

Pathways from Agriculture-to-Nutrition: Design and Conduct of the National PoSHAN Surveys of Nepal

Klemm RDW^{1,2,*}, Manohar S¹, Rajbhandary R³, Shrestha K⁴, Gauchan D⁵, Adhikari R⁶,
Thorne-Lyman AL¹, KC A¹, Nonyane BAS¹, Ghosh S⁷, Webb P⁷, West KP Jr¹

¹Center for Human Nutrition, Department of International Health, Bloomberg School of Public Health,
Johns Hopkins University, Baltimore, Maryland, USA

²Helen Keller International, New York, NY, USA

³PoSHAN Study Team, Johns Hopkins University, Kathmandu, Nepal

⁴New Era (P.) Ltd, Kathmandu, Nepal

⁵Biodiversity International, Kathmandu, Nepal

⁶Institute of Medicine, Tribhuvan University, Kathmandu, Nepal

⁷Friedman School of Nutrition Science and Policy, Tufts University, Boston, Massachusetts, USA

*Corresponding author: rklemm1@jhu.edu

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Abstract Pathways through which agricultural production may influence markets, household food security, dietary patterns and nutritional status remain incompletely understood. While cross-sectional surveys are common, national, population-based, standardized data collection systems that annually monitor markets, local services, food security, dietary intake and nutritional status may be needed to understand time trends and relationships. We describe the design and methods of an annual nationally representative series of surveys of households with preschool aged children in 7 Village Development Committees (VDCs) sampled across each agroecological zone (mountains, hills and plains) in Nepal. Our sampling methodology yielded 21 VDCs, 63 wards (3 per VDC) and 40 markets in 2013, 2014 and 2016. Each year between ~ 4286-5097 consenting households were assessed for agricultural practices, socioeconomic conditions and food security; diet by 7-day food frequency and nutritional status by anthropometry (weight, height and arm circumference) of women (n=4509-5458) and children (n=5401-5468) using standardized procedures. Due to a major earthquake in April 2015, a truncated sample (wards n=27) was reached in 2015. Three VDCs, each representing a centroid of surveyed VDCs in each zone, served as year-round sentinel sites in which we conducted six surveys of seasonal conditions from 2013-2015. Representative, same-season, same-site surveys offer a feasible national framework for assessing annual status and trends in agricultural, food security and nutritional conditions to identify opportunities for policy and program interventions and observe population responses along a continuum leading from agriculture to nutrition.

Keywords: survey, surveillance, undernutrition, food insecurity, agriculture, sentinel sites

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1. Introduction

There is renewed interest in the potential that agricultural policies, practices and interventions have for improving food and nutrition security, dietary quality and nutritional status. The agricultural sector employs more than 80% of people in low-income countries, and is recognized as an important national determinant of the food supply, dietary patterns and also health outcomes [1]. However, more evidence is needed to understand the opportunities that agriculture may have to improve the nutritional status of children and women in these settings.

Multiple reviews have noted that the pathways that lead from food production to markets in ways that influence food purchases, diets, and nutritional status of populations are incompletely understood [1,2,3,4,5]. The limited availability of rigorous empirical data, explicitly collected with such pathways in mind, leaves efforts to improve nutrition through agriculture at risk of sub-optimal designs, targeting, content and implementation [4,6,7].

In Nepal, children have long been afflicted by undernutrition [8], with most recent national surveys reporting the status of ~36%, 10-17% and 27-34% of preschoolers to be below conventional cutoffs for stunting, wasting and underweight [9,10]. Childhood malnutrition is also

evident by a high prevalence of multiple micronutrient deficiencies [11,12], implicating a chronic dietary inadequacy, lending urgency to finding approaches to increase the diversity, quality and nutrient density of foods available to the rural poor. Pragmatic solutions would appear to have high potential for impact in Nepal, given that over 80% of the population is engaged in agriculture, farming households account for 75% of the country's poor [13,14], food production has not kept pace with population growth [13], and nearly 54% of the country's population is classified as chronically food insecure [13,14,15].

Aware of this situation, the Government of Nepal committed itself to accelerating nutritional improvements through its Multisectoral Nutrition Plan (MSNP) - an effort that has prominently featured investments in nutrition-sensitive agriculture, direct nutrition interventions, health care, and water, sanitation and hygiene [16]. In this paper, we describe the purpose, design and methods of a USAID-sponsored, nationally representative, multi-year agriculture-to-nutrition study that was implemented from 2013 to 2016.

1.1. The National Setting

Nepal is a geographically diverse, landlocked country, comprised of 3 major agroecological zones referred to as the Mountains, Hills and *Terai* (low-lying plains). The country has the greatest altitudinal variation in the world, extending from 194 feet above sea level to 29,029 feet (Mt. Everest) [17]. The country's population is 26 million, of which ~7%, 43%, 50% and 9% lives in the above 3 zones and the Kathmandu Valley, respectively [18]. The country is largely agrarian, with the most arable land and quantity of food grown in the *Terai*. During the data collection period, the country was divided west to east progressively into administrative regions, districts, Village Development Committees (VDCs, constituting small sub-district units) and wards, a structure that provided the sampling framework for the system.

1.2. The Policy and Science for Health, Agriculture and Nutrition (PoSHAN) Surveys

In 2012, the Feed the Future Innovation Lab for Nutrition initiated a program of research in Nepal called the PoSHAN surveys. Funded by the United States Agency for International Development (USAID), the PoSHAN surveys were designed and implemented as an annual assessment of community, household, individual conditions. The aim was to determine a) the links among agriculture, nutrition, health, and b) how exposure to a range of policy and program interventions may influence household food security, poverty, and the diets, health and nutrition of young children and their mothers.

2. Design of the Research Platform

The four-year design comprised a series of annual, same-season surveys of a nationally representative sample of 21 VDCs (each located in a separate district), in which

63 wards (3 per VDC) were visited and all eligible consenting households with children < 60 months of age were included in the study. Each survey generated data on market, community, household and individual factors hypothesized to influence health and nutrition of women and children. New households were added, and emigrated households were noted, providing a basis for valid cross-sectional analyses, as well as longitudinal follow-up of still-resident households whose children were <72 months in follow-up surveys. Recently married couples (within 2 years) without children were also included in the sample for their likelihood of having a young child in subsequent surveys.

The design also nested into each zonal sample one selected VDC (i.e., 3 wards), representing a 'centroid' of each stratum with respect to multiple, published features of districts within which sampled VDCs were located. In these singular zonal VDCs, two additional seasonal assessments were implemented that, when combined with annual surveys, provided year-round data for the years 2013-2015 (Figure 1).

Five key features of the design and rationale of the PoSHAN data system are as follows:

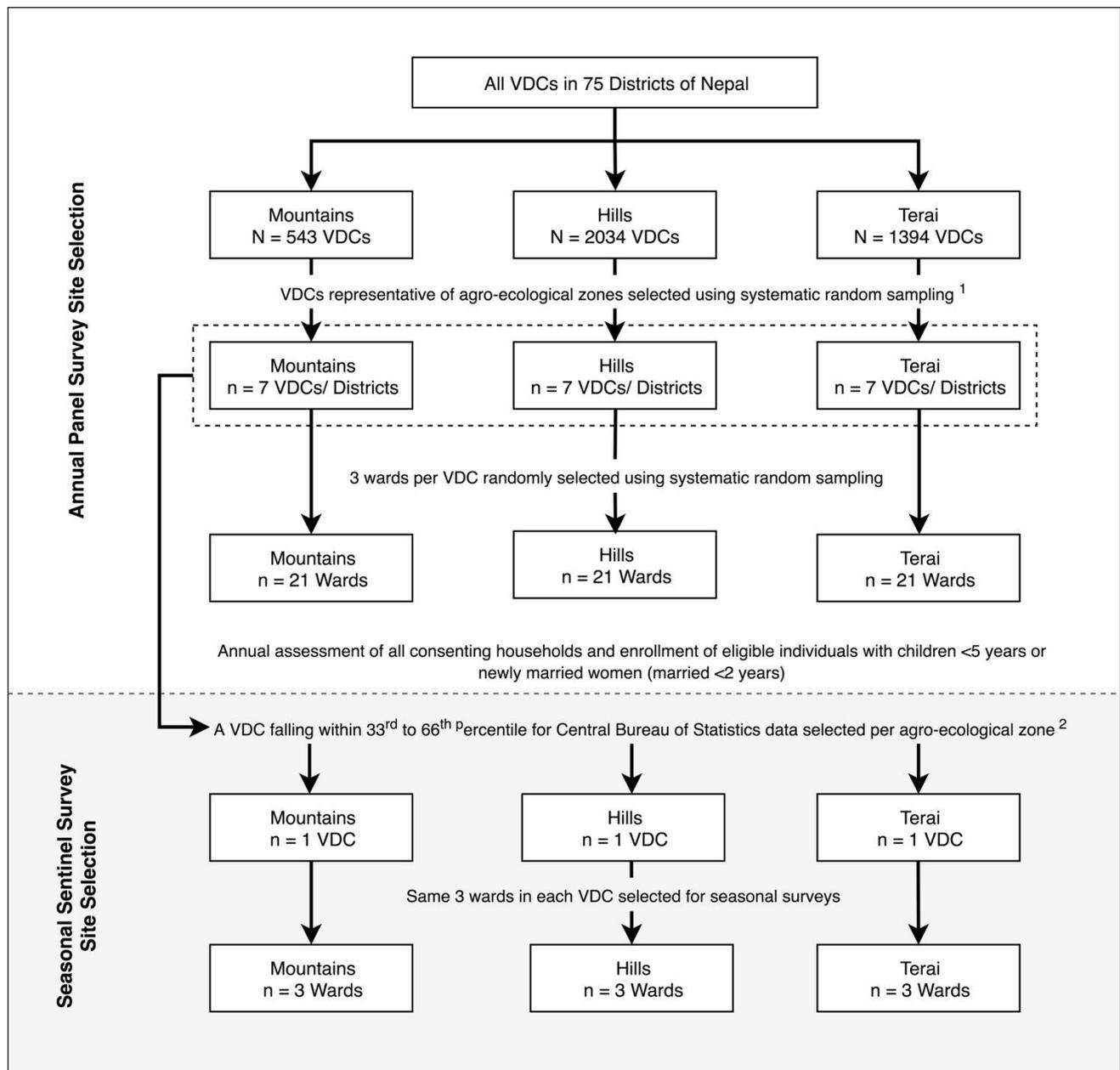
1. *Conceptual framework to guide content and sampling decisions.* The investigators developed a conceptual framework to map out hypothesized causal pathways through which agriculture may improve food security and maternal and child nutrition, in part adapted from others' works [3,19,20], that guided data acquisition at community, household and individual levels (Figure 2). The framework illustrates the potential for these complex pathways to interact positively or negatively at community, household and individual levels with mediating factors that include ecology and environment (e.g. water availability), markets, communications and infrastructure, household socioeconomic status (e.g. education, income, occupations), culture (e.g., caste, religion), sanitation and hygiene, food production/consumption patterns, and participation in agriculture extension, health, nutrition and other services, as well as dominant patterns of morbidity, women's status and lifestyle (e.g. smoking, women's workload), among other influences.

2. *Representative sample of major agroecological zones.* Given the significant variations across agroecologies in Nepal, the sampling strategy was designed to represent this diversity. We first stratified Nepal's 75 districts into Mountains, Hills and *Terai* zones, listing districts contiguously from west to east and their respective VDCs alphabetically, and used systematic random sampling to select seven VDCs from each agroecological zone. We then selected 3 out of 9 wards for each VDC, using systematic random sampling and a random start, yielding a total of 21 wards per agroecological zone or a total of 63 wards across the country (Figure 1 and Figure 3).

3. *Mixed longitudinal design.* PoSHAN was structured with mixed longitudinal components, providing a design in which annual surveys also continuously tracked eligible households each year, adding newly eligible households, noting emigrant households and censoring those households no longer eligible due to lack of eligible children (i.e., ≤ 60 months of age) or due to previously eligible children aging out (≥ 72 months of age) (Figure 4). This enabled

annual renewal of the demographic distribution while retaining eligible households and children for longitudinal assessment with respect to temporal change in nutritional status and risk factors. At present, much of the understanding of risk factors for malnutrition in Nepal and globally is built upon cross-sectional association with prevalent stunting, wasting or underweight as provided, for example, by the Demographic and Health (DHS) and Multiple Indicator Cluster (MICS) Surveys. Such an approach does not reveal the temporality of associations, identify incident events or allow one to draw cause and effect inferences. This is particularly relevant when examining how nutritional status and risk factor exposures (e.g., dietary quality) in the first 12 months of life may influence stunting 1-2 years later.

4. *Assessing and understanding seasonality.* Considering the influence of season on agricultural production, market prices, expenditure, food security, quality of diet, and nutritional status, we conducted each annual survey in approximately the same season to enable year-to-year comparability and examination of annual trends in malnutrition and other indicators. Thus, each zonal survey was conducted from approximately mid-May/early June to mid-August/early-September each year, a period that typically marks the end of the hot dry season/start of the rainy (monsoon) season, and end of monsoon season, respectively. The interval captures the sowing and growing periods of 3 main cereal crops--rice, maize and millet--though these crops are variable in their period of harvest.



¹ Each VDC selected represents a unique district.

² VDC selection based as centroids of Central Bureau of Statistics Indicators

Figure 1. Village Development Committee (VDC) and ward sampling scheme

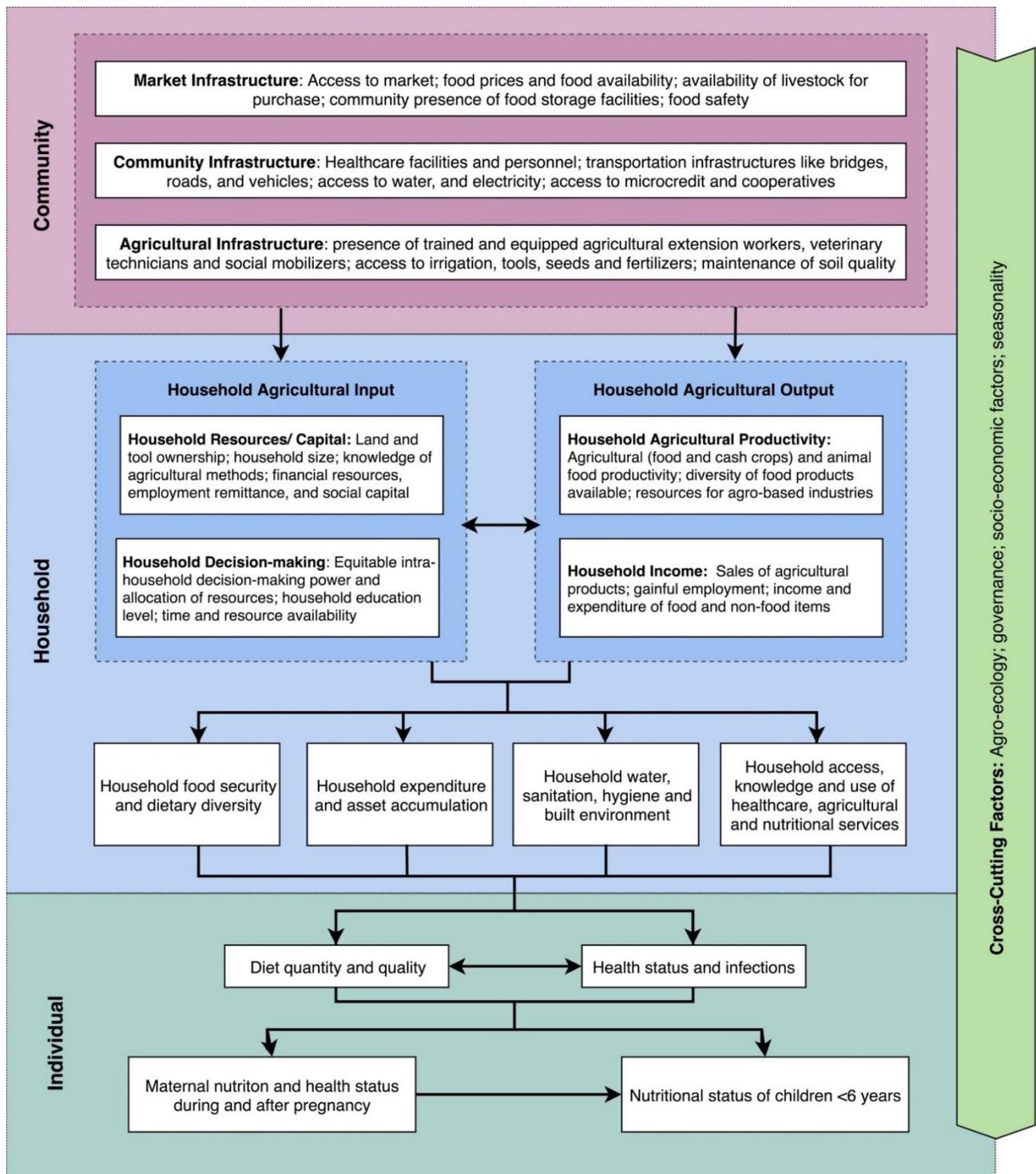


Figure 2. Conceptual Framework for the PoSHAN Study

While a same-season design provided a basis for comparing findings from repeated annual surveys, by itself it is incomplete because it does not explore the reality that agriculture production, food availability, food security, health and nutritional status have seasonal dimensions in Nepal. Thus, to better quantify the seasonality of agriculture, market availabilities, food prices, expenditure, household food security, diet and nutritional status, we conducted two year-round, seasonal assessments in 2013 and 2014 in one “sentinel” VDC (and its 3 wards) selected from among each of the 7 sampled VDCs across each agroecological zone based on their distributions of population by density, age and

sex, households with agricultural land, livestock and poultry, households operating small-scale non-agricultural economic activity, head of household literacy and other factors approximating the average of their respective zonal sample of VDCs, as obtainable from reports of the Central Bureau of Statistics of the Government of Nepal. [Figure 5](#) compares the chosen sentinel VDC’s child anthropometry measures against the average of each agroecological zonal sample, revealing sites that appear to generally reflect the centroid of each distribution. Median values from sentinel sites for a host of other variables fell within the inter-quartile range of zonal samples, suggesting that data gathered and the resulting analysis from

these sites could reflect the situation affecting the larger agroecological zone. Surveys in these sentinel sites were conducted in September-October 2013, January-February and September-October 2014 and January-February 2015, after which the seasonal surveys were stopped due to funding constraints.

5. *Enumerating all eligible households in a ward.* A feature of each survey was a 3rd stage (ward) sample that included enumeration and enrollment of all households with one or more children ≤ 60 months of age or, as a group of special interest, households with recently married,

nulliparous women. Households with enrolled children continued to be followed each year until < 72 months of age. This approach contrasts with many surveys, including the DHS and MICS, in which the final sampling stage is typically a sub-sample of a cluster (ward). Including all households with georeferenced coordinates in a ward, enabled the investigation of community-level services, programs or resources (e.g., sanitation), and their spatial proximity, receipt or access to which may also vary by socioeconomic status (SES), caste and other factors that could affect risk of stunting.

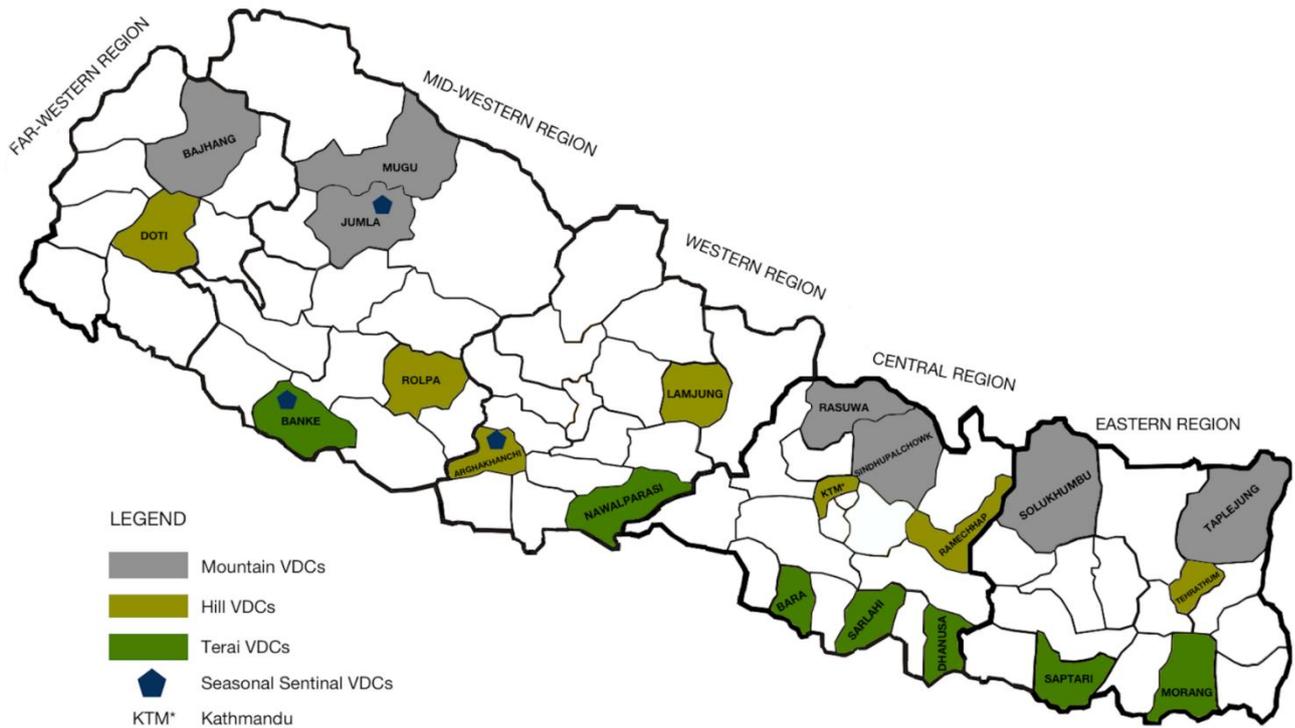
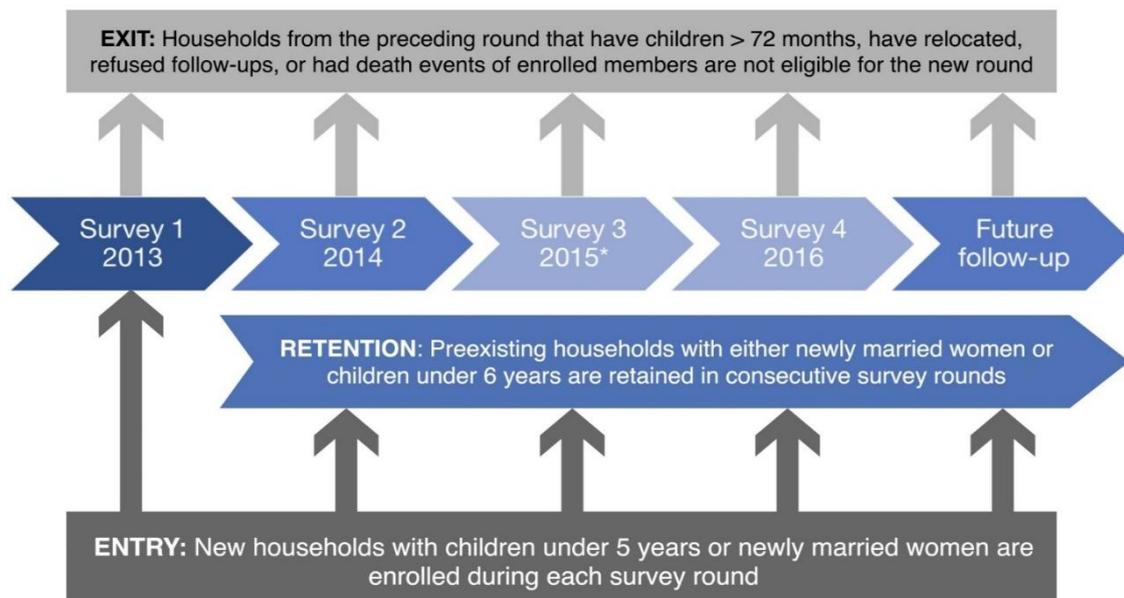
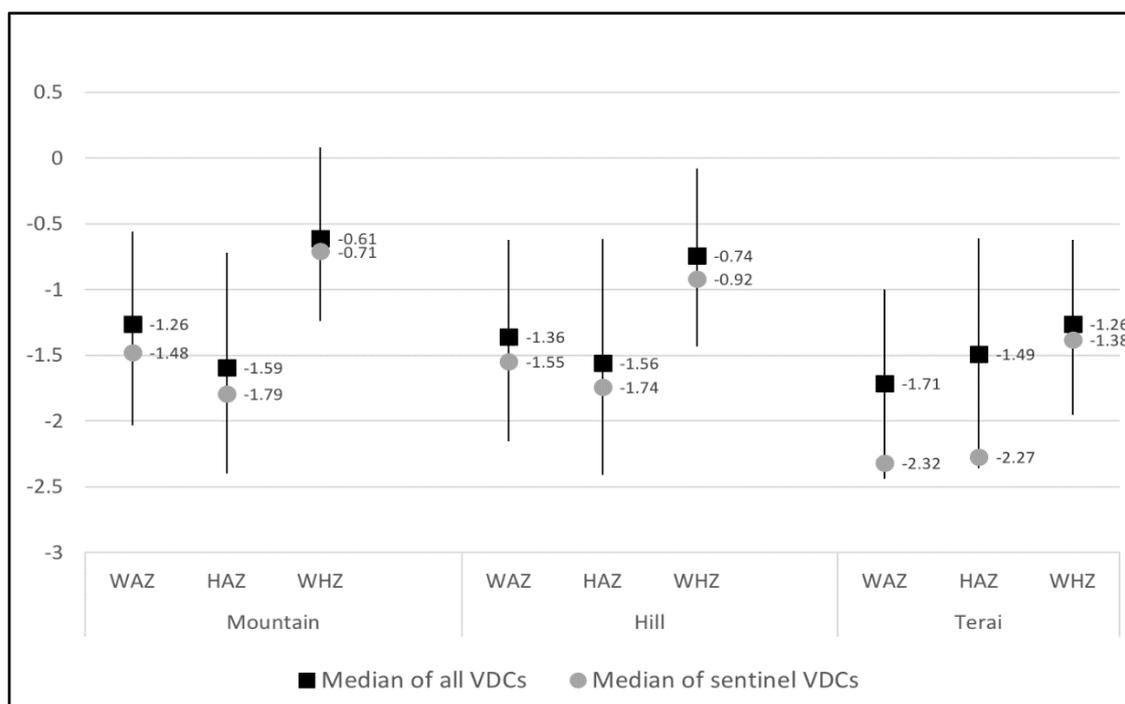


Figure 3. Map of PoSHAN survey areas



*Data collection was restricted to Terai VDCs due to the earthquake

Figure 4. Schematic representation of annual PoSHAN community surveys



Vertical bars represent the interquartile range for all VDCs by region.

Figure 5. Agroecological zone-specific median and inter-quartile ranges for weight-for-age (WAZ), height-for-age (HAZ) and weight-for-height (WHZ) of children ≤ 60 months of age in the PoSHAN National Survey of 2013 (dark boxes) and the median values for VDC sentinel subsample (1 per zone) in 2013-14 (light boxes)

Table 1. Data collection instruments, level, respondents and contents for PoSHAN Community Studies

Data Collection Instrument	Respondents	Contents
VDC Health and Agriculture Human Resource Form*	District health, agriculture and livestock officers	Number and type of health workers, agricultural extension workers, model farmers and veterinary workers in VDC
VDC Infrastructure*	VDC key informants	Number and location of community infrastructure (e.g. schools, clinics, hospitals, NGO centers, banks, paved roads, irrigation canals, government offices, etc.)
Market Food Survey	Market vendor	Unit price of indicator foods
Market Agricultural Supply Survey	Agricultural supply vendor	Unit price of indicator agricultural inputs
Ward Screening Roster*	Household head	Total number household members, number of children <5 years and number of newly married women
Household Roster	Household head	Name, age, education, main occupation, religion and caste of household members
Household Form	Household head	Socioeconomic status; household assets, income and expenditure; land size and use; agricultural production/sale/household consumption; animal ownership; animal products; water, sanitation and hygiene; household food security and economic shocks; use of improved agriculture technologies; group membership; agricultural training, inputs and practices
Women's Form	Newly married woman/ mother	Nutritional status (height, weight, MUAC, anemia); dietary intake; morbidity history and care-seeking behavior; pregnancy history; receipt and use of maternal health services; health, nutrition and child care knowledge; woman's decision making
Children's Form	Mother/ caregiver of children <5 years	Nutritional status (length/height, weight, MUAC, anemia); breastfeeding history; dietary intake; morbidity history and care-seeking behavior; receipt and use of child care services; health, nutrition and child care knowledge

*Data collected only during the annual panel surveys.

2.1. Data Collection Instruments and Procedures

Table 1 summarizes the levels (i.e. VDC, ward, household, and individual), primary respondents and content of data collection instruments by component of the system (i.e., annual mid-year or seasonal assessment), as described below. The detailed survey tools are also available online from the USAID Feed the Future Innovation Lab for Nutrition (henceforth referred to as the Nutrition Innovation Lab) website at <https://www.nutritioninnovationlab.org/>.

1. *District official interviews.* Publicly available data, verified and enhanced during interviews with district level officials, was obtained on the number of VDC-level government personnel providing specific health, agriculture and nutrition-related services to approximate capacity to provide services at the VDC level.

2. *Village Development Committee (VDC) Focus Groups.* Focus groups consisting of key informants and government personnel (e.g. VDC secretary, Female Community Health Volunteers (FCHVs), school principal, other health and agricultural extension workers) were assembled to collect

information about locations of markets, government and program offices, community services, major agricultural and food vendors as well as information about outreach activities were collected to begin ascertaining the infrastructure and services available within the study VDC and three selected wards.

3. *Market Survey.* Given the importance of food and agricultural input prices as a determinant of consumption, retail prices per standardized unit were collected on 30 commonly consumed food items and 18 agricultural input items from permanent or weekly markets, identified to be frequented by the study ward residents through focus group discussions. At times, the same markets were determined to service more than one ward in a VDC. The location of surveyed markets, physical infrastructure identified via the focus groups described above, and all surveyed households were geospatially indexed using Garmin etrex ®.

4. *Ward Enumeration.* In each of three sampled wards per VDC, a team supervisor carried out a door-to-door census of every household to identify and assign unique identifiers to all households with children <5 years of age or nulliparous women married within the past two years. Additionally, counts of live births and deaths among children <5 and <1 years of age in the past year were collected.

5. *Household Interviews and Observations.* Interview data was collected from heads of household on socioeconomic status and dynamic assets, economic shocks in the past year, participation in agricultural, health and microcredit extensions services, and agricultural activities, production and sales (e.g., cereals, fruits, vegetables, livestock) by season. Food security was assessed using the Household Food Insecurity Access Scale (HFIAS) [22], Months of Adequate Household Food Provisioning (MAHP) to measure year-round food availability [23], and a subset of questions from the Coping Strategies Index (CSI) [24]. Recall periods ranged from the past 30 days to a year, depending on type of questions and presumptive reliability. Field staff also conducted direct observations and recorded their findings related to house building material, toilet type and sanitary condition. An iodine test of the household's salt rapid test kits (MBI) was also used to assess the content of iodine in salt.

6. *Women Interviews.* Mothers/caretakers of eligible children and recently married women without a child were interviewed to record pregnancy history, pre- and post-natal care, recent morbidity, decision-making roles, access and participation in healthcare and nutrition services in the past year, and knowledge of infant and young child feeding practices as recommended by the World Health Organization. Diet was assessed using both 7-day and 24-hour food frequency questionnaire of about 50 frequently consumed foods adapted from previous studies conducted in Nepal, with the exception of the first round of data collection where only a 7 day recall was administered [25]. The child questionnaire was administered to mothers/caretakers to record morbidity symptoms in the past 30 days, receipt of health and nutrition services (growth monitoring programs, supplement receipt), breastfeeding and actual young child feeding practices using both a 7-day and 24-hour 50 item food frequency questionnaire, also adapted from earlier studies in Nepal [25].

7. *Women and Children's Anthropometry.* Anthropometric measurements were taken by trained staff, using standard equipment. Infant/child and maternal weight was measured to the nearest 100 g on a digital scale (Seca Scale, Columbia MD). Supine length for infants 0-23 months, standing height for children 24-59 months, and women's height was measured to the 0.1 cm in triplicate using a Shorr extendable height-length board. Mid-upper arm circumference (MUAC) was measured in triplicate to the nearest 0.1 cm on children and women using non-stretch insertion tapes. Children 6-59 months of age with MUAC measurements <11.5 cm and women with MUAC measurements <17.5 cm were referred to the local health post for evaluation and treatment.

8. *Women and Children's Hemoglobin:* One in four consenting households were randomly sampled as eligible for hemoglobin testing. Hemoglobin was assessed from a spot of whole blood using heel-sticks in children ≤ 6 months of age and finger-sticks in children > 6 months of age, their mothers/caretakers and from newly married women, using a Hb 201+ hemoglobinometer (HemoCue AB, Angelholm, Sweden). Only one child, selected at random, was included for hemoglobin assessment in households with more than one child of eligible age. Severely anemic children (Hb<7.0 g/dL) and women (pregnant<7.0 and non-pregnant <8.0 g/dL) were referred to the local health post for further evaluation and treatment.

9. *Additional modules:* Questionnaires were designed to accommodate additional modules to obtain information on areas of arising interest in given year. For example, in 2014, additional questions were added to assess exposure to nutrition messages via radio broadcasts. In 2015, a dental assessment of missing and broken teeth was added, and in 2016 modules were added to assess loss of life, injury, property damage and asset recovery following the massive earthquake in 2015.

2.2. Training of Data Collectors and Quality Control Procedures

Annual surveys were carried out by 21, pre-dominantly female, field teams, each consisting of 3 members, including a team leader, who were hired, trained and managed by a competitively selected, field research organization (New ERA (P.) Ltd., Kathmandu), and trained, standardized and overseen by the Nutrition Innovation Lab's Johns Hopkins in-country team. Survey instruments were pretested in two non-study districts in different agroecological zones before being finalized. Training took place for ~5 weeks prior to start-up of each survey during which staff learned about the purpose, forms, informed consent, interview and assessment methods, practiced and were standardized, including extensive anthropometric measurement exercises. Training of anthropometry included assessment of inter- and intra-enumerator measurement error and continued until all enumerators had relative total error of measurement (TEM) value of 2% of the gold standard measurement team.

A second competitively selected, local research organization (Nepali Technical Assistance Group (NTAG), Kathmandu) hired and managed three teams of 4-field staff in each of the three sentinel sites who conducted two additional

seasonal assessments protocols, in addition to the annual survey, to provide multi-season, year-round data. These teams followed similarly rigorous initial training and were retrained and standardized for anthropometric measurements prior to each data collection period by the Nutrition Innovation Lab's Johns Hopkins in-country team.

2.3. Quality Control

Once deployed, field teams performed daily, within-team cross-checking of forms for legibility, consistency and completeness, following standardized algorithms, prior to being transmitted to Kathmandu for data entry. A quality control team was mobilized to check questionnaire and revisit a randomly selected ~5% of households who re-administered selected questionnaire modules and obtained independent anthropometric measurements on women and children. Scales and height boards were regularly calibrated with standard weights and length rods, and MUAC tapes replaced after ~100 measurements. Finally, a series of weekly meetings, report and calls to resolve questions and report on progress throughout the data collection periods took place between the supervisors and investigator teams.

2.4. Data Flow and Management

Data forms were transmitted by bus, or occasionally by commercially scheduled aircraft, from all 21 field sites to the data management center in Kathmandu usually within 1-3 weeks of data collection, depending on weather and road conditions. On arrival at the data entry center (New ERA, Kathmandu), forms were date stamped, cross-checked against transmittal lists, examined for legibility, correct skip-patterns and out-of-range checks prior to double-entry by trained operators into FoxPro. Data was then migrated to an SQL server by the in-country Nutrition Innovation Lab team. Post-entry, standard range, consistency and logical checks were also performed.

2.5. Ethical Approval and Consent

Initial and annual renewal of ethical approvals for the PoSHAN Surveys were obtained from the Nepal Health Research Council, an autonomous body, under the Ministry of Health and Population, Government of Nepal, and the Institutional Review Boards at the Johns Hopkins Bloomberg School of Public Health, Baltimore, MD. Field staff were trained in the ethical conduct of research, including informed consent procedures, in accordance with standards described in "A Field Training Guide for Human Subjects Research Ethics" [26]. In addition, prior to each survey, the Child Health Division of the Ministry of Health and Population in Kathmandu was briefed and permission obtained to proceed into the field.

2.6. Analytical Approaches

After each round of data collection, a report summarizing key zone-specific and national descriptive parameter estimates was produced, accompanied by a detailed set of tables that characterize maternal and child nutritional status and dietary intake, indices of household food insecurity, agricultural productivity, income and

expenditures, and participation in agricultural, health and nutrition interventions. Also, with each subsequent annual panel survey, year-to-year differences in these indicators are produced to quantify rates of change and explore their trends.

2.7. Dissemination and Communication of Findings

Different approaches to dissemination and communication are used to help ensure uptake of findings by an array of stakeholders including local program managers, policy makers, donors, and researchers. These include annual panel survey reports mentioned above, periodic presentations made to key stakeholder groups (e.g. Nepal Nutrition Working Group, Government of Nepal, USAID), briefs that present more easily digestible findings to district-level health, agriculture and livestock officers, and peer-reviewed scientific publications. Also, each year the Nutrition Innovation Lab organizes an Agriculture-to-Nutrition Scientific Symposium attended by 150-300 national level policy makers, local and international researchers, program managers, and donors. These annual symposia highlight key findings from program- and policy-relevant analyses and stimulate discussions about policy, program and research implications across disciplines and sectors.

3. Summary of Survey Findings

Data collection for three of the annual surveys was completed from May to September in 2013, 2014, and 2016. A massive earthquake in April 2015 preceded planned field work in April 2015 and the decision was made to be limited to the VDCs in the *Terai* and the sentinel VDCs due to infrastructural damage, losses in livelihood, homes, assets and lives in the hill and mountain areas.

Table 2 reports the numbers of VDCs, wards, households and respondents for each of the four annual panel surveys conducted between 2013 and 2016. We returned to all the same wards and VDCs during each panel survey except for Panel 3 (2015) where data was only collected in non-earthquake affected *Terai* districts and in one sentinel district in the mountains and hills. The number of households visited and screened ranged from a low of 6,687 in 2015 (when the earthquake limited data collection to mostly *Terai* VDCs) to a high of 12,143 in 2016. Among the households visited, 43% to 49% met the eligibility criteria, depending on the panel year, and of these ~98% consented to participation and interviews were completed for all consenting households. The number of eligible women interviewed ranged from a low of 3,436 in 2015 (again, due to restricted data collection imposed by the earthquake) to 5,458 in 2016, among whom 11%-12% were pregnant at the time of the survey. The number of children ranged from a low of 3,436 in 2015 to a high of 5,568 in 2016, with 7%-9% <6 months of age, 10%-12% 6-11 months of age, 19%-21% between 12-23 m and 59%-62% between 24-59 months of age, depending on the panel year. The proportion of households that were surveyed in 2013 and remained in longitudinal cohort in subsequent years were 86.9%, 49.9% and 64.1% in the 2014, 2015 and 2016 panels respectively.

Table 2. PoSHAN attained sample sizes over four rounds of data collection¹

	Survey 1 2013	Survey 2 2014	Survey 3 2015 ²	Survey 4 2016
VDCs surveyed	21	21	9	21
Markets surveyed	40	39	14	40
Wards surveyed	63	63	27	63
Households visited	9316	10689	6687	12143
Eligible households	4379 (47.0)	5096 (47.7)	3256 (48.7)	5173 (42.6)
Households consented ³	4287 (97.9)	4980 (97.7)	3210 (98.6)	5109 (98.8)
Interviews completed ⁴	4286 (100.0)	4947 (99.3)	3199 (100.0)	5097 (99.8)
Women	4509	5202	3436	5458
Pregnant ⁵	517 (11.5)	544 (10.5)	404 (11.8)	569 (10.4)
Children <5 years	5401	5474	3650	5568
<6 months	458 (8.5)	414 (7.6)	267 (7.3)	446 (8.0)
6-11 months	557 (10.3)	644 (11.8)	423 (11.6)	600 (10.8)
12-23 months	1068 (19.8)	1073 (19.6)	773 (21.2)	1091 (19.6)
24-59 months	3318 (61.4)	3343 (61.1)	2187 (59.9)	3431 (61.6)
Households from Survey 1 ⁶	4286 (100.0)	3725 (86.9)	2138 (49.9)	2749 (64.1)
Households from Survey 2 ⁶	-	4947 (100.0)	2628 (53.1)	3416 (69.1)
Households from Survey 3 ⁶	-	-	3199 (100.0)	2649 (82.8)

¹ Values shown are n and (%) unless otherwise stated

² Sample size was smaller in 2015 due to the earthquake as only *Terai* VDCs and sentinel VDCs in the hills and mountains were surveyed

³ Among eligible households

⁴ Among consented households

⁵ Among eligible and consented women

⁶ Among households with completed interviews in the respective survey round, the proportion of households that are re-interviewed in subsequent rounds.

4. Discussion

We describe the design of a national panel survey implemented in Nepal, a country where significant efforts are being made to address problems of low agricultural productivity, low market and dietary diversity, high food insecurity and poor nutritional status of the population. The design of a longitudinal panel including ~5,000 households, repeatedly visited between 2013 and 2016, offered a rare opportunity to identify conditional pathways that link agriculture, livelihoods, health and nutrition. This research platform was designed to be replicable, exchangeable in content, and adaptable to country priorities and offers lessons that may be of use to other efforts to understand agriculture to nutrition pathways.

The idea of linking food security and nutrition goals with agriculture is not new, but gaps exist in our understanding about what agricultural programs and policies can accelerate improvements in nutritional status, which impact pathways are the most important ones in specific contexts, and how best to positively influence those pathways to benefit food insecure and high-risk populations. Many study design options exist, and careful consideration of the strengths and weaknesses of each is needed. As countries develop their own data systems for better understanding the linkages between agricultural programs and nutrition, we offer lessons learned from designing and implementing the PoSHAN surveys.

First, study design options will depend in large measure on the nature of the questions to be answered, time and resources. In contexts where agricultural programs and interventions can be gradually scaled up, serious consideration should be given to randomizing provinces or districts to phased implementation. In a context such as Nepal where multiple development partners are rolling out

similar programs simultaneously throughout the country, establishing a nationally representative system that tracks individuals over time, allows for estimation of indicators that require cross sectional data collection (e.g. child malnutrition), and has a sub-component that tracks a subset over multiple seasons, is likely the most appropriate design option.

Second, designing an information system to understand the complex and multiple pathways from food production to nutritional status requires collecting a breadth of information from multiple sectors and levels. Finding a balance between questionnaire comprehensiveness and respondent burden is challenging, particularly when exploring trans-disciplinary cross-sectoral issues. The use of a conceptual framework should guide data collection decisions, but extensive effort is needed to distill questionnaires to provide pixilation to hypothesized causal pathways whilst ensuring questionnaires are not protracted. Lengthy questionnaires can result in respondent fatigue and could introduce bias to responses provided. The importance of pretesting, time testing and minimizing cognitive complexity of data collection is vital especially in smallholder farming populations with high physical labor demands.

Third, where agroecologies vary widely in a country, choosing a sampling strategy that provides representative estimates of key indicators by major agroecological zone is vital because agroecology can strongly influence the kinds, amounts and costs of food produced, sold and consumed, as well as influence risks and exposures to other diet and nutrition factors.

Fourth, the strong and independent influence of seasonality on agricultural production, market prices, food consumption, nutritional status and other factors requires that annual panel surveys be conducted in the same season each year to minimize seasonal variability.

Fifth, the use of inter-seasonal surveys in a select number of sites allows the assessment and quantification of the many aspects of agriculture, dietary intake, household food security and nutritional status subject to highly seasonal swings. This information can provide insights on when to implement and/or intensify interventions to mitigate against seasonal food shortages.

Finally, ensuring data quality is paramount in all research endeavors, but is particularly challenging when data are collected at a large-scale, with multiple teams, across remote and geographically dispersed communities, in resource-poor settings, across different ethnic and caste groups, and involves questions and data collection procedures from several disciplines. Key activities for ensuring quality collection include streamlining and pretesting data collection instruments, training and standardization interview and measurement procedures, fielding an independent quality control team to monitor and cross check data collection, and using the same data collection teams across annual surveys.

5. Conclusions

The pathways through which agricultural and food system policies and programs influence health and nutrition outcomes is often long. Key components of these pathways often include some combination of incomes, prices, access to markets, access and utilization of health and nutrition services, women's empowerment, dietary diversity, access to and use of improved agricultural production, storage and/or processing methods, and household and individual behavior. These components are not easily shifted in the short term and therefore data systems intended to measure shifts require a long-term perspective. Because investments in agriculture interventions can be huge, investing in the collection, analysis and use of quality data to make smart agriculture and food systems policy and program choices is important.

Competing Interests

The authors declare that they have no competing interests.

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