99)	0.65 (0.31, 1.37)	0.45 (0.17, 1.17)

[1,]*$P < 0.05$ (level of significance for the ORs). HAZ, height-for-age *z* score; MDDW, Minimum Dietary Diversity for Women; ref, referent; WAZ, weight-for-age *z* score.
[2]Adjusted models include: mother's and father's educational attainment (none, primary, lower secondary, higher secondary, college, beyond), mother's and father's employment status (yes/no for formal employment, informal employment, or self-employment), mother's current age, child birth order, months of exclusive breastfeeding, whether the birth was at a health facility (yes/no), child sex, household wealth (quartile group), and mean MDDW score.

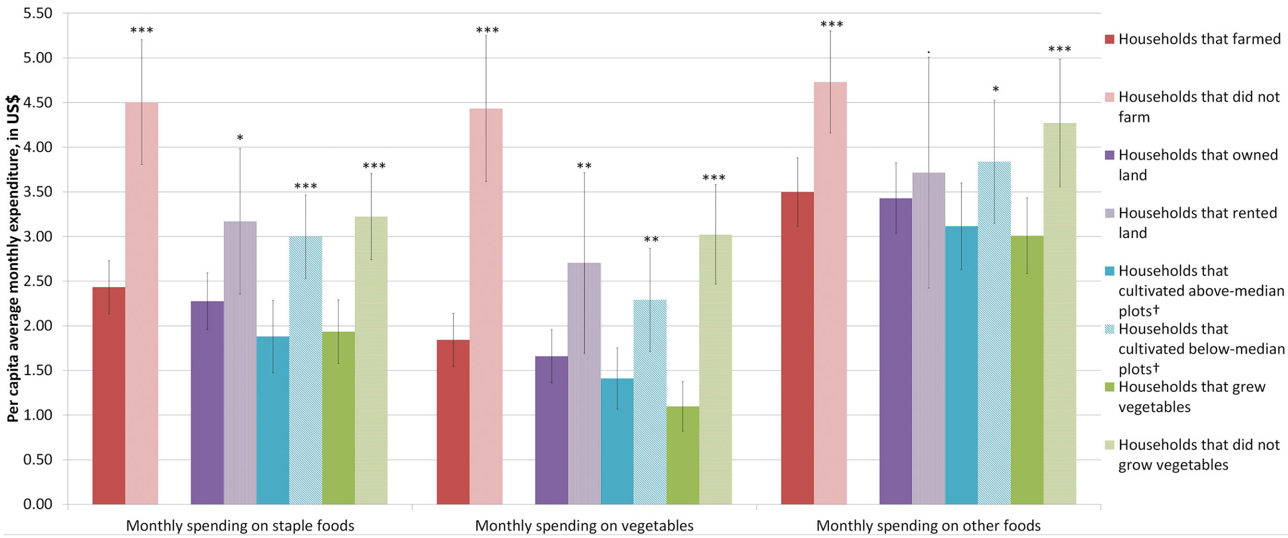

FIGURE 2 Association between households' reported agricultural activity, and monthly per capita food expenditures (in current US$) ($n = 353$ households). Red (leftmost per expenditure category) histogram bars report on all households; remaining histogram bars are only among the subset of households that reportedly cultivated any land. Vertical error lines represent 95% CIs. *,**,***Wilcoxon rank-sum tests of difference between groups: $^{*}P < 0.1$, $^{**}P < 0.05$, $^{***}P < 0.01$. †Median = 0.1 hectares.

studies, although it has been investigated in rural contexts [e.g., Olney et al. (31)].

Livestock ownership, which in this setting consists primarily of poultry, was not associated with child stunting or underweight. This may be because the number of chickens owned by each household was quite low (median of 2 chickens per household), which may not provide a steady source of eggs/meat or income sufficient to affect nutritional status. The literature on this topic is nuanced, and few studies have examined the entire pathway from livestock ownership and storage to meat/egg/milk consumption, and on to child nutritional status (25). Some observational studies have found a positive association between consumption of animal source foods or purchase of animal source

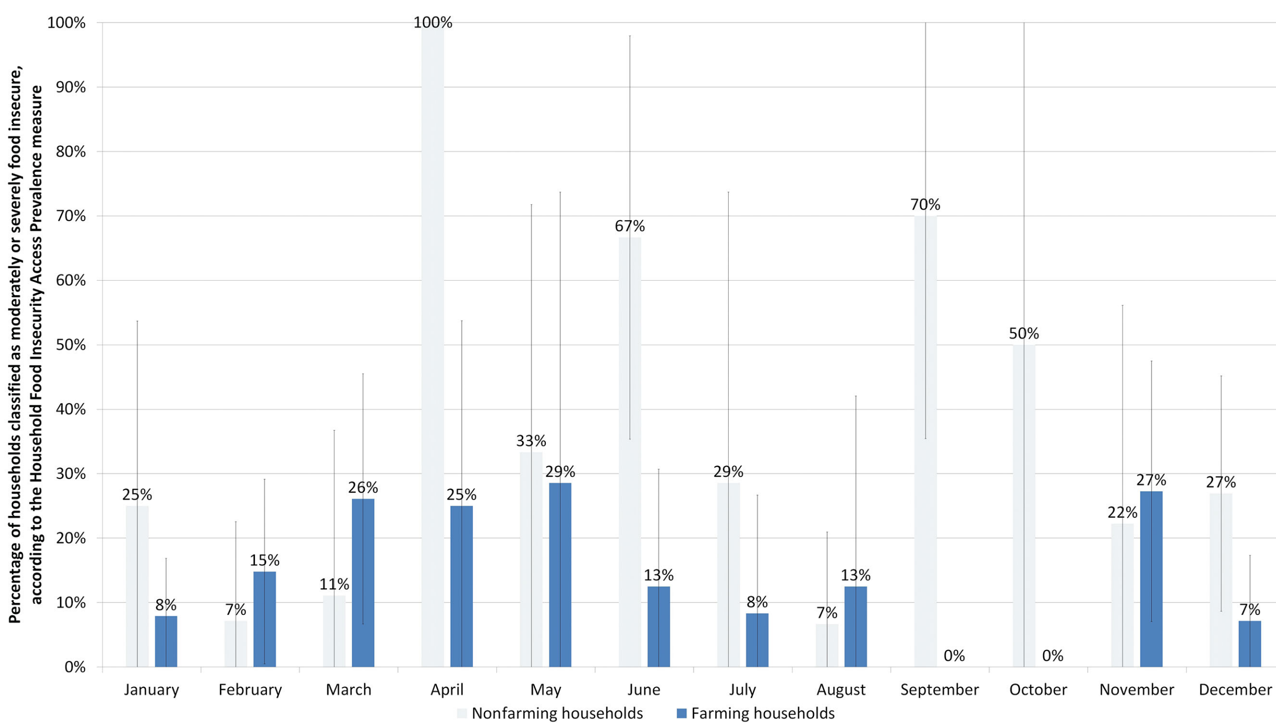

FIGURE 3 Monthly reporting of food insecurity, among farming compared with nonfarming households ($n = 340$ households). Vertical error lines represent 95% CIs.

TABLE 4 Association between households' reported agricultural activity, and food security[1]

	Household Food Insecurity Access Scale domains OR (95% CI), unadjusted estimates			Classified moderately or severely food-insecure OR (95% CI)	
	Anxiety domain	Quality domain	Intake domain	Unadjusted model	Adjusted model[2]
Farming households (ref: nonfarming households)	0.41*** (0.26, 0.65)	0.49* (0.31, 0.78)	0.39** (0.22, 0.67)	0.38*** (0.22, 0.64)	0.32** (0.17, 0.62)
Livestock owning households (ref: nonlivestock-owning households)	0.54*** (0.32, 0.91)	0.70 (0.32, 1.16)	0.53* (0.28, 1.03)	0.46* (0.24, 0.88)	0.29** (0.13, 0.66)
Among farming households					
Households that owned land (ref: rented land)	0.95 (0.41, 2.18)	1.29 (0.55, 3.03)	0.41 (0.17, 1.04)	0.59 (0.23, 1.51)	0.50 (0.16, 1.61)
Households with more land (>0.1 hectares) (ref: below-median land size)	0.31** (0.16, 0.62)	0.52* (0.27, 1.00)	0.40* (0.17, 0.99)	0.41* (0.18, 0.98)	0.29* (0.09, 0.88)
Households that, in the last year, grew:					
Rice	0.26*** (0.14, 0.51)	0.54 (0.28, 1.03)	0.50 (0.22, 1.14)	0.42* (0.19, 0.94)	0.36* (0.13, 0.95)
Wheat	0.67 (0.35, 1.28)	1.17 (0.63, 2.17)	0.83 (0.36, 1.90)	0.79 (0.36, 1.76)	0.61 (0.22, 1.68)
Maize	0.61 (0.29, 1.28)	0.80 (0.40, 1.60)	0.18* (0.04, 0.78)	0.15* (0.04, 0.67)	0.13* (0.02, 0.72)
Vegetable(s)	0.53 (0.28, 1.00)	0.78 (0.42, 1.45)	0.61 (0.27, 1.38)	0.65 (0.30, 1.41)	0.54 (0.21, 1.44)

[1]*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$ (level of significance for the ORs). MDDW, Minimum Dietary Diversity for Women; ref, referent.
[2]Adjusted models include: mother's and father's educational attainment (none, primary, lower secondary, higher secondary, college, beyond), mother's and father's employment status (yes/no), household wealth (quartile group), and mean MDDW score.

foods and child growth or lower stunting risk (32–37). A randomized study in rural Nepal evaluated the effects of a community development and livestock promotion program, and found a significant impact on child weight and height, potentially mediated by greater livestock ownership and income, and better sanitation practices (38). Moreover, a recent observational study from Ethiopia found that ownership of poultry was positively associated with child mean height-for-age *z* scores, but that confinement of poultry within the house had a negative association with child growth at age 2 y, suggesting that effect might be mediated through exposure to pathogens from the animals or feces (36). In these different studies, livestock ownership appears to be a potential source of key nutrients needed for child growth, a potential risk factor for growth-inhibiting pathogens, and an important marker of greater socioeconomic status (and therefore subject to confounding). More studies are needed to tease out these relations, particularly with randomized designs that will allow for causal inference.

Our findings suggest that there are meaningful associations between participation in agriculture, women's dietary diversity (which may also reflect dietary diversity of other household members), and child stunting in this peri-urban setting. Of particular note were findings linking household production of vegetables and greater consumption of vegetables, and greater consumption of vegetables with lower odds of child stunting. These findings are consistent with observational findings from Indonesia and Nepal suggesting greater height and less stunting among children with more vegetable consumption and share of vegetables, respectively, (39, 40). Other studies have also suggested links between homestead gardening and lower risk of stunting (41). Although much of the literature on home gardening assumes the primacy of the pathway from greater income to lower malnutrition, our findings raise the possibility of a direct link from consumption to lowered stunting risk. This requires more investigation because the underlying mechanisms through which vegetable consumption could influence child growth are unclear, and it is not possible to rule out the possibility of unmeasured confounding given the observational and cross-sectional nature of the design.

Overall, stunting was present in 33% of these children (aged between 44 and 79 mo, with a mean and median of 61 mo). Although it is difficult to find comparable data on children in this age group, our finding is similar to the observed stunting prevalence among children aged 48–59 mo from the urban sample of 2011 Nepal DHS (26%) (42). Other recent DHS analyses in southern Asia have found prevalence rates of stunting among children in this age group of 42% (Bangladesh, 2011) and 46% (Pakistan, 2012) (43).

Our finding of a high rate of maternal overweight among the mothers of children adds to the evidence that urban parts of Nepal are experiencing the double burden of malnutrition. Interestingly, we also observed that women living in households who grew maize or wheat were less likely to be overweight or obese. These crops are known to be more labor-intensive, and it may be possible women living in households cultivating them may have higher energy expenditure as a result of greater involvement in agriculture.

One novel feature of our study is the breadth of information collected and the ability to examine the pathway from agricultural engagement through to nutritional outcomes. We were also able to adjust for many potential confounders, a limitation of many prior studies. The main focus of our data collection was on outcome measures, which included both intermediate outcomes (dietary diversity, food security, expenditures) and nutritional status (child and maternal anthropometry and maternal anemia). As such, time limitations constrained our ability to collect detailed information on exposure variables. Our study used relatively coarse measures of agricultural participation, and we were not able to examine in detail issues such as productivity, land use, agricultural inputs, the extent to which foods produced through agriculture were consumed compared with sold, income from nonagricultural sources, women's participation in agriculture and time use, and how households used the money derived from agriculture. That said, we were still able to investigate and capture numerous relations in line with our main research questions of interest.

Some findings should be interpreted with care. First, the cross-sectional and observational nature of our findings limits our ability to draw causal inference. It is important to recognize that the peak period of growth velocity of children occurs during fetal development and early childhood. For children in our study, this time period was 5–7 y before the measurements presented here. Based on our knowledge of the local context, we do feel that it is likely that households currently practicing agriculture were also doing so in the past, although the collection of prospective information on agriculture-related exposures would have enabled stronger confidence that findings related to stunting risk were not due to confounding. In addition, given the relatively crude nature of the women's dietary diversity score, it is also possible that this measure is not sensitive to true differences in dietary quality or reflective of the consumption of other household members.

Second, although the original baseline sample was designed to statistically represent households with young children in Bhaktapur, loss to follow-up over the 5 y between the baseline survey and the follow-up survey through which data for this paper were collected limits our ability to claim that these findings represent the district. Most likely, the participants who were available for the follow-up survey were in more stable households, and therefore more likely to be economically better off than those who moved away. The follow-up survey also did not include people who moved into the study area during the intervening period, and because Bhaktapur has seen a rapid population growth in recent years, this also may limit the generalizability of these results. Furthermore, there is the potential for reporting or recall bias. For example, many questions—most significantly, about food insecurity, recall of agricultural production and expenditures—included long periods (6 mo in the case of food security and a full year for agricultural production). Although many tools use similar recall periods, the validity of such tools to capture seasonal patterns has not been well explored. We would speculate for agricultural production that a longer recall period would lead to an underestimation of production, leading to an attenuation of estimates of the relation with other outcomes, but cannot test this hypothesis in the present dataset. As data collection spanned 11 mo, we feel that it is unlikely that the dataset would have systematic bias due to seasonality; each household only contributed data at 1 time point, but any such bias should not be present in the aggregate dataset.

Many urban areas in Asia and Africa are experiencing rapid population growth, and one of the great challenges associated with urbanization is how to ensure a diverse and nutritious food supply. Although our findings suggest that farming and livestock ownership in peri-urban areas have benefits for farming households, important questions persist about the scale to which these benefits apply in other urban parts of Nepal or elsewhere. An analysis of multiple household income and expenditure surveys including a 2003 Nepal survey concluded that "it is hard to see urban agriculture playing a substantial role in poverty alleviation outside of Africa" based on the small amount of income shares derived from agricultural activities in Asian countries (26). The same study found that on average only ∽11% of household income in urban areas of Nepal came from agriculture but that 52% of households participated in crop activities and 36% in livestock activities, and that poorer households were more likely to engage in agriculture. The relevance of those numbers to the present situation in Nepal should be taken with caution given rapid population growth and change during the 13 y since the 2003 survey.

Our findings do suggest that agricultural participation in Bhaktapur may have benefits that extend beyond just income-related effects and suggest that greater exploration of the potential benefits of policies that support agricultural participation in urban parts of the Kathmandu valley may be useful. It is also important to note that Kathmandu valley, in which Bhaktapur district is located, houses a finite amount of cropland, much of which is being rapidly turned into housing. This trend follows global patterns in Asia and Africa, and it has been noted that croplands near urban areas tend to be much more productive than other land (44). Given that agricultural production appears to have an important role in shaping the food security, dietary diversity, and nutritional status of households, it is unclear how the continued reduction in urban and peri-urban agricultural land will affect the food security and nutrition of farming households, or of nonagricultural households potentially via decreased availability of high-quality perishable goods for purchase. Further work is needed to develop strategies to mediate potential adverse effects of reduced access to land for agriculture close to urban areas.

In conclusion, the findings from this survey conducted in peri-urban Nepal suggest that agricultural participation, and specifically land cultivation and vegetable production, but not livestock ownership, is associated with lower odds of stunting, but few significant relations with maternal nutritional status. We also found evidence that land cultivation and livestock ownership were associated with less household food insecurity. Our findings provide some of the first quantitative evidence that agriculture in peri-urban areas appears to have benefits that extend to nutritional status. This has implications for the design of national-level multisectoral nutrition policies in Nepal, including the role of agriculture. The potential for supporting urban nutrition through tailored agricultural investments within urban and peri-urban settings needs more attention in such a policy context.

Acknowledgments

We thank field supervisor Bimala Karmacharya, data and data manager Pravin Rajbhandari. We are thankful for research support from Lauren Aiko Graybill and Stacy Griswold. The authors' responsibilities were as follows—RKC, SH, TAS, MU, WWF, LML, PW, and ALT-L: designed and conducted the underlying research study; CM and ALT-L: designed this analysis and analyzed the data, and wrote the article and had primary responsibility for the final content; and all authors: read and approved the final manuscript.

References

1. Orsini F, Kahane R, Nono-Womdim R, Gianquinto G. Urban agriculture in the developing world: A review. Agron Sustainable Dev 2013;33(4):695–720.
2. World Bank [Internet]. Washington, DC; 2016 [Cited 2017 June 15]. Databank, Urban population (% of total). Available from: https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?end=2016&start=1960.
3. Fan S, Pandya-Lorch R, editors. Reshaping agriculture for nutrition and health [eBook on the Internet]. Washington, DC: International Food Policy Research Institute; 2012 [Cited 2017 June 15]. Available from: http://www.ifpri.org/publication/reshaping-agriculture-nutrition-and-health.
4. Masset E, Haddad L, Cornelius A, Isaza-Castro J. Effectiveness of agricultural interventions that aim to improve nutritional status of children: Systematic review. BMJ 2012;344:d8222.
5. Webb P, Kennedy E. Impacts of agriculture on nutrition: nature of the evidence and research gaps. Food Nutr Bull 2014;35(1):126–32.

6. United Nations [Internet]. Sustainable Development Goals: 17 goals to transform our world; 2016 [Cited 2017 June 15]. Available from: https://www.un.org/sustainabledevelopment/home/.
7. Poulsen MN, McNab PR, Clayton ML, Neff RA. A systematic review of urban agriculture and food security impacts in low-income countries. Food Policy 2015;55:131–46.
8. Korth M, Stewart R, Langer L, Madinga N, Rebelo Da Silva N, Zaranyika H, van Rooyen C, de Wet T. What are the impacts of urban agriculture programs on food security in low and middle-income countries: A systematic review. Environmental Evidence 2014;3(1):1–10.
9. Warren E, Hawkesworth S, Knai C. Investigating the association between urban agriculture and food security, dietary diversity, and nutritional status: A systematic literature review. Food Policy 2015;53:54–66.
10. Muzzini E, Aparicio G, editors. Urban growth and spatial transition in Nepal: An initial assessment. Directions in development: countries and regions [eBook on the Internet]. Washington, DC: World Bank. © World Bank; 2013 [cited 2017 June 15]. Available from: https://openknowledge.worldbank.org/handle/10986/13110.
11. Central Bureau of Statistics—National Planning Commission Secretariat Government of Nepal. Nepal living standards survey 2010–2011 [Internet]. Thapathali: Kathmandu Central Bureau of Statistics; 2011 [cited 2017 June 15]. Available from: http://cbs.gov.np/nada/index.php/catalog/37.
12. Hillbruner C, Egan R. Seasonality, household food security, and nutritional status in Dinajpur, Bangladesh. Food Nutr Bull 2008;29(3):221–31.
13. Central Bureau of Statistics—National Planning Commission Secretariat, Government of Nepal. Population monograph of Nepal, Volume 1: population dynamics [monograph on the Internet]. Kathmandu: Government of Nepal; 2014 [cited 2017 June 15]. Available from: https://nepal.unfpa.org/en/publications/populationmonograph-nepal-2014-volume-i-demographic-analysis.
14. Henjum S, Torheim LE, Thorne-Lyman AL, Chandyo R, Fawzi WW, Shrestha PS, Strand TA. Low dietary diversity and micronutrient adequacy among lactating women in a peri-urban area of Nepal. Public Health Nutr 2015:1–10.
15. Nepal Rastra Bank [Internet]. Nepal; Nepal Rastra Bank [updated 2018 Dec 03; cited 2017 June 15]. Foregn exchange rates. Available from: https://www.nrb.org.np/fxmexchangerate.php.
16. Howe LD, Hargreaves JR, Huttly SR. Issues in the construction of wealth indices for the measurement of socio-economic position in low-income countries. Emerg Themes Epidemiol 2008;5(1):3.
17. Psaki SR, Seidman JC, Miller M, Gottlieb M, Bhutta ZA, Ahmed T, Shamsir Ahmed AM, Bessong P, John SM, Kang G, et al. Measuring socioeconomic status in multicountry studies: Results from the eight-country MAL-ED study. Popul Health Metrics 2014;12(1):8.
18. Rutstein SO. Steps to constructing the new DHS Wealth Index. Rockville, MD: ICF International; 2015 [cited 2017 June 15]. Available from: https://dhsprogram.com/programming/wealth%20index/Steps_to_constructing_the_new_DHS_Wealth_Index.pdf.
19. Coates J, Swindale A, Bilinsky P. Household Food Insecurity Access Scale (HFIAS) for measurement of food access: Indicator guide (v3) [eBook on the Internet]. Washington, DC: FHI 360/FANTA; 2007 [cited 2017 June 15]. Available from: https://www.fantaproject.org/sites/default/files/resources/HFIAS_ENG_v3_Aug07.pdf.
20. Food and Agriculture Organization of the United Nations, FHI 360. Minimum dietary diversity for women: A guide to measurement [eBook on the Internet]. Rome: FAO; 2016 [cited 2017 June 15]. Available from: http://www.fao.org/3/a-i5486e.pdf.
21. Onis Md, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ 2007;85:660–7.
22. Pandey VL, Dev SM, Jayachandran U. Impact of agricultural interventions on the nutritional status in South Asia: A review. Food Policy 2016;62:28–40.
23. Carletto G, Ruel M, Winters P, Zezza A. Farm-level pathways to improved nutritional status: Introduction to the special issue. The Journal of Development Studies 2015;51(8):945–57.
24. Kadiyala S, Harris J, Headey D, Yosef S, Gillespie S. Agriculture and nutrition in India: Mapping evidence to pathways. Ann NY Acad Sci 2014;1331(1):43–56.
25. Leroy JL, Frongillo EA. Can interventions to promote animal production ameliorate undernutrition? J Nutr 2007;137(10):2311–6.
26. Zezza A, Tasciotti L. Urban agriculture, poverty, and food security: Empirical evidence from a sample of developing countries. Food Policy 2010;35(4):265–73.
27. Maxwell D, Levin C, Csete J. Does urban agriculture help prevent malnutrition? Evidence from Kampala. Food Policy 1998;23(5):411–24.
28. Maxwell DG. Alternative food security strategy: A household analysis of urban agriculture in Kampala. World Dev 1995;23(10):1669–81.
29. Mkwambisi DD, Fraser ED, Dougill AJ. Urban agriculture and poverty reduction: Evaluating how food production in cities contributes to food security, employment and income in Malawi. J Int Dev 2011;23(2):181–203.
30. Yeudall F, Sebastian R, Cole DC, Ibrahim S, Lubowa A, Kikafunda J. Food and nutritional security of children of urban farmers in Kampala, Uganda. Food Nutr Bull 2007;28(2_suppl2):S237–S46.
31. Olney DK, Pedehombga A, Ruel MT, Dillon A. A 2-year integrated agriculture and nutrition and health behavior change communication program targeted to women in Burkina Faso reduces anemia, wasting, and diarrhea in children 3–12.9 months of age at baseline: a cluster-randomized controlled trial. J Nutr 2015;145(6):1317–24.
32. Darapheak C, Takano T, Kizuki M, Nakamura K, Seino K. Consumption of animal source foods and dietary diversity reduce stunting in children in Cambodia. Int Arch Med 2013;6(1):1.
33. Krebs NF, Mazariegos M, Tshefu A, Bose C, Sami N, Chomba E, Carlo W, Goco N, Kindem M, Wright LL, et al. Meat consumption is associated with less stunting among toddlers in four diverse low-income settings. Food Nutr Bull 2011;32(3):185–91.
34. Marquis GS, Habicht J-P, Lanata CF, Black RE, Rasmussen KM. Breast milk or animal-product foods improve linear growth of Peruvian toddlers consuming marginal diets. Am J Clin Nutr 1997;66(5):1102–9.
35. Sari M, de Pee S, Bloem MW, Sun K, Thorne-Lyman AL, Moench-Pfanner R, Akhter N, Kraemer K, Semba RD. Higher household expenditure on animal-source and nongrain foods lowers the risk of stunting among children 0–59 months old in Indonesia: implications of rising food prices. J Nutr 2010;140(1):195S–200S.
36. Headey D, Hirvonen K. Is exposure to poultry harmful to child nutrition? An observational analysis for rural Ethiopia. PLoS One 2016;11(8): e0160590.
37. Kavle JA, El-Zanaty F, Landry M, Galloway R. The rise in stunting in relation to avian influenza and food consumption patterns in Lower Egypt in comparison to Upper Egypt: Results from 2005 and 2008 Demographic and Health Surveys. BMC Public Health 2015;15(1):285.
38. Miller LC, Joshi N, Lohani M, Rogers B, Loraditch M, Houser R, et al. Community development and livestock promotion in rural Nepal: Effects on child growth and health. Food Nutr Bull 2014;35(3):312–26.
39. Gross R, Schultink W, Sastroamidjojo S. Stunting as an indicator for health and wealth: An Indonesian application. Nutr Res 1996;16(11):1829–37.
40. Shively G, Sununtnasuk C. Agricultural diversity and child stunting in nepal. J Dev Stud 2015;51(8):1078–96.
41. English R, Badcock J. A community nutrition project in Viet Nam: Effects on child morbidity. Food Nutr. Agric. 1998;22:15–21.
42. Ministry of Health and Population (MOHP) [Nepal], New ERA, and ICF International Inc. Nepal Demographic and Health Survey 2011 [Internet]. Kathmandu, Nepal: Ministry of Health and Population, New ERA, and ICF International, Calverton, MD; 2012 [cited 2017 June 15]. Available from: https://dhsprogram.com/pubs/pdf/FR257/FR257[13April2012].pdf.
43. STATcompiler [Internet]. Measure DHS, USAID; c2013–18 [cited 2017 June 15]. Available from: https://www.statcompiler.com/en/.
44. d'Amour CB, Reitsma F, Baiocchi G, Barthel S, Güneralp B, Erb K-H, Haberl H, Creutzig F, Seto KC. Future urban land expansion and implications for global croplands. Proc Natl Acad Sci 2017;114(34):8939–44.