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Brenna Bowlen Date

Spatial Distribution and Interaction between Diarrheal Disease and Food Insecurity in Haydom, Tanzania

By

Brenna Bowlen
Master of Public Health

Global Epidemiology

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Elizabeth Rogawski-McQuade, PhD, MSPH
Committee Chair

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By

Brenna Bowlen

B.S.
Indiana University
2021

Thesis Committee Chair: Elizabeth Rogawski-McQuade, PhD, MSPH

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Abstract

Spatial Distribution and Interaction between Diarrheal Disease and Food Insecurity in Haydom, Tanzania

By Brenna Bowlen

Background: Food insecurity and diarrheal disease in young children are inextricably linked. It is hypothesized that acute hunger and nutritional deficiencies propagated by periods of food insecurity prior to harvest in rural agricultural communities lead to increased diarrheal infectious disease prevalence.

Methods: We sought to quantify the relationship between food insecurity and symptomatic diarrheal disease prevalence during the hunger season in the Manyara Region of Tanzania. The sampling region was divided into 7 wards within a 20km radius from the Haydom Lutheran Hospital. 72,699 eligible quantitative survey responses from the Health and Demographic Surveillance Survey (HDSS) were analyzed. 11,412 observations were for children aged 12-59 months old. Diarrhea prevalence was reported as a dichotomous variable and food insecurity on a scale ranging from not enough to feed everyone in the household to more than enough to feed everyone in the household. Binary logistic regression methods were used to quantify the effect of food insecurity prior and post-harvest on diarrhea prevalence in children under 5, adjusted for age, sex, tribal affiliation, household size, and ward. All analyses were conducted in R version 4.3.1.

Results: Diarrhea period prevalence over the 7-day recall period was 1.68% for children under 5 years, increased from the overall 0.83% period prevalence estimate including adults and decreased from the infant (0-11 mo.) period prevalence estimate of 1.85%. Diarrhea period prevalence among children under 5 ranged from 1.05-1.89% between the 7 administrative wards. Food insecurity was more prevalent among the under 5 study population prior to harvest (22.1%) than afterwards (11.5%), as expected. Food insecurity prevalence varied by ward. The Maghang and Endimilay wards maintained the highest levels of food insecurity throughout the collection period. Adjusted ORs indicate food insecurity was associated with diarrheal disease prevalence prior to harvest (OR: 1.19; 95% CI: (0.84, 1.67)), but less so after harvest (OR: 0.99; 95% CI: (0.63, 1.55)).

Conclusions: Hunger seasons result in augmented food insecurity prevalence in the Manyara Region of Tanzania. We have reason to conclude there is an association between household food insecurity and diarrhea prevalence among children under 5, with a stronger association noted pre-harvest.

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BACKGROUND

Population food insecurity impacts individual nutrition and may present long-term consequences for young children whose primary food source is regularly disrupted. Preharvest hunger seasons often coincide with regional rainy seasons, when distinct increases in both diarrheal disease and malaria incidence are visible (Vaitla et.al, 2009). Acute hunger and undernutrition have been documented as indirect contributors to severe diarrheal infections. For example, estimates suggest vitamin A deficiency in a non-supplemented population increases risk of diarrheal mortality by a factor of 1.47 (Black et.al, 2008). Zinc supplementation is also known to have one of the greatest impacts on diarrheal disease incidence and mortality reduction in young children (Talley, 2018). Generally, consequences of seasonality are more pronounced in larger households of low socioeconomic status (Rogawski McQuade et.al, 2019). Raised prices of both dairy and egg products in affected regions during this time are strongly associated with high stunting rates (Agostoni, 2023). It is our intention to investigate how spatial fluctuation in food availability and composition in Haydom, Tanzania is linked to morbidity prevalence and outcomes in children under 5 years of age.

Haydom is located in the Manyara region of Tanzania. In agricultural communities like Haydom, preharvest hunger seasons generate seasonal trends in food insecurity, increasing risk for malnutrition and infectious diseases (Rogawski McQuade et.al, 2019). Malnutrition in the Manyara region is comparatively high with 40% of height-for-age Z scores less than -2 and 31% of weight-for-age Z scores less than -2. Stunting rates are presumed to be linked to insufficient diet, poor water quality or lack of improved sanitary facilities, and high prevalence of entero-pathogens (Mduma et.al, 2014). The most life-threatening consequence of undernutrition for young children is an increased susceptibility to infections. Previous studies of undernourished children in sub-Saharan Africa have found lower levels of natural-killer cells than adequately nourished children (Bourke, 2019). Inversely, disease incidence can also increase individual malnourishment, even in food secure households. Higher incidences of diarrheal diseases as well as infectious diseases such as malaria can result in dietary deficiencies by minimizing nutrient absorption (Navarro-Colorado, 2018). As a result, we expect to see a higher prevalence of diarrhea in times of increased food insecurity.

Our research is only becoming more crucial as ramifications of climate change are observed. Climate change worsens the underlying causes of malnutrition in children, namely household food insecurity, poor dietary diversity, poor nutrient quality, and low household income. Serious prolonged drought in sub-Saharan countries has resulted in 20-60% of animal losses during the past 20 years. Similarly, "crop yield potential has followed a consistently downward trend for maize (5.6%), soybean (4.8%), wheat (2.1%) and rice (1.8%)" (Agostoni, 2023). For an agricultural community like Haydom, decreased crop yield and animal husbandry will exacerbate food insecurity and malnutrition by diminishing food supply and household income.

Diarrhea remains one of the leading severe childhood illnesses. Overall, the 2-week period prevalence of diarrhea in children under 5 in sub-Saharan Africa was recently estimated at 15.3% (Demissie et.al, 2021). Protozoal, viral, and bacterial pathogens, including enterotoxigenic E. coli, Shigella, Rotavirus, and Cryptosporidium, are predominant causes of severe diarrhea in children under 5 years living in low- and middle-income countries (Cohen et.al, 2022) (Bouzid et.al, 2018). An analysis of survey data from 34 low- and middle-income countries found increased prevalence of severe illness among children born to younger mothers, children aged 12-23 months (OR = 1.5), and children living in households with increased distance from their primary water source (Demissie, 2021). Climate change is predicted to increase diarrheal disease frequency via influx of interaction with foodborne and waterborne pathogens. According to WHO (World Health Organization) projections, "climate change will cause an additional 48,000 deaths in children under age 15 due to diarrheal disease by 2030" (Agostoni, 2023).

Previous scientific projects conducted in the study area include both the ELICIT clinical trial and MAL-ED cohort study. Studies sought to answer 1) whether scheduled antimicrobial interventions would reduce subclinical enteric pathogen carriage to improve linear growth development, and 2) the etiology, risk factors, and interactions between enteric infections and malnutrition on growth, cognitive development, and vaccine response, respectively. The spatial association of food insecurity with diarrheal disease has not yet been quantified in Tanzania. Geospatial analysis of these trends and identification of potential overlap has broad implications for targeting nutrition interventions for diarrheal disease in rural agricultural communities.

This study's purpose is to describe the incidence of childhood illness, focusing on diarrhea, within the catchment area of the regional referral hospital. The catchment area's radius spans 20 km (about 12.43 mi) from the hospital and was used for prior prospective studies conducted in the area. Our goal is to better understand the etiology of enteric diseases in a food-insecure context and identify populations at greatest risk for infection to inform, and potentially improve, health interventions and healthcare delivery in Haydom.

METHODS

Gathering Data

The Health and Demographic Surveillance Survey (HDSS) contains quantitative data questionnaire results. This census study was conducted by the Haydom Global Health Research Centre from July 2021- January 2023 in collaboration with the University of Virginia. The Haydom Lutheran Hospital (HLH) Catchment Area is divided into clusters of tencels. Households located in a tencel were identified by community leaders to field staff. All households within a tencel were offered the opportunity to participate in the study. Informed consent was obtained from the head-of-household (HOH) at a scheduled at-home appointment prior to enrollment. All communications with participants were conducted in Kiswahili by research staff members based in Haydom. Community sensitization meetings held with community leaders and representatives highlighted the importance of the community census project. Consenting subjects were assigned a household ID (HID). Data were stored in an open data kit (ODK) to allow for collection via mobile phone. The HDSS utilizes a secure, password protected server for census data storage. Methods for data collectors are outlined in the *Health and Demographic Surveillance System (HDSS) for Haydom Lutheran Hospital (HLH) Catchment Area Manual of Procedures*, Version 5.0 (Updated May 2021).

All procedures were completed in compliance with the University of Virginia IRB (IRB-HSR) and the Tanzanian National Institute for Medical Research (NIMR), following the International Council for Harmonization (ICH) and Good Clinical Practice (GCP) guidelines. Signed consent forms and other research records are kept according to UVA Records Management policies. All staff in direct contact with study participants and/or study-related data possess current Human Subjects Protection (HSP) training. Investigators are involved in ongoing studies in Haydom, including the MAL-ED cohort and ELICIT trial. Descriptive studies (including a HDSS) have been performed in other countries in Africa. There is minimal potential risk to participating children and other vulnerable populations.

Analyzing Data

Access to the database was granted by the University of Virginia via Box. All analyses were conducted in R, version 4.3.1, and used to quantify any spatial correlation or interaction between food insecurity and diarrheal disease. 72,790 observations were recorded. Locations of households were listed by ward, village, hamlet, and tencel in order of largest to smallest administrative unit. Spatial data was collected using GPS coordinates, specifying latitude, longitude, and altitude of participating household location. Diarrhea in the past week was coded as yes or no for each observation. Diarrhea was defined as >3 loose or watery stools in 24 hours. 90 observations were removed from analysis due to missing diarrhea information. One was removed for missing GPS coordinates. Each observation represented an individual survey response (n = 72,699). Food insecurity assessment responses were among the key exposure variables analyzed. Questions sought whether the household contained enough food to feed everyone in the house over the last month prior to interview, in the month prior to the harvest season, or in the month following the primary harvest. Heads of household were also asked whether they borrowed or bought food from a neighbor or relative during these periods. Respondents were asked about their primary source of transportation, primary food source, occupation, land ownership, animal husbandry practices, household size and age composition, tribal affiliation, and primary method of waste disposal. Household primary water sources for rainy and dry seasons were not included in the analysis due to low response rate. Binomial logistic regression models illustrating the relationship between food insecurity and diarrheal syndrome in children under 5 were calculated using dichotomous variables for both exposure and outcome. Prevalence odds ratios were adjusted for respondent sex, age, tribal affiliation, and household size. The overall prevalence odds ratio encompassing all recorded observations for children under 5 was also adjusted for ward.

RESULTS

13,098 households participated in the survey. The mean number of members per household was 7.03 individuals (sd = 2.89). The mean number of household members under 5 years old per household was 1.114 (sd = 1.003). Observations were recorded for multiple members of the same household, totaling 72,699 survey responses over the collection period with complete diarrhea prevalence, food insecurity assessment, and GPS coordinate data. Respondents varied by age (mean = 22.29 years, sd = 19.55 years) and sex (51% Male and 49% Female). 2,600 observations corresponded to infants less than one year old and 11,412 observations to children under 5 years. Most households reported working in the agriculture industry (n = 65,845, 90.57%). Nearly 97% of individuals in the study population reported belonging to one of three ethnic groups: Nyiramba, Datoga, or Iraqw. Households were located in one of seven wards: Endimilay (n=4,849), Garawja (n=6,030), Getarer (n=12,165), Haydarer (n=5,213), Haydom (n=19,749), Maghang (n=8,369), or Mwanga (n=16,325). The majority of respondents under 5 years of age within the HLH catchment area resided in Haydom (Table 1). Crude diarrhea prevalence for the HLH catchment area over the 7-day recall period was 0.83% (or 8.31 per 1,000) when adults were included in the analysis. A higher prevalence of 1.68% (or 16.82 per 1,000) was observed for children less than 5 years old and 1.85% for infants aged 0-11 months (18.46 per 1,000). Diarrhea cases were majority female (57.6%) overall and majority male for children under 5 years old (56.8%). From this moment forward, all analysis will pertain to observations from children aged 12-59 months.

Demographic differences between children aged 12-59 months who reported having diarrhea in the last 7 days compared to children who did not can be found in *Table 1*. Diarrhea cases in children under 5 years were majority male (56.8%) and younger on average (mean: 1.71 years, sd: 1.11 years) compared to their symptom-less counterparts (mean: 2.22 years, sd: 1.40 years) (Table 3). 37.0% of observed diarrhea cases reported no accessible transportation, compared to 34.4% of non-cases. Access to a car and access to a cart resulted in the greatest division in transportation access between cases and non-cases. Respondents who reported diarrheal symptoms reported living in smaller households with an average of 5.69 members (sd: 2.33) compared to 7.02 members among non-cases (sd: 2.85). Further, diarrhea cases reported living with fewer household members under 5 years old (mean: 1.64 persons, sd: 0.71).

Table 1: Demographics for Children Under 5 Years by Diarrheal Status

Variable	No Diarrhea	Yes Diarrhea	Overall
	(N=11220)	(N=192)	(N=11412)
Sex			
Female	5434 (48.4%)	83 (43.2%)	5517 (48.3%)

Male	5786 (51.6%)	109 (56.8%)	5895 (51.7%)
Age (years)			
Mean (SD)	2.22 (1.40)	1.71 (1.11)	2.21 (1.40)
Median [Min, Max]	2.11 [0.05, 4.90]	1.50 [0.10, 4.80]	2.10 [0.05, 4.90]
Household Location: Ward			
Endimilay	755 (6.7%)	8 (4.2%)	763 (6.7%)
Garawja	1106 (9.9%)	20 (10.4%)	1126 (9.9%)
Getarer	1885 (16.8%)	36 (18.8%)	1921 (16.8%)
Haydarer	828 (7.4%)	12 (6.3%)	840 (7.4%)
Haydom	3063 (27.3%)	53 (27.6%)	3116 (27.3%)
Maghang	1297 (11.6%)	25 (13.0%)	1322 (11.6%)
Mwanga	2286 (20.4%)	38 (19.8%)	2324 (20.4%)
Tribal Affiliation			
Datoga	958 (8.5%)	15 (7.8%)	973 (8.5%)
Iraqw	8540 (76.1%)	141 (73.4%)	8681 (76.1%)
Nyiramba	1411 (12.6%)	33 (17.2%)	1444 (12.7%)
Other	311 (2.8%)	3 (1.6%)	314 (2.7%)
Household Toilet Type			
Flush Toilet	65 (0.6%)	3 (1.6%)	68 (0.6%)
Ground Flush Toilet	203 (1.8%)	5 (2.6%)	208 (1.8%)
No Facility/Bush/Field or Bucket Toilet	1395 (12.4%)	32 (16.7%)	1427 (12.5%)
Other	6 (0.1%)	0 (0%)	6 (0.1%)
Pit Latrine With Concrete Slab	890 (7.9%)	15 (7.8%)	905 (7.9%)
Pit Latrine Without Concrete Slab	8661 (77.2%)	137 (71.4%)	8798 (77.1%)
Access to a Car			
Yes	2866 (25.5%)	27 (14.1%)	2893 (25.4%)
No	8354 (74.5%)	165 (85.9%)	8519 (74.6%)
Access to a Motorcycle			
Yes	1723 (15.4%)	23 (12.0%)	1746 (15.3%)
No	9497 (84.6%)	169 (88.0%)	9666 (84.7%)
Access to a Bicycle			
Yes	6352 (56.6%)	110 (57.3%)	6462 (56.6%)
No	4868 (43.4%)	82 (42.7%)	4950 (43.4%)
Access to a Cart			
Yes	2777 (24.8%)	27 (14.1%)	2804 (24.6%)

No	8443 (75.2%)	165 (85.9%)	8608 (75.4%)
No Transportation Access			
Yes	3858 (34.4%)	71 (37.0%)	3929 (34.4%)
No	7362 (65.6%)	121 (63.0%)	7483 (65.6%)
Have a Bank Account			
No	10565 (94.2%)	187 (97.4%)	10752 (94.2%)
Yes	655 (5.8%)	5 (2.6%)	660 (5.8%)
Own Agricultural Land			
No	426 (3.8%)	9 (4.7%)	435 (3.8%)
Yes	10794 (96.2%)	183 (95.3%)	10977 (96.2%)
Household Size			
Mean (SD)	7.02 (2.85)	5.69 (2.33)	7.00 (2.84)
Median [Min, Max]	7.00 [2.0, 25.0]	5.00 [2.0, 14.0]	7.00 [2.0, 25.0]
Number of Children Under 5 in Household			
Mean (SD)	1.84 (0.827)	1.64 (0.711)	1.84 (0.825)
Median [Min, Max]	2.00 [0, 7.00]	2.00 [1.00, 4.00]	2.00 [0, 7.00]

Diarrhea prevalence fluctuated between 1-2% by ward within the HLH catchment area. Maghang and Getarer had the highest prevalence at 1.89% and 1.87%, respectively (*Table 2*). These wards are neighbors and fall within the central regions of the study area (*Figure 1*). Endimilay, the northernmost ward in the surveyed catchment area, had the lowest prevalence at a mere 1.05%. Despite housing the greatest number of reported diarrhea cases in children under 5, Haydom had the median prevalence of 1.70%, nearly identical to the overall study area estimate for children aged 12-59 months at 1.68%.

Figure 1: Diarrhea Prevalence in Children Under 5, by Ward

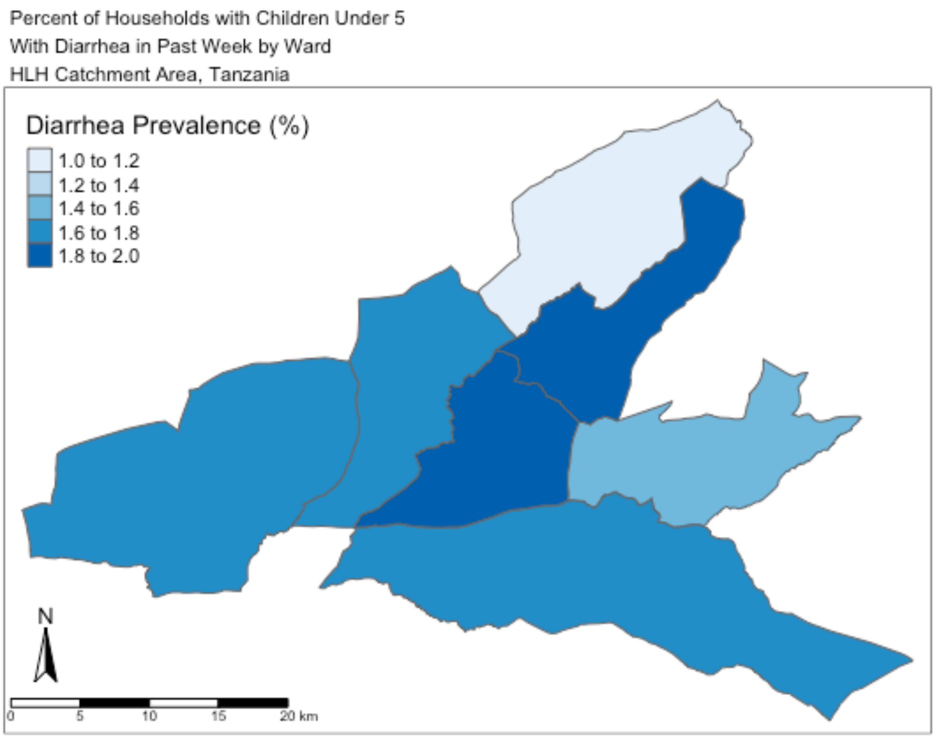

Table 2: Diarrhea Prevalence in Children Under 5, by Ward

WARD	U5 CASES	U5 RESPONDENTS	PREVALENCE (%)
Endimilay	8	763	1.05
Garawja	20	1126	1.78
Getarer	36	1921	1.87
Haydarer	12	840	1.43
Haydom	53	3116	1.70
Maghang	25	1322	1.89
Mwanga	38	2324	1.64

Food insecurity was defined by the head of household as not having enough food to feed all permanent residents at any point during the period specified by the interviewer. Respondents who answered as having either 'just enough' or 'more than enough' to feed all household members during the specified period were defined as food secure. 90.8% of households with children under 5 relied on the harvest as their primary food source. As expected, food insecurity was more prevalent among the study population prior to harvest (22.1%) than afterwards (11.5%) (*Table 3*).

Table 3: Food Insecurity Assessment for Children Under 5 Years Stratified by Diarrheal Status

Variable	No Diarrhea	Yes Diarrhea	Overall
	(N=11220)	(N=192)	(N=11412)
Household Primary Food Source			
Buying Food	1034 (9.2%)	18 (9.4%)	1052 (9.2%)
Harvest	10186 (90.8%)	174 (90.6%)	10360 (90.8%)
Food Secure in Month Prior			
Just Enough	8625 (76.9%)	149 (77.6%)	8774 (76.9%)
More Than Enough	958 (8.5%)	15 (7.8%)	973 (8.5%)
Not Enough	1637 (14.6%)	28 (14.6%)	1665 (14.6%)
Received Help in Month Prior			
No	9199 (82.0%)	159 (82.8%)	9358 (82.0%)
Yes	2021 (18.0%)	33 (17.2%)	2054 (18.0%)
Food Secure Prior to Harvest			
Just Enough	8054 (71.8%)	134 (69.8%)	8188 (71.7%)
More Than Enough	695 (6.2%)	12 (6.3%)	707 (6.2%)
Not Enough	2471 (22.0%)	46 (24.0%)	2517 (22.1%)
Food Secure After Harvest			
Just Enough	8779 (78.2%)	149 (77.6%)	8928 (78.2%)
More Than Enough	1146 (10.2%)	21 (10.9%)	1167 (10.2%)
Not Enough	1295 (11.5%)	22 (11.5%)	1317 (11.5%)
Received Food Aid Prior to Harvest			
No	8414 (75.0%)	141 (73.4%)	8555 (75.0%)
Yes	2806 (25.0%)	51 (26.6%)	2857 (25.0%)
Received Food Aid After Harvest			
No	9236 (82.3%)	164 (85.4%)	9400 (82.4%)
Yes	1984 (17.7%)	28 (14.6%)	2012 (17.6%)
Own Chickens			

No	1975 (17.6%)	46 (24.0%)	2021 (17.7%)
Yes	9245 (82.4%)	146 (76.0%)	9391 (82.3%)
Own Cows			
No	4491 (40.0%)	102 (53.1%)	4593 (40.2%)
Yes	6729 (60.0%)	90 (46.9%)	6819 (59.8%)
Own Pigs			
No	7334 (65.4%)	133 (69.3%)	7467 (65.4%)
Yes	3886 (34.6%)	59 (30.7%)	3945 (34.6%)
Own Goats			
No	5828 (51.9%)	117 (60.9%)	5945 (52.1%)
Yes	5392 (48.1%)	75 (39.1%)	5467 (47.9%)

Similarly, 7.4% fewer households reported receiving food assistance from a neighbor or relative after harvest than before harvest. Finally, a higher percentage of non-case respondents reported owning livestock compared to cases. Though poultry ownership was the most common form of animal husbandry in both cases (76.0%) and non-cases (82.4%), cattle raising showed the largest difference in prevalence between cases (46.9%) and non-cases (60.0%).

Food insecurity prevalence was greater in all wards prior to the harvest compared to after the harvest. Prior to the harvest, 30.67% of respondents were food insecure in Endimilay, 20.60% in Garawja, 24.31% in Getarer, 19.05% in Haydarer, 21.12% in Haydom, 31.47% in Maghang, and 15.06% in Mwanga (*Figure 2a*). After the harvest, 19.66% of respondents were food insecure in Endimilay, 12.26% in Garawja, 10.98% in Getarer, 8.21% in Haydarer, 9.15% in Haydom, 22.09% in Maghang, and 7.40% in Mwanga (*Figure 2b*). The northernmost wards within the study area, Endimilay and Maghang, had the highest prevalence of food insecurity in households with children under 5 both before and after the harvest. There appears to be a geographic gradient with the highest prevalence of food insecurity in the northeast and lowest in the southwest. This does not match our observed distribution of diarrhea prevalence, where most reported cases were concentrated in the study area's central east. Further, while Maghang recorded a high prevalence for both food insecurity and diarrhea in children under 5, Endimilay, one of the most food insecure wards both pre- and post-harvest, reported the least cases of diarrheal illness in the study area.

Figure 2: Food Insecurity Prevalence Before and After Harvest, by Ward

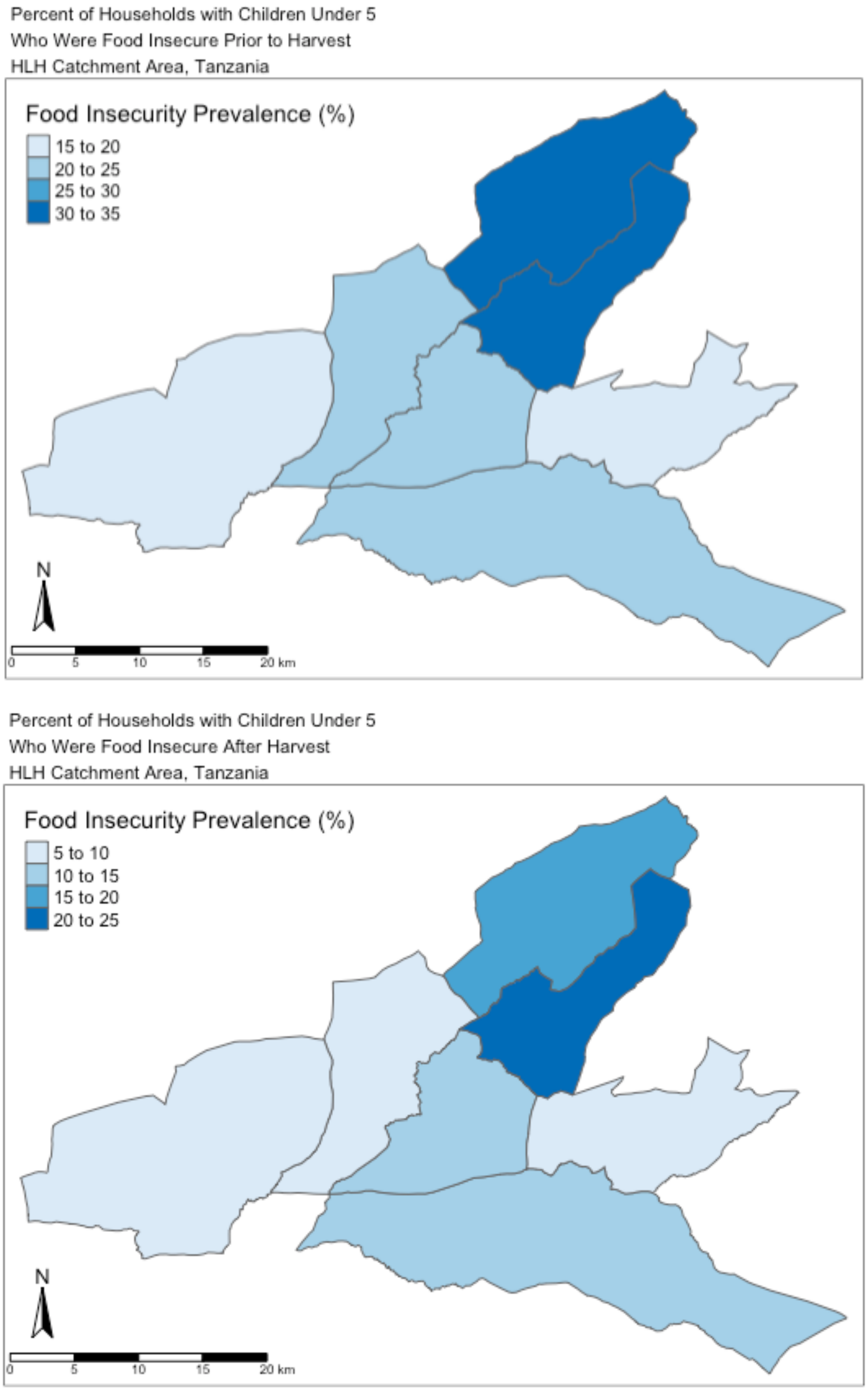

Table 4: Relationship Between Food Insecurity and Diarrhea in Children Under 5, by Ward

All estimates rounded to the nearest 0.01

WARD	FOOD INSECURE PRIOR TO HARVEST		FOOD INSECURE AFTER HARVEST	
	cOR (95% CI)	aOR* (95% CI)	cOR (95% CI)	aOR* (95% CI)
Endimilay	3.83 (0.91, 16.15)	3.98 (0.92, 17.28)	2.48 (0.59, 10.50)	2.36 (0.54, 10.30)
Garawja	2.11 (0.83, 5.35)	2.07 (0.79, 5.40)	1.27 (0.37, 4.39)	1.12 (0.32, 3.99)
Getarer	0.38 (0.14, 1.09)	0.40 (0.14, 1.15)	-- ‡	-- ‡
Haydarer	0.38 (0.05, 2.98)	0.45 (0.06, 3.55)	-- ‡	-- ‡
Haydom	1.22 (0.64, 2.29)	1.35 (0.71, 2.57)	1.27 (0.54, 3.01)	1.26 (0.53, 2.99)
Maghang	1.23 (0.54, 2.81)	1.25 (0.55, 2.87)	1.38 (0.57, 3.34)	1.38 (0.57, 3.34)
Mwanga	1.28 (0.56, 2.93)	1.49 (0.64, 3.44)	1.07 (0.33, 3.53)	1.09 (0.33, 3.63)
TOTAL	1.12 (0.80, 1.56)	1.19 (0.84, 1.67) †	0.99 (0.63, 1.55)	0.99 (0.63, 1.55) †

*Adjusted for sex, age, tribal affiliation, and household size

† Adjusted for ward

‡ Crude and adjusted odds ratios not measurable

The odds of diarrhea among children who reported household food insecurity prior to harvest was 1.19 (95% CI: (0.84, 1.67)) times the odds of diarrhea among children with enough food to feed all household members, adjusting for sex, age, tribal affiliation, household size, and ward (*Table 4*). Meanwhile, there is no association between food insecurity and diarrheal disease after the harvest in children aged 12-59 months within the aggregated study area in Tanzania (OR: 0.99, 95% CI: (0.63, 1.55)). The odds of food insecurity among children were highest prior to harvest in Endimilay (OR: 3.98, 95% CI: (0.917, 17.284)) and Garawja (OR: 2.07, 95% CI: (0.791, 5.403)). Measures of association for Getarer and Haydarer were unable to be estimated after the harvest. None of the odds ratio estimates proved statistically significant at the $\alpha = 0.05$ level.

Diarrhea prevalence was not uniform across all hamlets for children under 5. Qalodamarir and Harar-mlimani, hamlets along Haydom‘s boundary, reported individual diarrhea prevalence rates as high as 6.52% and 6.56%, respectively. Prevalence at the hamlet level ranged from 0% to 6.56%, with a mean of 2.08% and median of 1.66% (IQR: 0.02014). No cases of diarrhea syndrome in children under 5 were reported in the hamlets of dabischandi, dagonyandi, dakw-hhasang-harar, duxu-dofa, endabarack, endagew, or gwach at the time of interview.

DISCUSSION

Prevalence

Children aged 12-59 months who reported diarrhea episodes within the 7-day recall period were more likely to be male and of a younger age on average than children who did not experience symptoms in the past week prior to interview. Most households with children aged 12-59 months reported the annual harvest as their primary food source regardless of diarrheal incidence. As a result, overall food insecurity was more prevalent among surveyed households in the month prior to harvest than afterwards. Scarcities were felt more severely before food storage was replenished, as predicted.

Contrary to our hypothesis, the data revealed a diarrhea period prevalence estimate of 1.68% for children under 5. Opting for a 7-day recall period over a 2-week alternative to avoid misclassifications due to recall bias may have underestimated the true burden of disease. Additionally, our selected outcome would not account for asymptomatic infections since no confirmatory laboratory tests were used. Although similar across the seven surveyed wards, prevalence was not uniform throughout the study area. Central wards Maghang and Getarer had the highest diarrhea period prevalence estimates. As neighboring wards, this correlation may suggest a geographical relationship between diarrhea and a third factor aside fromfood insecurity. Maghang also had the highest food insecurity prevalence both before and after the harvest alongside Endimilay, alluding to an ongoing barrier to food access for households residing in the northeastern wards of the HLH catchment area that warrants further investigation. Sampling variability resulted in wide confidence intervals for all ward level estimates. Prevalence odds ratios, particularly based on data collected from Haydarer and Getarer, should be interpreted in the context of the HDSS sampling strategy.

Aggregating the results to the ward organizational level may have masked subtle differences in diarrhea period prevalence between hamlets. Crude diarrhea prevalence for children under 5 reported in the qalodamarir and harar-mlimani hamlets resemble the estimated burden of disease of 6.1% for similar Tanzanian populations when reported by heads-of-household (Mashoto et.al, 2014). However, it should be noted that results generated by hamlets, as a significantly smaller geographic organizational level, may not be generalizable to the entire study population.

Measures of Association

Our results indicate children under age 5 who are exposed to food insecurity are more likely to report diarrheal disease during the hunger season in the study area of rural Tanzania. Endimilay's high odds ratio prior to harvest may be overestimated due to the low number of cases reported in the ward. The strength of the association between the exposure and the outcome varied by site, indicating additional influencing factors aside from our primary exposure. We cannot draw strong conclusions where the number of cases reported were minimal. However, as the source for a majority of the reported cases of diarrheal syndrome, measures of association between food insecurity and diarrhea pre- and post-harvest drawn from Haydom encourages the possibility of a true direct correlation between exposure and outcome, strengthened by seasonality.

Limitations

The data intended for this study collected variables for numerous health conditions aside from this study's primary interests in food insecurity and diarrhea syndrome. Although our partners in Tanzania took the utmost care in collecting responses from the households surveyed, we cannot guarantee absolute accuracy in translation or categorization of survey responses. For example, the response for water source type was unable to be correctly categorized for many observations listed as "other" and could not be considered as thoroughly as other variables identified above for analysis despite the supported relationship between WASH and diarrheal illness in published scientific literature. Unlike the outcome of diarrhea, recall periods for food insecurity assessment variables were long and are subject to potential bias based on time of interview. Diarrhea, as an epidemiologic outcome, has been historically difficult to quantify. It is generally believed that symptom recall beyond 7 days is unreliable. Further, incidence, although the preferred measure of frequency, does not account for episode duration and it can be difficult to distinguish between episodes (Wolf-Peter Schmidt, 2011).

The survey was not conducted randomly. Researchers began at one edge of the study area and slowly worked their way to the other end of the specified region rather than selecting households at random during the 2-year data collection timeframe. Seasonality of sampling by region may affect survey responses for both exposure and outcome. Further investigation is warranted to explore whether these factors impact exposure or outcome prevalence or influence the relationship between food insecurity and diarrheal disease.

CONCLUSIONS

Food insecurity and diarrheal disease prevalence is not uniform across Tanzania's Manyara region. Although geographic prevalence of food insecurity both pre- and post-harvest did not match the distribution observed for reported diarrhea in children aged 12-59 months, there is evidence children living in food insecure households experience higher rates of diarrheal syndrome than food secure households. Periods of acute hunger prior to the primary annual harvest exacerbate this relationship. Ward level estimates, although less precise than overall prevalence odds ratios, were not uniform across the study area and highlighted where food insecurity and diarrhea were felt more severely. Longitudinal studies following children in the Manyara region are warranted to further confirm the increased prevalence of infection in food insecure contexts.

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