DECEMBER 2016

Feinstein International Center

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Water, Livestock, and Malnutrition

Findings from an Impact Assessment of "Community Resilience to Acute Malnutrition" Programming in the Dar Sila Region of Eastern Chad, 2012–2015

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Cover photo: child running through sorghum in a village near Goz Beida
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Acknowledgements

This work was funded by Irish Aid, under their support for the Community Resilience to Acute Malnutrition (CRAM) Program led by Concern Worldwide. It was also partially funded by UKAID, under their support for Concern's Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED) program. The views expressed do not necessarily reflect the funders' official policies.

We would like to thank all the staff at Concern Worldwide, especially their field office in Dar Sila, Chad for facilitating the logistics of data collection and for allocation of their staff to support every aspect of the work. In particular, we thank Anne-Laure Bauby, Nena Lafuente, Silvia Risi, Evanna Barry, Isaac Gahungu, Kate Golden, and Gretta Fitzgerald. Special thanks are extended both to the group of enumerators who for three years collected all of the data for this report and to the communities who patiently answered our questions and provided important insight into the context.

At the Feinstein International Center, Friedman School of Nutrition Science and Policy at Tufts University, we would like to thank Peter Walker for directing the first two years of this project and giving support at all times. For planning and implementing the various qualitative field studies, thanks and much appreciation to Elizabeth Bontrager and Jacqueline Frize. Finally, we would like to thank Erin Boyd for her thoughtful contribution to thinking through the findings and better understanding the results.

Copy-editor: Liz Vincent

Design: Bridget Snow

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ACRONYMS AND ABBREVIATIONS

CRAM	Community Resilience to Acute Malnutrition
CSI	Coping Strategies Index
FAO	Food and Agriculture Organization
FEWS NET	Famine Early Warning System Network
FGD	Focus Group Discussion
FIM	Food, Income, and Markets
GAM	Global Acute Malnutrition
HAZ	Height-for-Age Z-score
HH	Household
IAPF	Irish Aid Programme Funding
IDP	Internally Displaced Person
MAM	Moderate Acute Malnutrition
MSI	Morris Score Index
MUAC	Mid-Upper Arm Circumference
NGO	Non-Governmental Organization
SAM	Severe Acute Malnutrition
SISAAP	Information System on Food Security and Early Warning
SMART	Standardized Monitoring and Assessment of Relief and Transitions
TRMM	Tropical Rainfall Measuring Mission
UN	United Nations
WASH	Water, Sanitation, and Hygiene
WHO	World Health Organization
WHZ	Weight-for-Height Z-score
WLI	Weighted Livestock Index

EXECUTIVE SUMMARY

The Dar Sila region of eastern Chad experiences highly variable rainfall, seasonal food insecurity, and high prevalence of acute malnutrition. In 2012, Concern Worldwide put in place an integrated program that combines nutrition, health, water, sanitation, and hygiene (WASH), and food, income, and markets (FIM) in the Dar Sila Region of Chad called Community Resilience to Acute Malnutrition (CRAM). This program was designed to reduce child acute malnutrition in the face of seasonal shocks.

The CRAM design was based on Concern's positive programming experiences in Kenya and Niger. Concern collaborated with the Feinstein International Center, Friedman School of Nutrition Science and Policy at Tufts University to carry out a randomized control trial impact evaluation to better understand the level of program impact and the mechanisms behind it. Three surveys took place in November and December of 2012, 2014, and 2015 in 69 settlements encompassing the Concern program area. This report describes the impact of the CRAM program and explores what household and community characteristics are correlated with acute malnutrition in Dar Sila, Chad.

At the endline, children in the CRAM settlements performed significantly better than the non-intervention group on a host of key nutrition and health indicators. They had:

- Lower prevalence of acute malnutrition;
- Higher weight-for-height z-scores;
- Lower prevalence of chronic malnutrition;
- Higher height-for-age z-scores;
- Lower prevalence of illness.

Even when controlling for child-, household-, and settlement-level characteristics, both being in the intervention group and moving from not receiving CRAM to receiving CRAM was significantly correlated to better household child nutritional status (i.e., minimum household weight-for-height z-score; see methodology section for more detail).

These findings indicate significant program impact, particularly in relation to the main outcome indicator—acute malnutrition. The design of the evaluation allows us to say with little ambiguity that CRAM is achieving its main stated goal of preventing an increase in the prevalence of acute malnutrition in the intervention group in comparison to the non-intervention group. The analysis also helps us to partially unpack why CRAM is working and how it could potentially be improved. The analysis in the report and conclusions drawn from the data are primarily based on quantitative research and statistical analysis from the baseline, midline, and endline data collection. Additional insights are provided by the qualitative data collection carried out in February and November of 2013, November of 2015, and May of 2016.

One cautionary note is that, for the duration of the program, the prevalence of global acute malnutrition remained at around 15 percent or above, while stunting prevalence (weight-for-height) was between 30 and 45 percent. At this point, there is no statistical evidence that CRAM reduced the rate of malnutrition in the intervention settlements; rather, unlike in the non-intervention settlements, malnutrition rates did not increase over time. These continuing high rates of acute malnutrition, and the increases seen in the non-intervention settlements, are causes for concern and indicative of the extreme vulnerability of these communities as they emerge from more than a decade of protracted crises. There is, however, greater resilience in CRAM settlements as a result of the program.

In addition to determining the impact of CRAM, the data offer clues into the mechanisms related to impact and how the impact could potentially be increased. The WASH promotion activities also showed a significant positive impact of CRAM and were correlated to child nutrition outcomes, specifically in relation to the following variables:

- Greater utilization of boreholes;

- Greater reports of regularly washing the transport and storage container with soap;
- Greater knowledge around the two main times for hand washing.

Regression analysis allows us to further explore the relationship between WASH and indicators of child nutrition and health. Utilizing a borehole, without good training around the water chain (the handling of the water from its collection at the source up until it is used), does not in itself significantly decrease rates of malnutrition (as is evident in the non-intervention settlements that had similar utilization of boreholes but that did not receive training on maintaining a good water chain). Through routine water testing, Concern Worldwide found that while contamination levels (coliforms) of borehole water at the point of collection were low to nonexistent, they increased at certain points along the water chain (from borehole to transport container to storage container). This finding suggests that the positive impact of CRAM on malnutrition may be via its WASH activities that are focused on reducing the risk of contamination of potable water further along the water chain. These activities promote good hygiene in relation to water containers.

Linked to the above, a possible source of water contamination is the concentration of cattle in a village. The regression analysis shows that as the concentration of cattle in a village increases, so do rates of acute malnutrition. A similar finding, establishing a relationship between cattle density and a child's weight-for-height z-score and how that relationship is mediated by better hygiene practices along the water chain, was also identified in the midline data (Marshak et al., in press). Counterintuitively, households living in a *damre* (former pastoralist or nomadic communities with greater livestock ownership) have significantly lower levels of acute malnutrition compared to non-*damre* or village settlements (primarily sedentary farming communities with fewer livestock). Possible explanations are the differences in livestock water management practices between the villages and the *damrat*. However, other differences between the two types of settlements, including seasonal mobility of livestock, could be driving the relationship.

INTRODUCTION

This report describes and evaluates the integrated program known as Community Resilience to Acute Malnutrition (CRAM) implemented by Concern Worldwide in Dar Sila, Chad from 2012 through 2015 with the goal of reducing the prevalence of acute malnutrition in children under the age of 5. The main objective of the study was to determine whether CRAM has an impact on a host of nutrition- and health-related variables, with a focus on acute malnutrition. The study pulls from three years of quantitative and qualitative data collection, which was done to better understand why the program had an impact and what could improve that impact in the long run.

Concern Worldwide has worked in the Dar Sila Region since 2007, when it first established a presence in response to the massive displacement related to conflict on both sides of the Chad-Sudan border. Since that time, Concern has focused its work on humanitarian support to internally displaced persons (IDPs) and host communities in the Department of Kimiti, in the eastern half of Dar Sila. Concern focused its programming in the swath of communities extending to the northeast of the city of Goz Beida, where many IDPs initially arrived in the 2000s. As the security situation in the region has stabilized in recent years, Concern has begun responding to the other external shocks that continue to regularly affect the region. Concern's goal was to transition programming away from short-term humanitarian response to longer-term programming focused on building community resilience to shocks, while maintaining its capacity to respond to future crises on a timely basis. Experience from other Concern country programs—notably in Niger and Kenya—contributed to the development of the CRAM program, which aims to mitigate the impact of the emergencies that regularly occur in the region through a structured and multi-sectoral approach in which communities become better prepared to cope with and recover from shocks when they do inevitably occur.

The CRAM program is an integration of four Concern Worldwide program sectors: food, income, and markets (FIM), which includes livelihoods; water, sanitation, and hygiene (WASH) promotion; nutrition and health; and an early warning component (see Box 1 for more detail). While the CRAM intervention was provided to only 35 settlements (see methodology section for more details) to test program impact, Concern provided emergency response to all settlements when needed. Concern also provided year-round support to the health services throughout the entire district (see Box 1).

Box 1.

The CRAM program

Food, Income, and Markets

The two main interventions were training and support for: a) uptake of climate-smart agriculture practices—specifically, the introduction of short-season varieties of millet, a legume rotation, mulching, and integrated pest management; and b) dry-season vegetable gardens in settlements with access to water (generally *wadis* (seasonal rivers)). The program distributed cereal and vegetable seeds, and trained Lead Farmers to mentor other farmers on the climate-smart agriculture and vegetable garden techniques.

Water, Sanitation, and Hygiene

The WASH component included the construction of boreholes in every settlement (that did not already have one), establishment of water management committees, promotion of good hygiene (principally via periodic hand-washing campaigns), promotion of behavior change

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around the water chain through house-to-house visits and general messaging, and promotion of environmental sanitation and the Community-led Total Sanitation (CLTS) approach to trigger community commitment to end open defecation, followed by support for latrine maintenance and construction.

Health, Nutrition, and Behavior Change Communication
Under health and nutrition, CRAM supported the existing District Health Management team to deliver health services. CRAM also provided more direct support to the four health centers in the CRAM program area and a satellite outreach site around each facility. This effort included technical training of health staff on the integrated management of childhood illness (IMCI), some maternal health services, and the community-based management of acute malnutrition (CMAM). Concern also provided some medical and nutritional supplies to the four health centers when supplies from the government and UN partners were not sufficient. Other activities included transport and supervisory support for government staff, mosquito net distribution, and support to the vaccine cold chain when required. This health systems support was the same across intervention and non-intervention settlements, as all had relatively equal access to those health facilities and outreach sites. At the community level, Concern set up mother support groups for pregnant women and those with children under 5, which met regularly to discuss health and nutrition topics. House-to-house visits were also made by Concern staff, supported by community volunteers in each of the CRAM villages.

Early Warning and Early Response
While a robust early warning system was not fully developed, the program did use data from various sources to assess the risk of a poor harvest for each year of the project. The data came from the national early warning systems (SISAAP, FEWS NET), rainfall data, key informant interviews, and focus group discussions (FGDs) with farmers throughout the program areas. This information led to a food distribution following the poor harvests in 2011, 2013, and 2015.

Concern recognized the importance of establishing a solid evidence base for the CRAM model and therefore included a rigorous research component from the very beginning of the program's development and implementation. To this end, the Feinstein International Center worked in collaboration with Concern to increase the organization's understanding of the programming context and evaluate the CRAM program. One significant component of this support is an evaluation of the impact of this program on household and community resilience, with the aim of answering the following research question: "To what extent has the implemented CRAM package of activities contributed to improvements in child malnutrition of the participating households, compared to the non-intervention group?"

The evaluation found that children in the CRAM settlements had significantly lower prevalence of wasting, higher weight-for-height z-scores, lower prevalence of stunting, higher height-for-age z-scores, lower rates of child morbidity, an increase in access and utilization of boreholes, better practices around the water chain, lower open defecation, and increased knowledge on hand washing by the endline. However, an important consideration that is not accounted for by the annual panel study design is the seasonal variation in malnutrition and its potential causal links. While seasonality is not well understood, it is assumed that seasonality impacts nutritional status in Chad in two main ways. First, different nutrients are available at different points in the year through consumption of more, or less, diverse foods. In addition, variations in dietary adequacy affect variations in available energy throughout the year. Second, different infectious diseases are more prevalent at different points in the year (Ferro-Luzzi, 2001), and these can also impact growth in different ways (Ferro-Luzzi and Branca, 1993). It is therefore important to consider the findings (which provide a snapshot in time) within the wider seasonal context.

It is also important to note that Dar Sila experiences significant variations in rainfall between years and hence in pasture availability and crop productivity. The relative conditions of the research years of 2011,[1] 2012, 2013, 2014, and 2015 have important implications for the findings, both in terms of driving some of the indicators (such as food insecurity) and in potentially influencing the causal links to other outcome variables (such as malnutrition), irrespective of the intervention. In brief, both 2012 and 2014 were identified as good harvest years, compared to 2011, 2013, and 2015, which were years with poor harvests. In all three poor-harvest years, a general seed or food distribution was carried out. The implications of these variations are explored in greater detail in the background section.

Throughout the report, we will also be discussing two different types of settlements: a *damre* and a village. A *damre* is a traditionally nomadic or pastoralist settlement, with a resident community who tend not to migrate with livestock (predominantly women, children, and older people), while other members of the community move seasonally with their herds (a more detailed description is provided in the background section). A village, on the other hand, is a primarily farming community in which nearly all members reside in the community through all seasons. And while both types of settlement occupy the same geographical area and often share natural resources, there are important distinctions and similarities identified in the data and reviewed in this report.

This report focuses on the impact of CRAM after four years of programming and is divided into four sections. First, we describe the methodology, then provide information on the context and livelihoods in the program area of Dar Sila. Next, we present the findings specifically related to the impact evaluation, focusing on child nutrition and health and WASH. We then use regression analysis to identify links with acute malnutrition whose interpretation is informed by the qualitative data. Finally, we discuss the findings and share conclusions.

[1] Data were not collected in 2011. However, data on food insecurity were collected retrospectively in 2012 at the baseline, and thus information on 2011 is included in the report.

METHODOLOGY

For the quantitative evaluation, enumerators collected data from participating households on a host of variables that are potentially linked to malnutrition and mortality. The framework for analysis is based on the original UNICEF Conceptual Framework explaining the causes of malnutrition, first adopted by UNICEF as part of their strategy to improve nutrition in the 1990s (UNICEF, 1990). While we used the conceptual framework to initially design the evaluation instrument, throughout the baseline, midline, and endline our analysis evolved based on findings and relationships identified in the previous data collection.

The study uses household panel data covering three sets of data collection over the course of four years of programming (2012–2015) to evaluate the impact of CRAM. The baseline survey for this impact assessment was conducted in November and December of 2012, with qualitative data collected in February and March of 2013. The Feinstein International Center collected midline data in November and December of 2014, and endline data (both quantitative and qualitative) in November of 2015. In addition, a small qualitative exercise was carried out at the height of the dry season in May of 2016 to follow up on some of the livestock-related findings coming out of the quantitative data collection. Thus, the data collection spanned the four years of CRAM programming. This report presents findings from the three sets of quantitative and qualitative data collection. In the remainder of this section, we present information on the study design and sampling, attrition, data collection, and data analysis used in the report.

Study design and sampling

The CRAM impact evaluation used a randomized control trial design (with 69 settlements serving as clusters, split evenly and assigned randomly between non-intervention and intervention; there were 20 households per cluster and an intended total sample of 1,400 households). The sampling universe included all households served previously by Concern Worldwide as part of a humanitarian blanket food aid distribution and general ration program in 2010. Concern identified households according to the lead female, in order to ensure that polygamous households were equitably targeted and to distribute the general ration primarily to the female caretaker. These women served as the survey respondents,[2] as we believed that they would likely have a more accurate perspective of household dynamics related to children, food, and health.

Prior to the blanket food aid program carried out by Concern in 2010, Concern conducted a participatory wealth ranking in the recipient settlements. Concern worked with each community to categorize every household by their comparative status in terms of livestock ownership, income, and livelihoods (indicators self-selected by the community as proxies for wealth). Following the categorization exercise with the communities, Concern rated each household on a scale from A through D, with A being the most well off and D being the least well off. Concern then selected the households to receive the program from the three bottom wealth groups, B, C, and D, using simple random selection within each settlement.

Each settlement served as a cluster. Given a power of .80, a significance level of 0.05, a minimum effect size of .22, and an intra-class correlation of .06, the study required a total of 1,400 households clustered in 70 settlements. We used child mid-upper arm circumference (MUAC) for the initial calculation to determine the sample size. Concern provided the MUAC data from a rapid assessment carried out in 2010 in preparation for the blanket food aid distribution. Once all the baseline data were collected, the same calculation was repeated for all the settlements. The intra-class correlation remained .06, validating the initial sample size.[3]

[2] The household list provided by Concern contained only the names of women (which fit the purposes of the study nicely). However, due to the polygamous nature of the context, it is possible that some of these women shared the same husband.

[3] The CRAM program, however, has had an impact of increasing the clustering of malnutrition, and thus the intra-class correlation (ICC) drastically increased in the midline (10 percent ICC) and endline (20 percent ICC).

In order to meet this requirement and keep clusters of equal size (variance of the total sample is likely to be larger with unequal clusters), only settlements that had 20 households or more with a B, C, or D wealth ranking were selected. Settlements were randomly assigned to the intervention and non-intervention group.

Data for the annual survey were collected from 69 settlements, 7 of which were *damrat*. Settlements were oversampled in the baseline to account for possible attrition over time, with the total number of sampled households coming to 1,420 (Table 1). In the midline and endline, the same households were tracked in order to control for household-level characteristics in the analysis that are not necessarily captured in the data. It is important to note that, though the same household were tracked, the same children were not tracked. While some of the same children should appear in the surveys, others would have grown out of the under-5-years-old category. Due to mortality, migration, and relocation, approximately 11 percent of the baseline households were not re-surveyed in the endline. While this attrition rate is not ideal, household attrition was not correlated to intervention (i.e., there was no difference in the rate of attrition between non-intervention and intervention settlements) and therefore does not introduce bias in the analysis.

Table 1. Sampling and attrition

		Non-intervention	Intervention	Total
Household	Baseline	719	701	1,420
	Midline	638	609	1,247
	Endline	632	627	1,259
	Attrition (#)	87	74	161
	Attrition (%)	12%	11%	11%
% of households with children 2 years of age or younger	Baseline	47%	42%	44%
	Midline	41%	33%	37%
	Endline	35%	44%	39%
% of households with children 5 years of age or younger	Baseline	64%	53%	59%
	Midline	57%	47%	52%
	Endline	50%	60%	55%
Child roster[4]	Baseline	860	795	1,655
	Midline	801	772	1,573
	Endline	751	754	1,505
Children with anthropometric data	Baseline	647	614	1,261
	Midline	572	555	1,127
	Endline	543	487	1,030
Household roster	Baseline	3,826	3,686	7,512
	Midline	3,604	3,352	6,956
	Endline	3,501	3,453	6,954

[4] The survey followed the same households, but not the same children, over time. Thus, as children got older (over the age of 59 months), the survey no longer collected information on them. Given cultural norms, it is expected that older children would be in school, working, living with a different family, etc.

For the children[5] who were sampled, we were only able to collect anthropometrics for approximately 70 percent (throughout all three rounds of data collection). In the endline, information on why children were unavailable for anthropometric measurements was collected. Eighty-four percent of the children who were not available were physically not present, while the remaining 16 percent were too ill to have data collected on them. While there was no significant difference in rates of absence due to illness between the intervention and non-intervention group, a significantly larger proportion of children were absent from the intervention settlements ($p < 0.05$). Children who were absent at the time of data collection were significantly older (on average 40 months) and significantly less likely to have been sick in the past two weeks ($p < .05$). There was no difference in these characteristics of absent children between the intervention and non-intervention settlements. Thus, while this difference does introduce bias in the data, the bias likely strengthens our conclusions, as it removes data on healthier children from the intervention settlements. Therefore, any impact we are seeing on malnutrition is biased downwards by the absence of these children. Another possibility is that having a greater number of older children missing from the intervention settlements would bias the rate of stunting downwards, thus making it more likely that the data would show an impact of CRAM on stunting. While this is a possibility, we did not observe a relationship between age and stunting in the data as a whole or in the baseline and endline. There was a significant relationship at the endline, but in the opposite direction: younger children were significantly more likely to be stunted ($p < 0.05$). Thus, it is not likely that the bias introduced by more missing older children in the intervention settlements overestimates CRAM impact.

We undertook qualitative data collection in February and March 2013, including a total of 21 focus groups and 16 key informant interviews in 24 settlements within Concern's program area. Then, in November of 2015, we carried out 9 focus groups and 30 key informant interviews in four villages and two *damrat*, with the aim of deepening understanding of livelihoods in the local context. Finally, we conducted 6 focus groups spanning 6 settlements, divided evenly between *damrat* and villages, in May of 2016. The qualitative data and analysis allowed for further exploration of the plausibility of causality in the significant relationships observed in the quantitative data. Settlements were selected purposively, in an effort to represent a variety of perspectives, reflecting the settlements' experiences of recent conflict and displacement, predominant livelihood activities, ethnicities, previous Concern programming, locations, and sizes.

Focus groups were composed of five to eight individuals from the settlement and were organized around specific themes for each of the focus groups: livelihoods and wealth, agriculture, community mapping, gender, health and hygiene, risk and vulnerability, water access, livestock, child mortality, and coping strategies. Key informant interviews were conducted with settlement chiefs, community health workers, elders, and WASH committee members about the history of the community, land tenure practices, relationships to other local communities, and access to water.

Data collection

We carried out household interviews using a quantitative survey and used the household as the main unit of analysis. For the purpose of the survey, households were defined as the group of individuals who normally eat their meals together. In the context of polygamy, which is widespread in the region, households were sampled by the name of the woman or wife, and the identified/selected woman served as the survey respondent.[6] Among those households that were successfully followed up, the same respondent was interviewed in every round of the survey.

[5] It is worth noting that information was collected on all children in the household. The respondent was not necessarily the mother of these children, however.

[6] The sampling frame provided by Concern was the list of these women.

The enumerator training prior to the data collection took two and a half weeks and included a training on the survey, survey methods, anthropometrics, and proper use of tablets. Data collection was carried out over the course of five weeks, covering the same time period for each survey: November and December. We used four enumerator teams that were made up of five enumerators each, including the supervisor.

The enumerators conducted one-on-one interviews using a standardized questionnaire on a tablet in the intervention and non-intervention settlements. The enumerators were not informed which group they were surveying. Each interview took approximately an hour and a half, with each enumerator typically completing two to three interviews a day.

Data analysis

Program impact analysis

Prior to the analysis, we cleaned and analyzed the quantitative household data, including the anthropometric data, using Stata. After transforming the anthropometric data into z-scores,[7] we removed outliers (z-score greater than negative or positive 5 for weight-for-height and z-scores greater than negative or positive 6 for length-for-age). We then checked the data for patterns with enumerators to make sure that no enumerator was consistently marking children at higher or lower values. No such patterns were identified in the data.

We then adjusted the cleaned data for the sampling design and assigned each settlement population weights[8] according to the settlement registration provided by Concern Worldwide. We used logit and ordinary least squares (OLS) regression models for binary and continuous outcome variables, respectively. Given that the intervention was randomized at the baseline, all significant differences after the baseline can be attributed to the intervention. At the baseline, all indicators were compared across the intervention groups to make sure that the randomization "worked." Only two indicators showed a significant difference: mortality (at 1 percent) and seeking care for an ill child (at 10 percent). All results, unless otherwise specified, use population statistics. Relationships are identified as significant if the p-value[9] is less than ten percent.

Three types of analysis were carried out for each of the variables in the program impact section. Each is noted with its own notation:

1. Whether the difference between the intervention and non-intervention was significant in each time period (notation: *);
2. Whether there was a significant difference over time for the full dataset (intervention plus non-intervention households/children combined) (notation: [a]);
3. Whether there was a significant difference over time (i.e., from the baseline to the endline) for the non-intervention (notation: [c]) or intervention (notation: [t]) households/children.

[7] WHO standards were used for the transformation. Transforming the data into a z-score (or standard deviation score) allows us to standardize it against international norms of growth (i.e., optimal growth under ideal conditions). Thus, the z-score tells us how far and in what direction (positive or negative) a measured value (in this case weight-for-height or height-for-age) deviates from the population mean (the value 0), expressed in units of the population standard deviation (i.e., -2 standard deviations in a weight-for-height z-score from the population mean implies the child is wasted). It is derived from dividing the difference between individual values and the population mean by the population standard deviation. Thus, data are standardized and easily comparable across age and gender and context.

[8] A correction technique was applied to the sample. Given that an equal number of households were chosen from each village, despite the size of the village, children living in smaller villages were over-represented in the sample, and people living in larger villages were under-represented compared to their actual proportion of the population. Hence, a weight equaling the inverse of the probability of being selected from a village was applied in order to calculate representative population statistics, which are reported here.

[9] The p-values is the degree of confidence at which there is certainty that any observed change or comparison group difference of the magnitude specified would not have occurred by chance. For example, a p-value of 0.05 denotes a 95 percent confidence that the observed difference did not occur by chance.

For each notation, one notation (ex: ★) means it was significant at p-value less than 10 percent, two notations (ex: ★★) means it was significant at p-value less than 5 percent, and three notations (ex: ★★★) means it was significant at p-value less than 1 percent. The p-value is the probability of finding the observed difference if the observed difference did not actually exist, so the smaller the p-value, the more significant the difference. Thus, we want a very small p-value so we know the probability of our being mistaken in the existence of a significant difference is quite small.

For example, given the notation in Table 2, we can say there was a significant difference over time ($p < 0.05$) for the whole population, a significant difference over time in the intervention group ($p < 0.01$), a significant difference over time in the non-intervention group ($p < 0.1$), and a significant difference between the intervention and non-intervention group at endline only ($p < 0.05$).

Links to malnutrition analysis

To take advantage of the panel nature of the data (i.e., following the same households over three time periods), two models were run: a random and a fixed effects model.[10, 11] The fixed effects regression model specifically captures change within a household over time. This approach exploits within-household variation over time by holding the average effect of each household constant. It therefore removes omitted variable bias. The fixed effects model is a particularly strong tool for panel data analysis, because the model directly controls for household-level characteristics that are not necessarily captured in available variables or are simply unobservable predictors. However, because the fixed effects model relies on within-household variation over time, it cannot assess the impact of variables that are constant over each time period (such as intervention designation, *damre* status, etc. For this assessment, we use the random effects regression, which allows the model to capture changes between households and within households over time.

Both the fixed and random effects models can only be run on panel data. While we followed the same household over time, we did not follow the same child over time. Thus, all the data in the model had to be aggregated at the household level. While this has no impact on variables such as water access, household food security, household size, etc., it does impact how the child data are included. The dependent variable in the model is the minimum weight-for-height z-score in the household. Thus, even if a household has multiple children, only information (such as age and gender) on the child with the lowest weight-for-height z-score is included in the regression. The regression results tell us how different child, household, and settlement characteristics affect the weight-for-height z-score of the most malnourished child in the household. In order to account for the fact that the number of children under the age of 5 in a household included in the regression varies from one to five, a variable that captures this information is included (and is significant) in the model. However, it is important to note that, because the survey did not follow the same child across time, the fixed effects model cannot be used to interpret what the impact of changes in the child's age and gender might have on the minimum household weight-for-height z-score. We can (and did), however, use the random effects model to

Table 2. Example of significance notation

	Non-intervention[c]	**Intervention[ttt]**	**Total[aa]**
Baseline	2.44	2.36	2.41
Midline	2.65	2.70	2.68
Endline	2.75	2.81★★	2.78

★★★ significant at 1%, ★★ significant at 5%, ★ significant at 10%

10 A Hausman test was carried out on the models to make sure that both a random and fixed effects model could be run.

11 While a difference-in-difference model was considered, the authors decided to use the fixed and random effects models to determine impact in order to take advantage of all three data points.

interpret how age and gender affect differences in outcomes between children.

In order to better compare the impact of included variables, all coefficients were centered. When a variable is centered, a constant is subtracted from every value of the variable. Thus, the interpretation of the coefficient changes but not the slope between the independent and dependent variable. This means a significant coefficient of value X translates into an expected increase of X point/units when the independent variable goes up by 1 from the mean. For binary variables, no centering is needed, and a similar interpretation can be applied: a value of X means an expected change of X points/units in the dependent variable when the independent variable changes from 0 to 1 and vice versa.

To better understand the role of the intervention on malnutrition rates, we included an "intervention" term in the model that took the value of 0 at the baseline (because the package of CRAM activities had not fully been put in place yet) and the value of 1 at the midline and endline if the household lived in the intervention settlement.[12] This allows the model to capture both the difference between households in the intervention and non-intervention settlements (random effects model) and also the impact of going from not receiving to receiving the intervention in the intervention settlements. In addition, we ran the models for the full dataset and separately for the intervention settlements (baseline, midline, and endline) and non-intervention settlements (baseline, midline, and endline) in order to better understand how child, household, and settlement characteristics might affect malnutrition differently in the two sets of settlements.

Finally, we based variable selection for the model on a combination of trying to model the UNICEF framework and limiting the inclusion of variables to only those that contributed to the explanation of the variance in weight-for-height z-score between and within households. The only exception was the inclusion of household size and age of household head (neither of which was significant), both of which showed variation between households and were considered important controls for the interpretation of other household characteristics. On the other hand, livelihood type was both insignificant (in all iterations of model construction) and generally homogenous across time and household, with at least three-quarters of households, at any one time, practicing subsistence production. Hence, livelihood type only encumbered the model, without changing the significance and interpretation of other included independent variables. Thus, livelihood type was excluded from the model.

Qualitative analysis

Researchers took notes during the focus group discussions (FGDs) and interviews, and made personal observations while in the field. They later compiled a set of field notes, one set per settlement, and from this set developed a report based on key themes. For example, the 2013 report provides a summary of the information and perspectives gained through FGDs and interviews according to the following thematic areas: livelihoods (land allocation, livestock, diversification, and migration), community perceptions of wealth and poverty, gender dynamics in the household and community, health and hygiene, and community perceptions of risk and vulnerability (Bontrager, 2013). These reports provided important contextual background and insights that assisted with

[12] Another way of putting it is that we have three rounds of data collection on the same settlements. At baseline, the 35 non-intervention villages take the value 0 for this variable, because they do not receive the CRAM package. Similarly, the 34 non-intervention villages also take the value 0 at baseline, because it took a while for CRAM to be implemented. However, at the midline and endline, the non-intervention villages keep taking the value 0 because they never receive the CRAM package, while the intervention villages take the value 1 at midline and baseline because they receive the CRAM package. In the fixed effects model, the binomial intervention term (0 or 1) allows us to capture how intervention household malnutrition changes between the baseline and the average value of the other two points of data collection. In the random effects model, the binomial intervention terms allow us to look at the average difference between all the households in the baseline, plus non-intervention households in the midline and endline versus the intervention households in the midline and endline.

interpreting the quantitative data and explored themes arising from the quantitative analysis. The qualitative work both helped determine the focus of the quantitative research on the WASH sector as a potential driver of acute malnutrition in the region and helped the researchers better understand the implications of the relationships identified in the "links to malnutrition" analysis. Throughout the report, the qualitative findings are incorporated into the analysis in order to better understand the relationships being drawn out from the quantitative research.

Limitations

A few limitations were identified in the study. One limitation of the research is that the study did not follow the same children. In order to take full advantage of the panel nature of the data, the main regression analysis has to aggregate child data at the household level. Given the nature and duration of the research, following the same children would not have been appropriate and would have been extremely difficult. However, the result is that we cannot control for innate child characteristics (e.g., age and sex) that are not captured in existing variables and are different from those of the household when doing time-series analysis.

Another limitation is due to the timing of the survey. To best understand the impact of the program on malnutrition, data collection would have ideally occurred during the annual period when malnutrition rates are at their worst. While initially we assumed that malnutrition peaks at the end of the hunger gap (August and September), there are hints in the data and available historical Standard Monitoring and Assessment of Relief and Transitions (SMART) surveys for Dar Sila that a peak might also occur immediately preceding the hunger gap (May and June).

It is also important to note how the sampling strategy impacts the interpretation of the findings. The survey population is potentially biased by the inclusion of only certain settlements (primarily focused on farming and cultivation and not taking account of pastoralists who are not cultivating), households (limited to the most vulnerable households as identified by Concern's wealth ranking), and wealth indicators (livestock wealth is notoriously difficult to measure). While the exclusion of non-cultivating pastoralists does not affect the impact analysis, it does mean that the data are not representative of Kimiti or Dar Sila more broadly. For example, the inclusion of only the lowest wealth ranking might make it appear as if malnutrition rates are significantly higher than what is found in more representative surveys.

BACKGROUND: ENVIRONMENT, SHOCKS, AND LIVELIHOODS IN THE DAR SILA REGION

The Dar Sila Region of Chad is located in the far east of the country on the border with the Republic of Sudan (see map in Figure 1), more than 900 km from the capital Ndjamena. It lies just south of the Sahelian belt that borders the Sahara Desert, in the region known as the "Sahelo-Sudanian" agroclimatic zone. This region is characterized by open grasslands and seasonal rivers (*wadis*), that support the area's main livelihood options (Morton, 1985). Livelihood strategies in this area are predominantly rainfed cultivation, market gardening, and livestock production. Pastoralist herds move through the area according to their seasonal migration patterns.

This impact evaluation captures information only on agricultural[13, 14] and agropastoral households due to Concern's historical programming focus. However, even households that derive their main income from agriculture may also practice animal husbandry and labor migration. Furthermore, while the rural settlements included in the study are agriculturally based, the area (and sample) is also dotted with *damrat* that often practice different livelihood strategies. From the qualitative interviews, we found that many of these settlements originate from the migration south associated with the 1984–1985 famine. Both Arab nomads who lost livestock and farmers from Ouaddai, north of Dar Sila, arrived in Dar Sila in large numbers during the drought. Similar migratory patterns south were evident in the neighboring Darfur region (de Waal, 1989). This dynamic history has resulted in an ethnically diverse population in the region, one which, while often peaceful, has also at times contributed to tensions, often through exploitation by outside groups.

Rainfall variability, crop production, and food security

Livelihood systems and food security in this region are strongly influenced by the extreme seasonal and interannual variability in rainfall patterns (see Figure 2).[15] Annual rainfall for the study area ranged from 663 mm (in 2014) to 884 mm (in 2012), showing great variability across years. However, the timing and distribution of rainfall within the year is as important as the

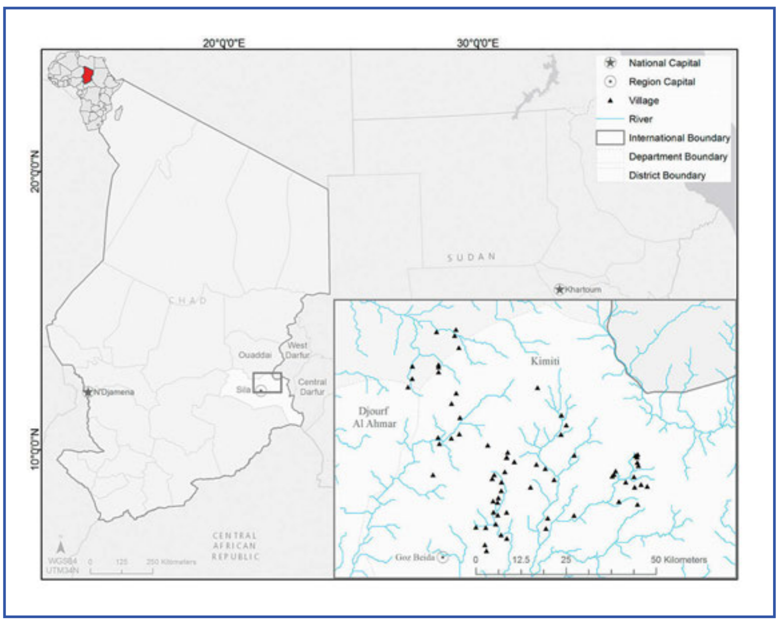


Figure 1. Map of Dar Sila and the CRAM research catchment area.

[13] While agriculture usually denotes both crop cultivation and livestock, in this report it is synonymous with cultivation, unless otherwise stated.

[14] Between 12 and 27 percent of households in the sample reported having no livestock.

[15] Monthly rainfall distribution (and not cumulative yearly rainfall) is closely correlated with millet crop productivity (kg/ha).

annual total, as this influences the scheduling of rainfed agricultural activities (planting, weeding, harvesting, etc.) and the timing of livestock migrations.

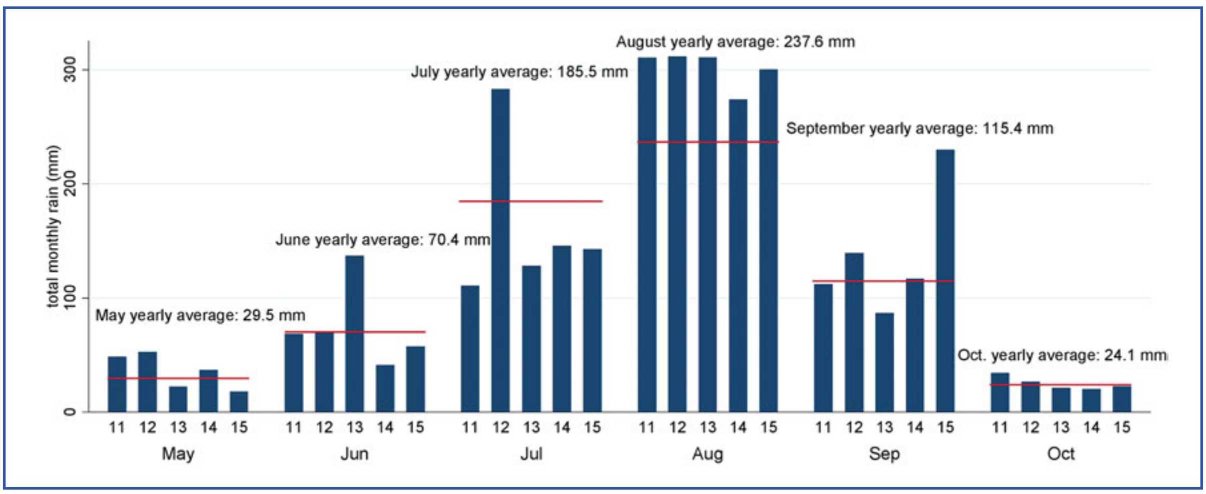
In terms of more long-term decadal trends, while serious concerns have been expressed about an increasing frequency of drier years since the seventies (Bromwich, 2008; UNEP, 2007), an analysis of the past 100 years of historical rainfall in the Sahel shows that any evidence of a persistent and coherent regional trend in diminishing rainfall is minimal. Where change is present is in the highly localized interseasonal, interannual, and multiannual variability (Hermance, 2014). In other words, the general trend is not so much toward an overall drier climate; rather, the climate is more unpredictable, with larger changes from one year to the next and more frequent extreme wet or dry years.

The baseline was carried out in November and December of 2012. By all accounts, in terms of both rainfall and crop productivity, 2012 was one of the best years in Dar Sila in the past decade. In 2012, cumulative rainfall was 884 mm,[16] and the millet yield was 875 kg/ha.[17] On the other hand, 2011 was one of the worst years in the last decade in terms of the same measures: 688 mm of rainfall fell cumulatively, and a millet yield of 292 kg/ha was recorded. Households, having experienced a below-average harvest in 2011 and significant flooding in 2010, had depleted food stocks, limited labor opportunities, increased migration, and were particularly vulnerable to any shocks in 2012, even though the 2012 harvest promised to be exceptional.

The midline data were collected during the 2014 harvest. The 2014 cumulative rainfall was 663 mm, with an above-average millet yield of 750 kg/ha. Similar to 2012, the harvest preceding the data collection (2013) was very poor, with a reported millet yield for Kimiti of 350 kg/ha. During the endline data collection, the situation was reversed. In 2015, the millet yield (400 kg/ha) and reports from the field indicate a poor harvest, following an above-average 2014 harvest.

The variation in crop production is reflected in household food insecurity data collected during CRAM (number of months of food insecurity; and an additional data collection in 2013 from a small sub-sample of the beneficiaries). Similar to

Figure 2. Total rainfall, by month, for 2011-2015 and average total monthly rainfall for 1998-2015.



16 All rainfall data are sourced from NASA's Tropical Rainfall Measuring Mission (TRMM) (http://trmm.gsfc.nasa.gov/) and cover only the area immediately surrounding Concern's programming catchment area. The rainfall values, on average, are larger than what is described in the FEWS NET reports. The discrepancy is likely due to the use of different satellite data and requires further exploration.

17 All yield data comes either from FAO Chad or the regional Office National du Développement Rural (ONDR).

reported millet productivity, retrospective monthly food insecurity was lowest in the baseline (2012, following 2011 harvest/rains) and at the time of the 2013 data collection (2013 IAPF sub-sample, following 2012 harvest/rains) and highest at the time of the midline (2013, following 2012 rains) and the endline (2015, following 2014 rains) (see Figure 3). However, we see that, even in "good" harvest years, seasonal peaks are still extremely apparent.

In an average year, households during the qualitative investigation reported planting in mid to late June with the coming of the first days of consecutive rainfall and starting to harvest in October. However, in 2015 (the year of the endline), the rains were significantly delayed by over a month. Thus, households reported that they did not begin planting until almost the end of July, leading to delays (compared to previous years) in harvesting. Thus, while data collection occurred in the same time period all three years (November and December), the 2015 endline data might be more reflective of what households normally experience in October, at the very beginning of the harvest rather than at the end. The impact can apply to food availability, labor opportunities, water access, morbidity, etc. This distinction of the endline can have reverberating effects on the comparability of many of the CRAM indicators, which are sensitive to rainfall, over time.

Exposure to risks, shocks, and hazards

Droughts are a frequent occurrence, and as explained above, impact crop production in the region and, in turn, market supply and local livelihoods. As a border region, there has been a long history of cross-border conflicts that served as the backdrop for a Sudan/Chad proxy war (Tubiana, 2008, Burr and Collins, 1999). Between 2005 and 2010, Dar Sila region of Chad experienced large-scale displacement resulting from conflict on both sides of the Chad-Sudan border, with the worst of the violence and displacement occurring in 2006 and 2007. The region continues to recover, and although the UN and NGO presence has diminished since the years of conflict and immediate recovery, some international agencies have remained.

While insecurity has decreased, the region remains vulnerable to food insecurity related to a number of factors, including unpredictable rainfall patterns, market price variability, limited community and household assets, and limited alternate livelihood options for the maintenance of food stocks. In the past 50 years alone, the Emergency Disasters Database (EM-DAT) has documented 57 natural disasters in Chad, including droughts, floods, epidemics, and pest infestations. The impact on households is exacerbated because of the low level of services

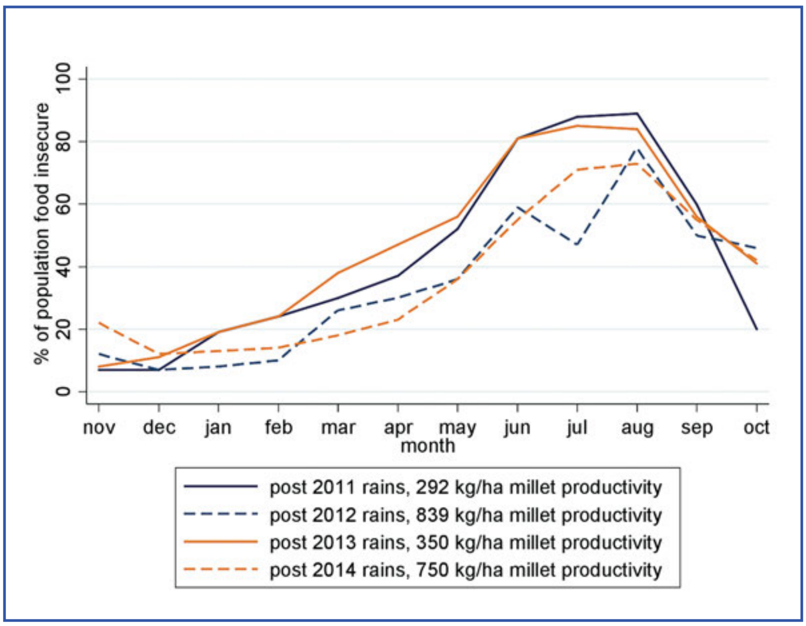


Figure 3. Food insecurity by month and year.

and infrastructure. For example, for all of Dar Sila, there are only two doctors, both of whom reside in the department capital of Goz Beida.

Livelihood strategies

The livelihood strategy of a household includes the bundle of livelihood activities that provides food and income for the household, supports the development of five types of livelihood assets (financial, social, natural, human, and physical), and reflects the household's livelihood goals. This section reviews the main livelihood activities that contribute to the households' food and income and reviews trends in livelihood diversification and migration and remittances, all of which are crucial to managing risk and are thereby indicative of resilience.

For this analysis of food and income sources, we aggregated 55 activities[18] into six groups: casual and permanent wage labor, primary production (cultivation or livestock), farm monetary self-employment, off-farm monetary self-employment, and "no activity."[19] These groups are used throughout the report. We chose these five categories because they represent a general description of livelihood options in the area, and they potentially represent the relative resilience of the livelihood system. Thus, movement from one category to another over time or by treatment would show a change in the household risk portfolio rather than simply movement between jobs. An earlier study in Darfur found that people select particular sources of income in a strategic pattern and move in and out of various income streams, as the context and their assets allow, to maximize their immediate and long-term outcomes while coping with and recovering from shocks (Fitzpatrick and Young, 2015).

The households sampled in the survey primarily practice primary production. Agriculture or livestock production is practiced by between 65–75 percent of households in any given year. See Table 3.

We observed a significant jump in the proportion of households relying on casual/day wage labor from the baseline to the midline, with only slightly lower rates at the endline. This trend likely corresponds to the greater availability of jobs in Goz Beida building the stadium and boulevard.

Table 3. Main household livelihood activity by time

	Baseline	Midline	Endline
Casual labor [aaa]	2%	12%	7%
Permanent wage labor	< 1%	< 1%	0%
Primary production	70%	66%	75%
Monetary farm employment [a]	9%	5%	6%
Monetary off-farm employment [a]	8%	8%	6%
Outside support/nothing [aaa]	10%	9%	6%
Livelihood diversification [aaa]	1.26	1.16	1.16

18 Casual wage labor includes agricultural labor, day labor, water carrying, working as a porter, mason construction, and gold mining. Permanent wage labor includes domestic work and government job. Primary production includes subsistence farming, pastoralism, sedentary livestock production, and shepherding. Monetary farm employment includes selling crops or garden produce in the market. Monetary off-farm employment includes livestock trading, petty trade, business, travelling sales, working as a traditional healer, brewing of local alcohol, and working as a butcher, engineer, tailor, blacksmith, or artisan. In the outside support/nothing category, sources of income include: selling collected firewood, government allowance, support from relatives, support from host family, community wealth redistribution, begging, and none.

19 This group included individuals who reported no activities (for example, because they are a student) or activities that are dependent on support from relatives, friends, or the community.

We observed a significant difference in livelihood diversification[20] over time. Households had a significantly less diversified portfolio at the endline compared to the baseline. This change is due to the shift from farm employment (both primary and monetary) to casual wage labor on the individual and household level. Usually, in rural settings, diversification implies moving away from strictly crop and livestock production and toward a combination of farm and non-farm activities, self-employment and wage labor, and local versus migratory activities (Hussein and Nelson, 1999; Ellis, 2000). While this movement is observed in Dar Sila, it is actually linked with a less-diversified household. This implies that, unlike in many rural settings, in Dar Sila there is not a surplus of labor. Households have to reallocate members to the most lucrative livelihood opportunities (i.e., labor is the limiting factor). The shift to casual labor corresponded with a reduction in other livelihood sources and a reduction in total number of livelihood activities a household is involved in.

Migration plays a key role in household livelihoods in Dar Sila. Between one-quarter and one-third of all households reported having at least one person migrate in the past year. Migration significantly increased from the midline and baseline to the endline (from 30 percent of households having at least one member migrate to 39 percent of households; $p < 0.01$). This is likely correlated to the difference in the harvest between the three years. The endline data were collected during a poor harvest compared to the baseline and midline data, which were collected during a good harvest. Thus, while migration (both short and long term) is frequently utilized, it can also be partially seen as a coping strategy to diversify and increase income during poor harvest years. However, only 15 percent of households reported receiving remittances in the endline.

Livelihood assets

Livelihoods are based on a range of assets that a household owns or can access, which can be categorized into five groups: financial (and/or economic capital measured using the Morris Score Index or MSI), natural assets (primarily access to land and water), physical assets (livestock ownership), human resources (education, health, and nutrition), and social capital (decision-making power, local institutions). The latter is not included in the analysis.

Financial capital

The MSI has been developed as a proxy for household wealth using data on asset ownership (Morris et al., 2000). Given the difficulty in collecting information on household expenditure or income, particularly in settings where the majority of households rely on production instead of wage employment, the MSI has been shown to be a good wealth proxy (Morris et al., 2000). The MSI is constructed by weighing each durable asset by the share of households that report ownership of that asset in the sample. In order to measure change in the MSI over the course of the three studies, weights from the baseline were applied to the midline and endline, despite changes in ownership proportions of different assets.

Wealth (as measured by the asset index) significantly increased from the baseline to the

[20] The livelihood diversification variable was constructed by summing the different livelihood type categories described above: casual wage labor, permanent wage labor, primary production, monetary farm employment, and monetary off-farm employment. The livelihood diversification variable captures household risk diversification rather than just different sources of income. If all the activities performed by household members are subject to the same risks—for example, if all activities are rainfall-dependent—then while the activities themselves may appear to be diverse (i.e., subsistence agriculture and keeping sedentary livestock), the risks are not reduced through this form of diversification. It may be more appropriate to look at activities in terms of how they diversify the risks to which the household is exposed rather than only as sources of income. Additionally, several activities that function more as coping or supplemental strategies than as diversification of risk strategies were removed entirely. These included collecting firewood/fodder, receipt of support from community, receipt of government allowance, community wealth redistribution, and begging. On average, a household engages in activities from one to two different livelihood groups.

endline for the entire Concern catchment area ($p < .01$), thus indicating that households continued to build up their asset base from year to year, irrespective of the shocks mentioned.

Natural capital

The majority of households reported having access to land for cultivation, whether via sharecropping or cultivating their "own" land (see Figure 4). While there were no changes over time in the average proportion of households that reported each category of land ownership, it is worth noting the mercurial nature of land ownership that is most likely a reflection of the fluidity of customary land tenure regimes. Approximately half of all households reported the same type of land ownership from baseline to endline; however, the remaining 50 percent changed their status between time periods.

Physical capital

Though cultivation was identified as the primary livelihood activity for the majority of households, between 70 and 86 percent of households reported livestock ownership throughout the course of the data collection. This is a reflection of the importance of livestock production as a source of income and its integration into agrarian livelihood systems in the Sahel belt. Most households in the sample, while deriving the majority of their food from cultivation, also practice animal husbandry. For those households that own livestock, it serves not only as a source of food but also is an important investment and buffers the household against shocks. Hence, livestock is used as an additional measure of wealth in the research.

A weighted livestock index (WLI) was constructed for the measurement of livestock wealth, using the animals reportedly owned by the household. In order to account for different types of livestock and their variable values, weights were attached based on cost ratios for the region. For example, the cost of a camel is equivalent to 110 chickens, and the cost of a goat is equivalent to 8 chickens. There was no significant difference in WLI over time. However, there were some significant changes over time for the population as a whole in relation to donkeys, goats, chicken, sheep, and cattle ownership. The most relevant change to this report is a significant increase in the proportion of households owning cattle ($p < 0.01$) over the course of the four study years (see Figure 5).

Human capital

When comparing levels of formal education by age group over the long term, it appears that access to education has increased. However, the levels of formal education remain extremely low and have been consistently and significantly dropping in Dar Sila, driven by fewer younger

Figure 4. Land ownership by time and intervention.

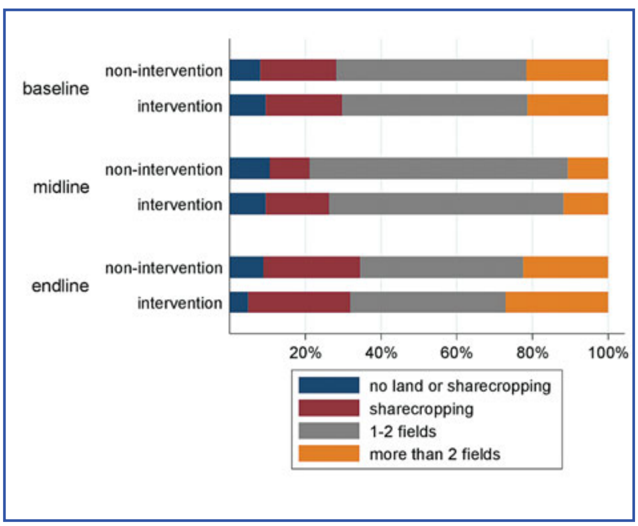
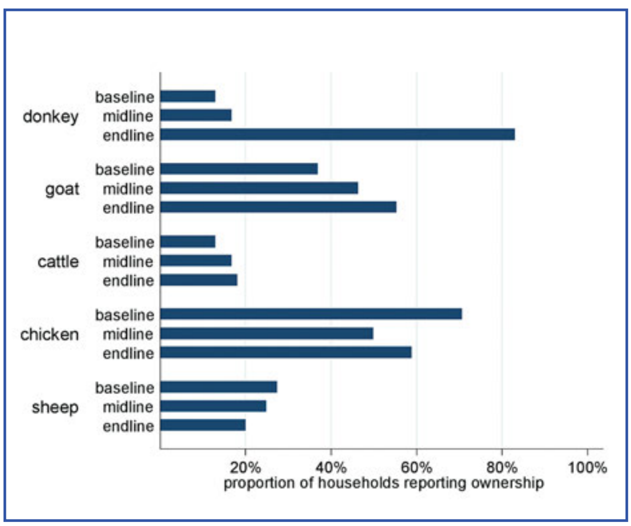


Figure 5. Change in livestock ownership over time.



children being enrolled in formal education every year (see Figure 6). Thus, we find that the beneficiaries in the CRAM catchment area have extremely low, and declining (due to fewer children being sent to get a formal education), values of human capital.

The main reason why households reported that their child did not attend school was distance or lack of a school in the area (82 percent). The proportion of households reporting this reason significantly increased over time ($p < .01$). Households that reported distance as a barrier were some of the farthest households from a school.

Conclusion

The high level of variability in rainfall, both within and between our years of data collection, influences livelihoods and underlies changes in household wellbeing over time. The timing, amount, and distribution of the rains affect the harvest and hence food availability and price, access to and behavior around natural resources, and household livelihood strategies. These annual and seasonal differences in rainfall have important implications for the interpretation of the findings in the following sections, as variation in rainfall impacts our population as much as, and in some cases more than, any direct impact of CRAM.

In addition to the variability of rainfall, households in Dar Sila frequently experience a range of idiosyncratic and covariate shocks, including conflict. However, households in our study catchment area appear to be on a general trajectory of recovery following the cross-border conflict and large waves of displacement experienced between 2005 and 2010. This trend toward recovery is most apparent when looking at household physical and financial capital. Both asset wealth (as measured by the Morris Index) and livestock wealth have steadily but consistently and significantly increased over the course of the three points of data collection. We can also interpret the livestock data to note the greater investment households are making in livestock, particularly goats and cattle, as they recover. Cattle are particularly relevant to our findings. We show in the "links to malnutrition" section the significant and negative relationship between village livestock cattle density and child nutrition outcomes.

Finally, while households appear to be recovering in terms of their ability to grow their financial and physical capital, human capital in the area appears to be on a slow and steady decline, with fewer young children enrolled in formal education with each consecutive year. This is particularly unfortunate given the significance and relevance of the level of education of the household head to child nutrition outcomes (see links to malnutrition section).

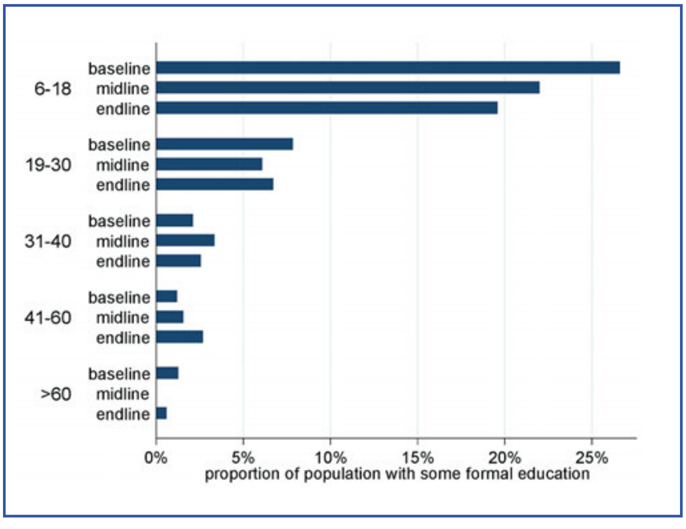


Figure 6. Formal education by age and time.

CRAM PROGRAM IMPACT: NUTRITION, MORBIDITY, AND WASH

In this section, we present data on where the CRAM program had an impact. CRAM had a significant impact in relation to child nutrition, morbidity, and water access. For child nutrition and morbidity, an impact is observed on both acute and chronic malnutrition at the endline. Taken together, there is sufficient evidence to show that CRAM has a positive impact on short-term malnutrition outcomes—wasting—and on longer-term malnutrition outcomes—stunting. It took the full four years of the program before we observed this impact, which indicates the need for long-term programming and multiple-year evaluations.

This section is divided into two parts: analysis and a brief summary of the program impact findings. We will focus on the two sectors where the program had an impact: nutrition and morbidity, and WASH. The analysis in this section is limited to comparisons between intervention and non-intervention settlements within each time period and across time for the population as a whole, as well as for the intervention and non-intervention population subset. In the next section, we explore the overall impact of CRAM, when controlling for a host of indicators. Then, in the "links to malnutrition" section, we will bring the individual findings together for an overall picture of program impact.

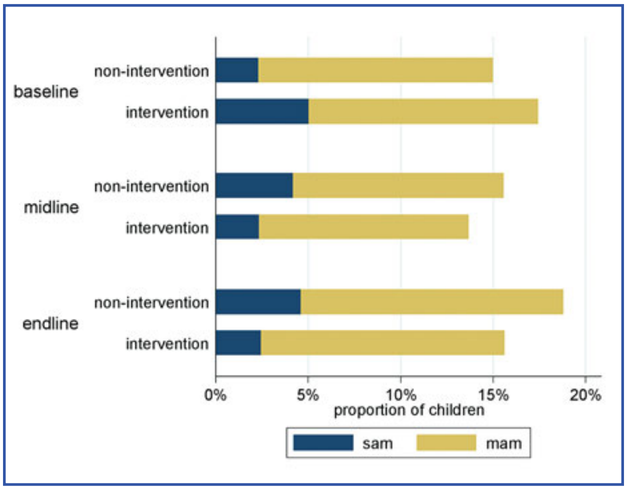
The impact of CRAM on nutrition, morbidity, and WASH

Nutrition and morbidity

In this section, we discuss the impact of the intervention on both nutrition and morbidity. At all three points of data collection, having a sick child and acutely malnourished child were significantly and closely correlated. Thus, while we cannot claim causality because the relationship between illness and malnutrition can be cyclical, exploring the impact of the intervention on all three of these measures (acute malnutrition, chronic malnutrition, having a sick child) and the randomized nature of the CRAM assignment allows us to triangulate the conclusion that CRAM had a positive impact on the prevalence of malnutrition in the program area.

For the duration of the study, the prevalence of acute malnutrition[21] (less than -2 WHZ) in the surveyed population remained at around 15 percent or higher (see Figure 7). At the endline, we see a large and significant difference in overall rates of wasting between the intervention and the non-intervention group (see Figure 7). Six percent fewer children in the intervention settlements were wasted compared to the non-intervention settlements (see Table 4) ($p < 0.05$). The prevalence of global acute malnutrition (GAM) significantly increased over the three time periods in the non-intervention settlements only (see Table 5). There was no relationship with time of data collection in the intervention settlements. While there is no statistical evidence that the intervention is decreasing the rate of malnutrition in the intervention settlements, it is preventing the rate from increasing (as is observed to be happening in the non-intervention settlements).

Figure 7. Acute malnutrition by time and intervention.



[21] There was no oedema in the dataset.

At the time of the endline, children living in the intervention settlements had a significantly higher weight-for-height z-score, on average, compared to children measured in the non-intervention settlements (see Table 4). Once again in the non-intervention settlements, we see a significant increase in acute malnutrition over time as measured by the continuous z-score.

At both the midline and endline, boys were significantly more likely to be malnourished (see Table 5) in the population as a whole ($p < 0.05$ and $p < 0.1$ respectively). In the intervention settlements, boys were more likely to be acutely malnourished at the midline ($p < 0.1$). In the non-intervention settlements, boys were more likely to be acutely malnourished at the baseline ($p < 0.05$). The impact of the program can be best observed on boys: at the endline, boys were significantly less likely to be malnourished in the intervention settlements versus the non-intervention settlements. While a difference is visible for girls, it is not significant.

The intervention did not have a significant impact on severe acute malnutrition (using WHZ < -3).[22] However, there is a significant increase over time in the non-intervention settlements only ($p < 0.1$). The significant increase in severe acute malnutrition over time among children in the non-intervention settlements ($p < 0.1$) is primarily driven by a large and significant increase in the rate of malnutrition among boys. At the midline, girls in the intervention settlements were significantly less likely to be severely malnourished compared to girls in the non-intervention settlements.

There is no significant difference in prevalence of acute malnutrition (using WHZ < -2) between children in the age group 6–23 months and the age group 24–59 months for the data overall (intervention and non-intervention combined). While the impact of the intervention on global acute malnutrition is apparent for the sample as a whole, when looking at the relationship by age group, the impact of the

Table 4. Weight-for-height mean z-score by intervention

	Non-intervention[cc]	Intervention	Total
Baseline	-0.95	-0.92	-0.93
Midline	-0.88	-0.85	-0.87
Endline	-1.13	-0.85**	-1.01

*** significant at 1%, ** significant at 5%, * significant at 10%

Table 5. Prevalence of GAM (WHZ<-1) by intervention and gender

	Boys			Girls		
	Non-intervention	Intervention	Total	Non-intervention	Intervention	Total
Baseline	19.3%	15.1%	17.3%	11.5%	16.7%	14.0%
Midline	15.1%	19.5%	17.0%	11.9%	12.0%	12.0%
Endline	24.2%	16.5%*	21.0%	17.0%	13.1%	15.0%

*** significant at 1%, ** significant at 5%, * significant at 10%

22 However, it is worth noting that the study was not designed to pick up significant differences in severe acute malnutrition (WHZ < -3), but rather in general acute malnutrition (WHZ < -2). A much larger sample size would have been required if the goal were to see a significant reduction in SAM due to CRAM.

intervention is only statistically significant for children between the ages of 6 and 23 months at the endline (see Table 6). The difference for children 24–59 months is large and quite close to significant (p = 0.117), but the difference is not large enough for the sample size for us to say anything definitively. Thus, the data show an overall positive impact of the intervention at the endline for children between the ages of 6 and 23 months.

At the start of the program, there was no significant difference in stunting between children in the intervention and non-intervention settlements. See Table 7. At the endline, children living in intervention settlements were significantly less likely to be stunted compared to children living in non-intervention settlements. This relationship is further supported by a significant difference between intervention and non-intervention settlements at the endline when using the continuous form of the stunting variable: height-for-age mean z-score (HAZ) (see Table 8). Similar to severe wasting, we did not observe impact from the program when looking at the most severe form of stunting (below 3 standard deviations).

At the baseline, children under the age of 2 years were significantly more likely to be stunted ($p < 0.05$). By the endline, children over the age of 2 were significantly more likely to be stunted ($p < 0.1$). The CRAM program was significantly correlated with lower stunting rates for children ages 24–59 months living in the intervention

Table 6. Prevalence of GAM (WHZ < -2) by age group, time, and intervention

	6–23 months			24–59 months		
	Non-intervention	**Intervention**	**Total**	**Non-intervention[cc]**	**Intervention**	**Total**
Baseline	22.40%	17.10%	19.70%	12.50%	15.40%	13.90%
Midline	13.60%	16.30%	14.80%	13.50%	15.10%	14.30%
Endline	24.4%	15.60%*	20.40%	19.20%	14.20%	17.10%

*** significant at 1%, ** significant at 5%, * significant at 10%

Table 7. Prevalence of stunting (HAZ < -2) by intervention

	Non-intervention	**Intervention**	**Total[a]**
Baseline	39.5%	36.7%	38.2%
Midline	41.8%	45.6%	43.6%
Endline	36.6%	30.1%**	33.6%

*** significant at 1%, ** significant at 5%, * significant at 10%

Table 8. Height-for-age z-score by intervention

	Non-intervention[cc]	**Intervention[tt]**	**Total[aaa]**
Baseline	-1.47	-1.41	-1.44
Midline	-1.68	-1.88	-1.77
Endline	-1.27	-1.07*	-1.18

*** significant at 1%, ** significant at 5%, * significant at 10%

settlements compared to children living in the non-intervention settlements (see Table 9).

Boys were significantly more likely to be stunted at both the midline and endline ($p < 0.01$) (see Table 10). At both the baseline and endline, girls living in the intervention settlements were significantly less likely to be stunted. Given that this relationship existed prior to the programming (i.e., at the baseline) it is hard to attribute the significant differences observed at the endline to the program alone. However, it is worth noting that girls in the intervention group saw a significant decline in stunting rates over time.

Closely tied to malnutrition, one-third of all children at the endline were reported to have been sick in the past two weeks prior to the survey. The rate of illness was similar to the baseline, but significantly lower than the midline. More importantly, while there was no difference in rate of illness between intervention and non-intervention children at the baseline or midline, there was a significant difference at the endline (see Table 11), with children in the intervention settlements 25% less likely to have been reported sick in the previous two weeks.

Across the sample as a whole, children were significantly more likely to be sick with diarrhea, respiratory illness, and/or malaria at the midline. While the rate of respiratory illness and malaria was comparable between the baseline and endline for all children, the rate of diarrhea was significantly reduced, by 66 percent. Differences in the incidence of specific illnesses between intervention and non-intervention children were

Table 9. Prevalence of stunting (HAZ < -2) by intervention and age group

	6–23 months			**24–59 months**		
	Non-intervention	**Intervention**	**Total**	**Non-intervention**	**Intervention**	**Total**
Baseline	34.1%	29.8%	31.9%	41.6%	39.7%	40.7%
Midline	41.0%	46.3%	43.4%	42.1%	45.4%	43.6%
Endline	44.5%	36.0%	40.6%	34.3%	28.4%★	31.6%

★★★ significant at 1%, ★★ significant at 5%, ★ significant at 10%

Table 10. Prevalence of stunting (HAZ < -2) by intervention and gender

	Boys			**Girls**		
	Non-intervention	**Intervention**	**Total**	**Non-intervention**	**Intervention[tt]**	**Total**
Baseline	34.5%	39.5%	36.8%	43.8%	34.5%★	39.3%
Midline	48.1%	50.3%	49.1%	35.2%	41.6%	38.4%
Endline	40.8%	35.6%	38.6%	32.2%	25.5%★	29.0%

★★★ significant at 1%, ★★ significant at 5%, ★ significant at 10%

Table 11. Child sick in the past two weeks by intervention

	Non-intervention	**Intervention[ttt]**	**Total**
Baseline	35%	34%	35%
Midline	47%	49%	48%
Endline	37%	28%★★	33%

★★★ significant at 1%, ★★ significant at 5%, ★ significant at 10%

only observed at the endline. In the intervention villages at the endline:

- Children were significantly less likely to have had malaria (33 percent less likely);
- Children were significantly less likely to have had respiratory illness;
- Children were significantly less likely to have had multiple illnesses.

However, there were no differences in the prevalence of diarrhea between intervention and non-intervention villages at the endline.

Water, Sanitation, and Hygiene (WASH) promotion

At the baseline, households in intervention and non-intervention settlements both had equal utilization of borehole water (a little over 50 percent), traditional wells, and surface water (see Table 12). At both the midline and the endline, however, households in intervention settlements were significantly more likely to report using a borehole, and significantly less likely to report using a traditional well or surface water.

Some trends are also observed over time. In the intervention settlements, there is a significant increase from the baseline to the midline in the use of boreholes. While the data show a slight reduction from the midline to endline, this change is not significant. The proportion of households utilizing a borehole in the non-intervention settlements is slowly declining (possibly due to a deterioration of the boreholes themselves) and the proportion of households using surface water has significantly increased from the midline to the endline (significant for the sample as a whole at $p < .001$ and for the non-intervention settlements at $p < 0.01$) (see Figure 8).

Table 12. Water source by intervention and time

		Baseline	Midline	Endline
Borehole	Non-intervention	57%	55%	46%
	Intervention[tt]	52%	86%***	79%***
	Total	**55%**	**69%**	**62%**
Traditional well	Non-intervention[c]	23%	31%	33%
	Intervention	19%	10%**	14%**
	Total	**21%**	**21%**	**24%**
Surface water	Non-intervention	20%	14%	20%
	Intervention	29%	4%***	7%***
	Total	**24%**	**9%**	**14%**

*** significant at 1%, ** significant at 5%, * significant at 10%

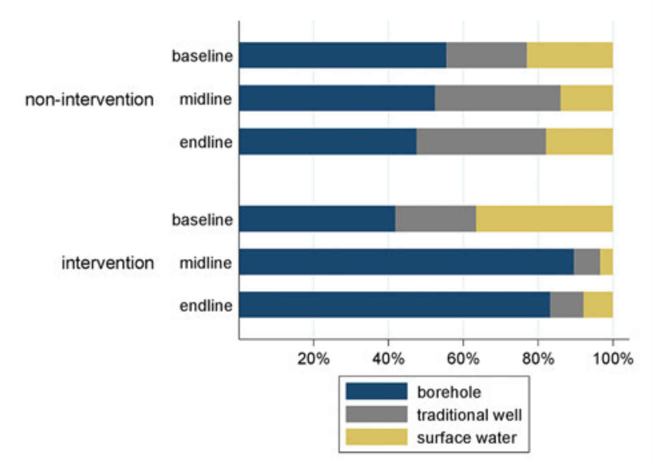


Figure 8. Water source by time and intervention.

Hygiene campaigns and messaging on correct practices around the water chain were provided for all the intervention settlements. However, impact is only observed on some of the water chain variables. There was no difference between intervention and non-intervention settlements in terms of how frequently households cleaned either their storage or transport containers or whether they kept the containers closed. Households in intervention settlements were significantly more likely to say they wash their transport or storage container with soap (or chlorine, but the number was very small for use of chlorine), the container was more likely to "look" clean to the enumerator, and overall they were more likely to have a container that fit all four properties (cleaned once a week, cleaned with soap/chlorine, container is closed, and container "looks" clean) (see Table 13). The implication here is that households in the intervention settlements have better practices along the water chain and hence are probably less likely to have their container and the water in the container contaminated from the point of collection to the point of consumption.

At both the midline and the endline, a significantly larger proportion of respondents could name the two main times for hand washing in the intervention settlements compared to the non-intervention settlements (see Table 14). However, not only was there no difference in having a water station with soap and water and correctly practicing hand washing

Table 13. Water chain by time and intervention

		Midline		**Endline**	
		Non-intervention	**Intervention**	**Non-intervention**	**Intervention**
Storage	Cleaned once a week	64%	64%	75%	74%
	Cleaned with soap/chlorine	31%	34%	38%	43%**
	Container closed	53%	54%	65%	66%
	Container "looks" clean	44%	43%	43%	58%***
	Cleaned 1x a week with soap, closed, and "looks" clean	8%	12%	16%	21%
Transport	Cleaned once a week	67%	67%	78%	79%
	Cleaned with soap/chlorine	27%	33%	29%	38%**
	Container closed	54%	57%	68%	70%
	Container "looks" clean	45%	49%	46%	58%***
	Cleaned 1x a week with soap, closed, and "looks" clean	6%	12%**	12%	21%***

significance: * $p < .1$, ** $p < .05$, *** $p < .01$

between the two groups, but the proportion of respondents correctly practicing hand washing significantly decreased ($p < 0.05$) in the intervention settlements only. Thus, while knowledge on hygiene practices is increasing (though at the same rate in both intervention and non-intervention settlements), this increase has not translated into any actual changes in behavior.

We observed a final link between water consumption and CRAM in relation to exclusive breastfeeding. Respondents in the intervention settlement were significantly more likely to exclusively breastfeed at the endline. The difference between the intervention and non-intervention settlements was primarily driven by a reduction in giving water to children under the age of six months (78 percent of mothers reported giving water in the non-intervention settlements, versus 54 percent in the intervention settlements, $p < .05$). At the midline, there was no significant difference in providing water to children under the age of 6 months, with the rate staying the same in the non-intervention settlements over the two time periods and dropping from 65 to 54 percent in the intervention settlements.

Conclusion

The CRAM program has shown significant impact in a variety of nutrition- and health-related measures, including the proportion of children who were wasted, average weight-for-height z-score, the proportion of children who were stunted, average height-for-age z-score, and child illness. In addition, CRAM increased utilization of boreholes, improved practices along the water chain, and increased knowledge about the two main times for hand washing. Taken together, the data help elucidate where the program was most effective and even shed some light on the mechanisms of impact on the nutrition and health indicators. The fact that CRAM had an unambiguous impact on measures of WASH and nutrition allows us to infer that a WASH component is likely contributing to the difference in malnutrition between the intervention and non-intervention settlements. In the next section, we explore these potential mechanisms using regression analysis. This analysis allows us to control for child, household, and settlement characteristics to further confirm CRAM's impact and isolate the potential pathways of causality.

Table 14. Hand washing and intervention

		Midline	Endline
Know the two main times for hand washing[23]	Non-intervention[ccc]	42%	57%
	Intervention[ttt]	53%**	67%**
	Total[aaa]	**47%**	**61%**
Have a water station with soap and water	Non-intervention	24%	29%
	Intervention	30%	31%
	Total	**27%**	**30%**
Correctly practice hand washing	Non-intervention	24%	19%
	Intervention[tt]	24%	16%
	Total[aaa]	**24%**	**18%**

[23] According to the survey, there are two main times for hand washing: after defecating and prior to eating.

LINKS TO MALNUTRITION: WATER AND LIVESTOCK

In the previous section—CRAM program impact—we looked at several indicators to see whether CRAM had a significant impact over time. While we observed that CRAM had an impact on malnutrition and a host of other variables, the information did not explain the potential drivers of malnutrition (although it did offer some clues). Nor did the above analysis control for any possible confounding child-, household-, or settlement-level characteristics. Thus, in this section, we use regression analysis to explore the links to malnutrition (for more detail on the modeling and the outcome variable, refer to the methodology section), controlling for a host of variables.

Identifying indicators correlated to malnutrition using regression analysis

A range of child (gender and age), household (education of household head, number of children in household, proportion of children working in the household, asset wealth, livestock wealth, water access, displacement), and settlement characteristics (*damre*, cattle density, and living in an intervention settlement) were significantly correlated to the minimum household weight-for-height z-score among children under the age of 5 (see Table 15). From this point on we will simply refer to the outcome variable as "child nutrition status."

Table 15. Minimum hh weight-for-height z-score: Mixed and random effects model (centered variables)

	All data		Non-intervention		Intervention	
	Fixed effects	Random effects	Fixed effects	Random effects	Fixed effects	Random effects
Female child	-	0.155***	-	0.149*	-	0.140*
Child age in months (centered)	-	0.021**	-	0.022*	-	0.019
Child age in months squared (centered)	-0.000*	-0.000**	0	-0.000*	0	0
Number of children (age < 5) (centered)	-0.033	-0.145***	-0.128	-0.188***	0.067	-0.101*
Age of household head (centered)	-0.001	0	0.005	0.003	-0.008	-0.002
Female household head	0.081	0.105	-0.128	0.035	0.247	0.183
hh head has at least some formal education	0.412*	0.343**	0.068	0.361	0.661**	0.414**
Household size (centered)	-0.023	-0.007	-0.008	-0.025	-0.034	0.015
Coping Strategies Index (centered)	0	0.001	0	0.002	0	0

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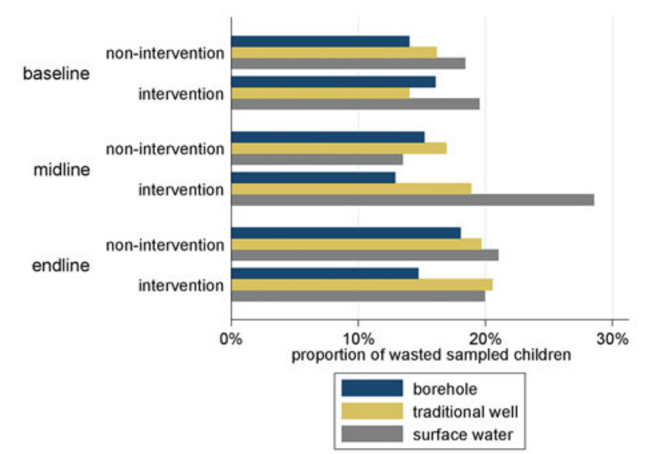
Prop. children (age < 14) working (centered)	0.145	0.171**	0.233	0.275***	0.067	0.092
Morris Score Index (centered)	0.098	0.05	-0.004	0.001	0.189*	0.134*
Weighted Livestock Index (centered)	0	0.000*	0	0	0.001*	0.001**
Water access (reference: surface water)						
Traditional well	0.181	0.201**	0.048	0.02	0.268	0.367**
Borehole	0.083	0.225***	-0.247	0.037	0.384**	0.408***
Household was displaced during conflict	–	0.215***	–	0.291***	–	0.119
Settlement with 150 hh or more	–	-0.093	–	-0.162	–	0.013
Damre	–	0.292**	–	0.399*	–	0.327**
Cattle in the settlement (centered)	0.009	-0.087**	0.128	-0.110*	-0.092	-0.079*
Intervention	0.193*	0.120*	–	–	0.077	0.071
Constant	-1.457***	-1.594***	-1.164***	-1.418***	-1.670***	-1.764***
Number of observations	1348	1348	689	689	659	659
R squared	0.05		0.054		0.117	
Degrees of freedom	570		285		270	

Borehole utilization and water chain
According to the regression analysis, utilization of water from a borehole was significantly and positively correlated with better child nutritional status. The significance of this relationship was primarily driven by changes in the intervention settlements. The size of the correlation was comparable to having a household head with some formal education. Households in the intervention settlements that moved from using surface water to using a borehole for household consumption improved their child nutritional status (i.e., increased their minimum weight-for-height z-score by one-third of a standard deviation).

Figure 9. Child wasting by water utilization, time, and intervention.



The same relationship was not significant in the non-intervention settlements, even though almost half (46 percent) of households reported utilizing a borehole (see Figure 9).

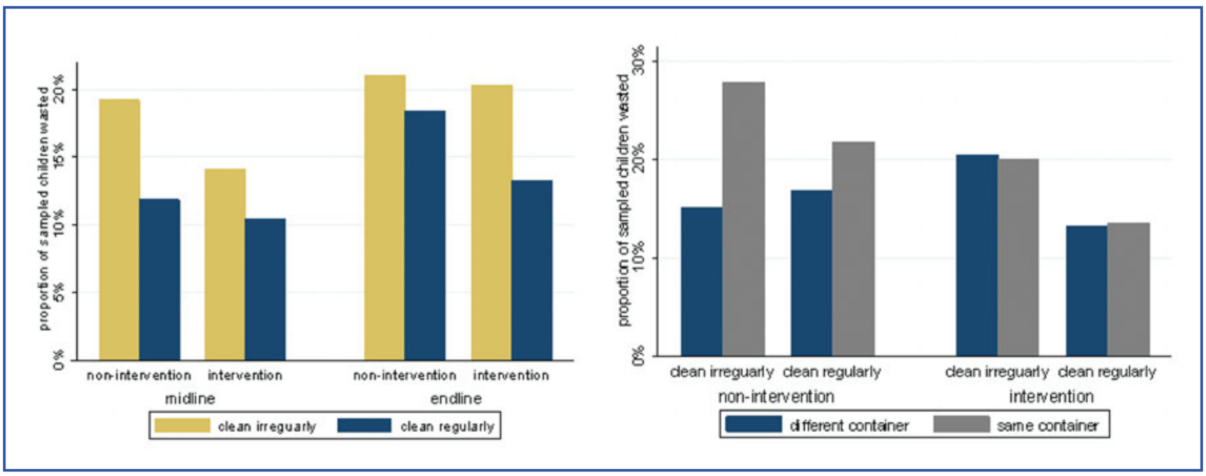
Why the difference in correlation to utilization of borehole water between intervention and non-intervention settlements?

We present two possible explanations. The first explanation is that there is a significant difference in the quality of water between boreholes in the intervention versus non-intervention settlements. A water analysis carried out by Concern Worldwide in the intervention settlements confirms that borehole water is potable (coliform concentration almost always zero or near zero). The same type of testing was not carried out in the non-intervention settlements, so we cannot evaluate potability in those settlements. A possible second explanation, for which we do have some data to evaluate, relates to differences in behavior and practice around the water chain between households in the intervention and non-intervention settlements.

Two specific water chain variables were significantly correlated to acute malnutrition (i.e., WHZ < -2): whether the household used the same transport container for getting water from a borehole and non-potable water (surface water or traditional well) ($p < 0.05$); and whether the household cleaned the transport container regularly ($p < 0.05$). However, these relationships were only significant when not controlling for child-, household-, and village-level characteristics. The first variable exists only for households that had access to a borehole. For the second variable, the relationship, while significant for the whole sample, also applies and has a stronger relationship among households that had access to a borehole. Given that water from a traditional well and/or surface water is likely to have a greater level of contamination in the first place, the analysis shows that hygiene practices around the water chain are important for preventing contamination, not removing it. Improving hygiene practices along the water chain is only relevant if a household is starting with clean water. Thus, the data show that hygiene practices along the water chain prevent contamination of clean drinking water rather than remove the contamination in surface water, which can only be done through water treatment. The remainder of this section only discusses households that reported accessing water for consumption from a borehole in the midline and endline (unfortunately, questions around the water chain were not included in the baseline).

When looking at the water chain variables separately (see Table 13), each one is individually correlated with acute malnutrition. However, at the endline (after all *intervention* settlements received water chain and hygiene training) there is no relationship in the intervention settlements between using the same or different containers and child wasting (see Figure 10). The only thing

Figure 10. Water chain and acute malnutrition over time and intervention.



that matters is if households cleaned the container regularly (second figure in Figure 10). In the intervention settlements only, at the endline any negative impact related to using the same container is negated by regularly cleaning the transport container. In the non-intervention settlements, even households that regularly clean their transport container show higher levels of malnutrition if they use same container for potable and non-potable water ($p < 0.1$). Furthermore, households that clean their transport container and are in an intervention settlement are significantly less likely to have a child who is wasted compared to households that clean their transport container and are in a non-intervention settlement ($p < 0.1$).

While we cannot say conclusively (because we can only test the full impact of CRAM and not its individual components), these findings point to the theory that households receiving the CRAM package (and in this instance, most likely specifically the hygiene and water-chain training provided to the CRAM settlements) are better equipped to reduce pathogen contamination in their water supply that might be correlated to child wasting. However, without testing the water quality in the non-intervention settlements, we cannot say for certain that the initial contamination in boreholes in non-intervention settlements is not simply higher and hence driving the difference.

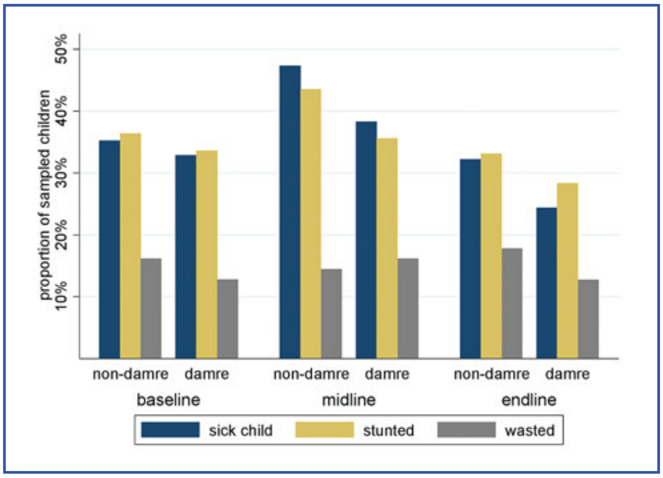
Livestock

Possibly linked to the above analysis is the relationship between cattle density in a settlement and child nutritional status. According to the regression analysis, the more cattle there were in a settlement (proxied by the sum of all cattle in a settlement identified in the sample), the worse the child nutritional status was. Running the same regression on the maximum weight-for-height z-score (impact on healthiest child in household) in the household, the level of significance increases to $p < 0.01$ for the sample as a whole, and in the intervention and non-intervention sub-samples. The coefficient also doubles. In other words, the regression model shows that for each additional cow in a settlement above the mean, the maximum household weight-for-height z-score falls by one-eighth of a standard deviation, and the minimum household weight-for-height z-score falls by one-twelfth of a standard deviation, showing decreasing child nutritional status. This finding means that village cattle density affects not just the least healthy child in a household, but brings down the overall health of even the healthiest child in the household.

Two additional relationships are observed in relation to livestock. In the intervention settlements only, there is a significant and positive relationship with each additional unit of livestock within a household (i.e., chicken unit) as measured by the WLI and child nutritional status. Thus, individual livestock ownership is positively correlated (likely as an indication of wealth), while settlement-level livestock ownership is negatively correlated to nutritional status.

Here it is important to remember that the data show that household investment in cattle has continued to steadily but significantly increase from year to year (see background section), possibly as an indicator of recovery. Thus, it is possible that recovery in one sector, without due consideration for any related reverberating effects, might directly undermine another sector.

Figure 11. Child health and nutrition by settlement type and time.



The second relationship identified in the data is linked to households that reside in a *damre*.[24] Households living a *damre* are significantly less likely to have a sick ($p < 0.05$), stunted ($p < 0.1$), or wasted child ($p < 0.05$)[25] (see Figure 11). A *damre* is a permanent settlement community primarily made up of formerly pastoralist and nomadic households. This specific characteristic is reflected in the household livestock ownership in a *damre* versus a village, particularly in relation to cattle (see Figure 12). Thus, given the relationship between cattle density and malnutrition found in the data, it is surprising that living in a *damre* has a similar positive impact on the minimum weight-for-height z-score as having a household head with some formal education.

A possible explanation for this variation is in the difference in livestock management practices between pastoralists (even formerly pastoralist households) and primarily agriculturally based households. Pastoralist livestock systems depend on seasonal migration and mobility of livestock herds to target grasses when they are most nutritious in the rainy season, while preserving pasture, fodder, and permanent water sources for the dry season. Seasonal migration means the main herds are often far from the *damre* and thus are less likely to share the water points used by humans for water consumption. As part of a small qualitative exercise carried out in May 2016, researchers discussed the varying livestock water-related practices between *damrat* and non-*damrat*. Given the larger herds of cattle owned in the *damre* (see Figure 12), households reported that during the dry season the cattle are kept near watering holes at least 3–5 hours away from the *damre*. In the villages, on the other hand, given the smaller number of cattle, the cattle tend to be kept closer to the village and rely on the same permanent water sources, such as a borehole or nearby traditional well, as people. If the link between livestock, particularly cattle, and malnutrition is due to water contamination from animal feces, then the greater distance between cattle herds and the *damre* during the dry season would explain why malnutrition rates are significantly lower in a *damre*.

Intervention

The significance of the intervention variable in both the fixed and random effects models in the regression presented at the beginning of this section is the most important finding we can put forward, because it means that, even when controlling for a host of child, household, village

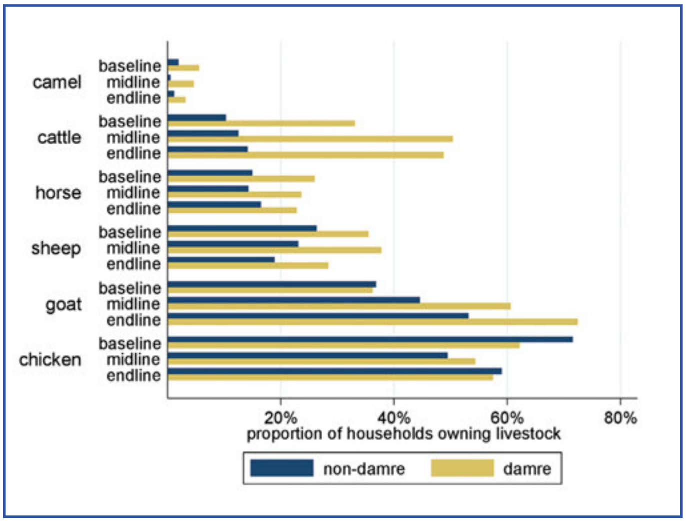


Figure 12. Livestock ownership by livestock type, settlement type, and time.

[24] While all *damrat* fall in the "small village" category, both *damre* and population are controlled for in the regression. The *damre* variable is not only more robust (significant in all regressions) but also has a higher coefficient, so it is unlikely that the *damre* variable is a proxy for population size and vice versa.

[25] Wasting and living in a *damre* were only significantly correlated when controlling for other household- and village-level characteristics.

characteristics, and even some components of the intervention itself, CRAM was significantly correlated with better nutritional outcomes. The model tells us that, on average, households living in the intervention settlements after components of CRAM were significantly underway (midline and endline) have better child nutritional status (a minimum household weight-for-height z-score that is one-tenth of a standard deviation higher) than in non-CRAM settlements. Even more telling is that, controlling for innate household characteristics that we are unable to model, having a household go from not receiving the CRAM package (at baseline) to receiving it (at midline and endline) improves child nutritional status (increasing the minimum household weight-for-height z-score by a quarter of a standard deviation). Taking these two findings together, we can definitively say that CRAM has had a positive impact on malnutrition in CRAM settlements in relation to non-CRAM settlements in the research catchment area.

Conclusion

The regression analysis identifies several links to malnutrition in the sampled population that help us to understand how CRAM has been effective in reducing malnutrition and how it can be made more effective. Primarily, the data show a robust and significant relationship between acute malnutrition and both using a borehole as the primary water source (positive association with nutrition) and cattle density in the settlement (negative association with nutrition). Most importantly, the regression analysis shows that CRAM has a significant and positive impact on child nutrition, even when controlling for a host of variables. In the next section, we combine the findings from the descriptive analysis of CRAM's impact on nutrition, health, and the WASH indicators with the regression analysis, in order to distill the lessons on the drivers of malnutrition in Dar Sila.

WHAT MADE CRAM EFFECTIVE, FOR WHOM, AND WHY?

In this section, we discuss the findings described in the two previous sections in order to better understand for whom and why CRAM was effective in relation to both acute and chronic malnutrition in Dar Sila.

At the endline, children living in the CRAM settlements had a significantly lower prevalence of acute malnutrition and a higher average weight-for-height z-score. The data do not show a reduction in acute malnutrition in the intervention settlements over time; however, they show that CRAM prevented the increase in acute malnutrition that was seen in the non-intervention settlements. Thus, statistically speaking, CRAM appears to have prevented an increase in acute malnutrition (which was observed in the non-intervention settlements), rather than causing a reduction in prevalence rates. This relationship is further confirmed by the regression analysis: households living in the CRAM settlements had children with higher nutritional status compared to non-CRAM settlements and also improved their child nutritional status when switching from not receiving CRAM (the baseline data) to receiving CRAM (the midline and endline data), even when controlling for possible confounders in the form of child-, household-, and settlement-level characteristics.

CRAM also had a positive impact on chronic malnutrition. At the endline, children living in the intervention settlements were significantly less likely to be stunted and had a significantly higher height-for-age z-score, on average, compared to children living in the non-intervention settlements.

Even though only some components of the health program were randomized (mother-to-mother care groups and counseling), we do see impact that could be directly linked to the reduction observed in malnutrition. Children living in the CRAM settlements, at the endline, were significantly less likely to be sick, particularly with malaria or respiratory illness. These children were also significantly less likely to be reported as having multiple illnesses simultaneously. Given the cyclical relationship between illness and acute malnutrition, as well as the consistently significant and positive correlation between malnutrition and morbidity across all three time periods, CRAM's impact on child health status helps triangulate our findings on wasting and stunting.

The findings show that the impact on acute malnutrition is primarily driven by an impact on children between the ages of 6 and 23 months (the period at which complementary foods are usually introduced). The fact that CRAM shows impact on the youngest cohort for whom anthropometric data are collected could potentially explain why we observed impact on stunting. The difference in stunting was primarily driven by significantly lower levels of stunting among children between the ages of 24 and 59 months in the intervention settlements compared to the non-intervention settlements.[26] This age cohort (children 24–59 months) would have had the most exposure to CRAM—starting at birth or potentially preconception in 2012.

There were also significant differences by gender. The overall impact of CRAM was primarily driven by significant differences in boys between intervention and non-intervention settlements at the endline, with no significant variation seen among girls. In the non-intervention settlements, there was a significant increase in the prevalence of severely malnourished boys over time. Irrespective of the intervention, boys were significantly more likely to be chronically malnourished (HAZ < -2) at both the midline and endline. Thus, we find that the impact of CRAM on malnutrition observed in the endline was driven by the prevention of an increase in acute malnutrition among boys under the age of 2 years and a decline in chronic malnutrition among

[26] But this could be a sample size issue, as less than a quarter of all children in the sample were between the ages of 6 and 24 months.

children between the ages of 24–59 months (i.e., those with the longest exposure to CRAM).

To help us understand why CRAM might have had an impact on acute and chronic malnutrition, we turn to the other sector that was positively and significantly affected by CRAM—WASH—as well as the regression analysis.

CRAM had an unambiguous impact on the household's utilization of potable water and hygiene practices around the water chain. Households in the intervention settlements were significantly more likely to report using water from a borehole, have better practices around the water chain, and know the two main times for hand washing. In addition, at the endline, rates of exclusive breastfeeding were significantly higher in the CRAM settlements, primarily driven by a significant and lower rate of water consumption by children under the age of 6 months.

Use of a borehole figured prominently in the regression analysis in several ways. In general, when comparing households that report using a borehole with households that do not, across all three time periods, children in households that reported using a borehole for their household water consumption had significantly better nutritional status. However, while this relationship was significant across the population, a more detailed story emerges when looking by intervention. Borehole utilization has the largest relationship with nutritional status in intervention settlements but is not significant in the non-intervention settlements. The lack of significance could be due to either poorer quality of water in boreholes in non-intervention settlements or the promotion of good practice via campaigns and behavior change communication under CRAM in intervention settlements.

Thus, we argue that having a borehole alone is not sufficient. The positive impact of the CRAM program is likely due to either CRAM households starting out with better-quality borehole water or to those households practicing better hygiene along the water chain that limits further contamination. A combination of both factors is also a possible explanation. Comparative water testing of boreholes in intervention versus non-intervention settlements was not conducted, so it is not possible to confirm whether a difference in borehole water quality is an important factor.

We do know, however, from water testing carried out by Concern, that coliform contamination increases along the water chain. In some cases, it is 500 times higher by the time the household water storage container is tested. Exactly how this contamination is occurring along the water chain from borehole to consumer is still unknown. Use of the same storage or transport container for water from multiple sources (i.e., borehole and unprotected sources, as people tend to use a combination of sources throughout the year) or not regularly cleaning the container are possible factors.

There is evidence that CRAM is actually reducing the risk of child wasting, potentially due to the prevention of the contamination of water. Findings from the midline show that households in the CRAM settlements who source their water from a borehole *and* regularly clean their water transport container are less likely to have a child who is wasted (Marshak et al., in press). However, this relationship did not hold when controlling for other child, household, and settlement characteristics at the endline. Interestingly, borehole use in non-CRAM settlements does not seem to have the same protective effect against malnutrition. Thus, households in CRAM settlements are likely starting out with cleaner water and/or are protecting that borehole water and themselves from contamination with good hygiene practices. Meanwhile, in non-intervention settlements, either the water from the borehole is already contaminated or households are contaminating that water via incorrect hygiene practices along the water chain, leading to higher rates of wasting. While ensuring access to and maintenance of boreholes is important, it is clearly insufficient on its own.

Thus, we see that CRAM was effective in reducing chronic and acute malnutrition relative to the non-CRAM settlements in Dar Sila. This result was most likely achieved by increasing access to potable water and better hygiene practices along the water chain to prevent the contamination of that water by cattle. This impact was not observed over the course of one year, but rather in the period between 2012 and 2015, highlighting the importance of long-term investment in programming and evaluation. The declining use of the boreholes and the lack of impact on actual hygiene practices further underscore that investment in the program needs to continue and evolve based on the evaluation findings.

TOWARD A NEW HYPOTHESIS: EXPLAINING THE LINK BETWEEN LIVESTOCK, WATER, AND MALNUTRITION

Building on the evidence presented in the previous section, here we explore the relationship between livestock, contamination of water, and acute malnutrition of infants and young children, in order to identify and explore potential points in the malnutrition causal pathway that may warrant further investigation and testing.

The data on livestock offer us some clues about how the water could become contaminated in the first place. Greater concentrations of village cattle are significantly correlated with worse child nutrition outcomes in intervention and non-intervention villages. However, this relationship is not seen among children who live in a *damre*. They had significantly better child nutritional status even though cattle ownership, and livestock ownership more generally, is significantly higher in a *damre*. Thus, while cattle density appears to be associated with poorer nutritional status in villages, this relationship does not hold for children living in *damrat*.

A possible explanation is that *damre* communities have different livestock water management practices than do villages. *Damrat* tend to be pastoralist or agropastoralist communities, with a long history of specialization in pastoralist livestock production. Their herds migrate seasonally and are far from the *damre* in the dry season, unlike the village livestock. This difference in livestock management and seasonal location of livestock, together with distinctive livestock water management regimes, could potentially be driving the difference in child nutrition outcomes between *damrat* and villages.

Building on this argument, *Cryptosporidium*, a pathogen associated with livestock, could plausibly be responsible for some of the child malnutrition in Dar Sila, through the contamination of water by livestock and subsequent infection of children with the pathogen. A recent Global Enteric Multicenter Study identified the five most common pathogens associated with diarrhea and death among infants and young children (Kotloff et el., 2013). Of the five pathogens, *Cryptosporidium* is the only one directly linked with livestock (Helmy et el., 2013). Furthermore, outbreaks of *Cryptosporidium* are usually water borne and associated with the bovine type of *Cryptosporidium* (*C. parvum*) (Wells et al., 2015). In particular, drinking and recreational water use (rivers, streams, *wadis*, etc.) are the most common ways by which the disease is spread. *Cryptosporidium* causes inflammation of the intestine, which can cause environmental enteropathy (Kelly, 2013). Evidence suggests that if a child under the age of 12 months has contracted cryptosporidiosis, the child's intestinal mucosa never fully recovers (Mølbak et al., 1997). Thus, *Cryptosporidium* is said to cause, rather than simply exacerbate, acute malnutrition (Kotloff et el., 2013). To be clear, however, the role of *Cryptosporidium* in the aetiology of malnutrition in Dar Sila is as yet undetermined and would require confirmation of the links between livestock contamination of domestic water by *Cryptosporidium* and *Cryptosporidium* infection of children (through the testing of water and the stools of cattle and children) and the association with acute malnutrition.

CONCLUSION

The CRAM program, implemented over the course of 2012–2015, was designed to reduce the rates of acute malnutrition through an integrated program of WASH, health and nutrition, and FIM. There are several conclusions that can be drawn from the key findings identified through the impact evaluation and research.

The CRAM program model protects against an increase in malnutrition, both acute and chronic.

CRAM appears to have prevented an increase in acute malnutrition, an increase that occurred in the non-intervention settlements, rather than causing a reduction in prevalence rates. Irrespective of the variable used (percent of children with weight-for-height z-score less than – 2 or the mean weight-for-height z-score), wasting was lower in the intervention settlements. This finding was further triangulated by a significantly lower rate of child illness (malaria and respiratory illness) in the CRAM settlements. We also observed a significant positive impact on stunting (percent of children with a height-for-age z-score of less than – 2 and the child's mean height-for-age z-score). Even when controlling for child-, household-, and settlement-level characteristics, the relationship between CRAM and child acute malnutrition remained significant.

The impact of CRAM was primarily driven by lower rates of wasting among 6- to 23-month-old children and was more significant for boys than girls. The impact of wasting in the younger group could potentially explain why CRAM is linked to a significant decline in child stunting, as the window of impact is among children under the age of 2.

Utilization of potable water and good hygiene practice along the water chain play an important role in malnutrition.

At both the midline and endline, households in the CRAM settlements were significantly more likely to report using a borehole for household water consumption compared to households in the non-intervention settlements. At the endline, additional improvements were observed around the water chain. CRAM households were significantly more likely to report washing the transport and/or storage container with soap, the transport and storage container were significantly more likely to look clean to the enumerator, and a significantly larger proportion of households were more likely to have a transport container that met all four requirements: cleaned with soap, washed regularly, closed, and looked clean to the enumerator. While knowledge around the two main times of hand washing was significantly higher in the intervention group at the endline, there was no significant difference in correctly practicing hand washing or in having soap and a wash station. While improved hygiene along the water chain as a result of the CRAM program is evident, more needs to be done on hand-washing practices, despite widespread knowledge on its importance.

Utilization of a borehole at endline was a key predictor of child malnutrition for the study population as a whole. Furthermore, the significant correlation between nutritional status (minimum weight-for-height household z-score) and having a borehole is driven by the CRAM intervention settlements and is not observed in the non-intervention settlement sub-group. Thus, we conclude that having a borehole alone is not sufficient. The positive impact of the CRAM program is likely due to either CRAM households starting out with better-quality borehole water or to CRAM households practicing better hygiene along the water chain that limits further contamination, or a combination of both. Exactly how contamination is occurring along the water chain from borehole to consumer is still unknown, but use of the same storage or transport container for water from multiple sources or not regularly cleaning the container are possible factors.

Finally, as explained above, children in the intervention settlements were more like to be exclusively breastfed and, specifically, less likely to be offered water before the age of 6 months. Furthermore, CRAM's impact on stunting and acute malnutrition was driven primarily by improvements seen in children between the ages of 6 to 23 months (i.e., children whose first 6 months would have occurred during, rather than before, CRAM implementation and therefore would be most likely to reap the benefits of CRAM's exclusive breastfeeding promotion). Taken together, these two findings further support the hypothesis that water contamination, particularly during the first 1,000 days, is a possible key driver of malnutrition in Dar Sila.

Cattle are a possible source of water contamination.

The relationship between livestock and nutrition is complex. Obviously, livestock make a valuable contribution to livelihoods and, by implication, food security. The study captured a positive significant relationship between household (not settlement) livestock ownership and malnutrition in both the intervention settlements and in the *damrat*. However, there is a clear indication that concentration of cattle in a settlement (cattle density) is negatively associated with malnutrition. Thus, the issue is how to improve and harmonize livestock and human water management.

The lack of such a relationship between cattle and malnutrition in the *damrat* suggests that pastoralist practices may hold some answers. However, pastoralism is a specialization, and whether these skills or practices are relevant or transferable is unknown. There may be other characteristics of a *damre*, and the people who live there, that might be driving this relationship. Further exploration is needed.

Wider learning and change coming out of CRAM.

To conclude, these findings indicate significant program impact and provide clues to how impact could be improved. They are also important in relation to implications for wider learning and change. In emergency settings, the links to malnutrition identified in this report—water, hygiene, and livestock—are frequently siloed under different international sectors known as clusters. For example, provision of water for domestic use is coordinated by the WASH cluster. The Sphere Project has developed "minimum standards" of disaster response in relation to water. However, the cluster generally pays little attention to water for livestock, which arguably is covered by the Food Security and Livelihoods cluster and the Livestock Emergency Guidelines and Standards (LEGS) (LEGS, 2009; LEGS, 2015). Neither the Sphere Project nor LEGS pay sufficient attention to the overlapping yet different water needs of humans and livestock. Because the causal links to acute malnutrition are complex and interconnected, programming with the aim of improving child nutritional status requires greater integration and coordination between the different sectors—WASH, Health, Nutrition, Livelihoods, etc.—based on contextual analysis of the sectors' relationship with acute malnutrition.

The four-year study demonstrates the potential importance of the water chain from water source to domestic consumption, hygiene practices or behaviors, and the role of livestock in the contamination of water for human consumption in relation to child wasting in Dar Sila, Chad. Furthermore, it demonstrates the interaction between livestock and water—two frequently siloed sectors. This confirms the complexity, interconnectedness, and effect modification of potential causal links to acute malnutrition (as implied by the UNICEF Malnutrition Conceptual Framework), and hence any programming that aims to reduce acute malnutrition requires nuanced and context-specific analysis.

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GLOSSARY

Acute malnutrition	Also referred to as global acute malnutrition (GAM). It is caused by a decrease in food consumption and/or illness resulting in sudden weight loss or oedema. It is the sum of the prevalence of moderate acute malnutrition (MAM) and severe acute malnutrition (SAM) at the population level.
Anthropometrics	The measurement of the proportions of the human body used to assess the nutritional status of children. The basic anthropometric information for children is age, sex, length, height, weight, and oedema.
Asset Index	See Morris Score Index.
Baseline	Data that provide an information base against which to monitor and assess an activity's progress and effectiveness during implementation and after the activity is completed.
Binomial variables	A variable that takes the value of either 0 or 1. For example: access to a borehole takes the value 0 if the household has no access to a borehole and the value 1 if the household has access to a borehole.
Borehole	Water wells created by installing a vertical pipe into the ground. A well screen keeps the borehole from caving and also helps prevent surface contaminants from entering the borehole.
Chronic malnutrition	Chronic malnutrition occurs over time, unlike acute malnutrition. A child who is chronically malnourished often appears to be normally proportioned but is actually shorter than normal for his/her age. It starts before birth and is caused by poor maternal nutrition, poor feeding practices, and poor food quality, as well as frequent infections, which can slow growth.
Climate smart techniques	A set of soil management practices that minimizes the disruption of the soil's structure, composition, and natural biodiversity.
Continuous variable	A variable that can take any value between the minimum and maximum. For example, time to a health center can take any value between 0 minutes and 240 minutes.
Coping strategies index (CSI)	An index that looks at household behavioral responses in times of a shortfall in food consumption. It includes only immediate and short-term alterations of consumption patterns, rather than the longer-term alterations to income earning, food production patterns, and one-off responses such as asset or livestock sales. The larger the CSI, the more coping strategies a household uses, the more severe the strategies, and/or the more frequently the household uses them.
Cryptosporidium	A parasite that can cause a respiratory and gastrointestinal illness that primarily involves watery diarrhea.

Damre	Traditionally nomadic or pastoralist settlements, with a resident community that tends not to migrate with livestock (predominantly women, children, and older people), while other members of the community move seasonally with their herds. *Damrat* is plural.
Endline	The final data collection period in a longitudinal study.
Enumerator	Data collector.
Exclusive breastfeeding	When a child receives only breast milk and no other food or drink, not even water (including milk expressed or from a wet nurse) during the first six months of life. An infant may receive oral rehydration solutions, drops, and syrups (vitamins, minerals, and medicines) and still be considered exclusively breastfed.
Food security	A condition related to the supply of food, and individuals' access to it.
Impact evaluation	A study that assesses the changes that can be attributed to a particular intervention such as a project, program, or policy, both the intended changes as well as, ideally, the unintended ones.
Logit regression	A model or regression where the outcome variable is binomial.
Midline	Data collected in the middle of a longitudinal study.
Moderate Acute Malnutrition (MAM)	Also known as wasting. WHO/UNICEF measures it as a weight-for-height z-score between -3 and -2 (standard deviations) of the international standard or by a mid-upper arm circumference (MUAC) of between 11 cm and 12.5 cm.
Months of Food Insecurity (MFI)	Measures the number of months that a household reports being food insecure by asking respondents to identify, for each month of the previous calendar year, whether they had more than enough food, just enough food, or not enough food.
Morris Score Index (MSI)	A proxy for household wealth that uses data on asset ownership. The MSI is constructed by weighing each durable asset by the share of households that report ownership of that asset in the sample.
Mid-Upper Arm Circumference (MUAC)	A measurement of the mid-upper arm circumference that is used to estimate levels of nutrition.
Oedema	A form of severe acute malnutrition in which a child appears puffy and is usually irritable, weak, and lethargic. Oedema is found on the lower limbs, and is verified when thumb pressure is applied on top of both feet for three seconds and leaves a pit or indentation in the foot after the thumb is lifted.
P-value	The level of marginal significance within a statistical hypothesis test, representing the probability of the occurrence of a given event. The p-value is used as an alternative to rejection points to provide the smallest level of significance at which the null hypothesis would be rejected.

Panel data	Observations of multiple phenomena obtained over multiple time periods for the same firms or individuals.
Pop stats	Statistics for the population as a whole, which are inferred from the sampled data.
Randomized	A study in which people are randomly allocated to receive the intervention. The study is used to test the impact of the intervention as it compares to the group that did not receive the intervention.
Regression model	A statistical process for estimating the relationships among variables. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables (or "predictors").
Resilience	The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.
Severe Acute Malnutrition (SAM)	The most dangerous form of malnutrition. WHO/UNICEF measures it by a weight-for-height z-score of less than -3 (standard deviations). SAM compromises the body's vital processes. Even if a child is treated and his/her nutritional status is restored, his/her physical and mental development and general health status may be adversely effected in the long term.
Stunting	See chronic malnutrition.
Wasting	See moderate acute malnutrition. It is the massive loss of body fat and muscle tissue resulting from MAM.
Water chain	The pathway from water supply to water consumption. In the case of this study, the water chain is from point of use (borehole, traditional well, surface water), to transport container, to storage container.
Weighted livestock index	A measure of livestock wealth using the animals reportedly owned by the household. To account for different types of livestock and their variable values, weights are attached based on cost ratios for the region.
z-score (including all types)	A z-score, or standard deviation, is a measure of the dispersion of data. In this case, a z-score is used to express the difference between an individual child's weight and the average weight of comparable children in the reference population. WHO/UNICEF set standards for z-scores that indicate certain levels of malnutrition.

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