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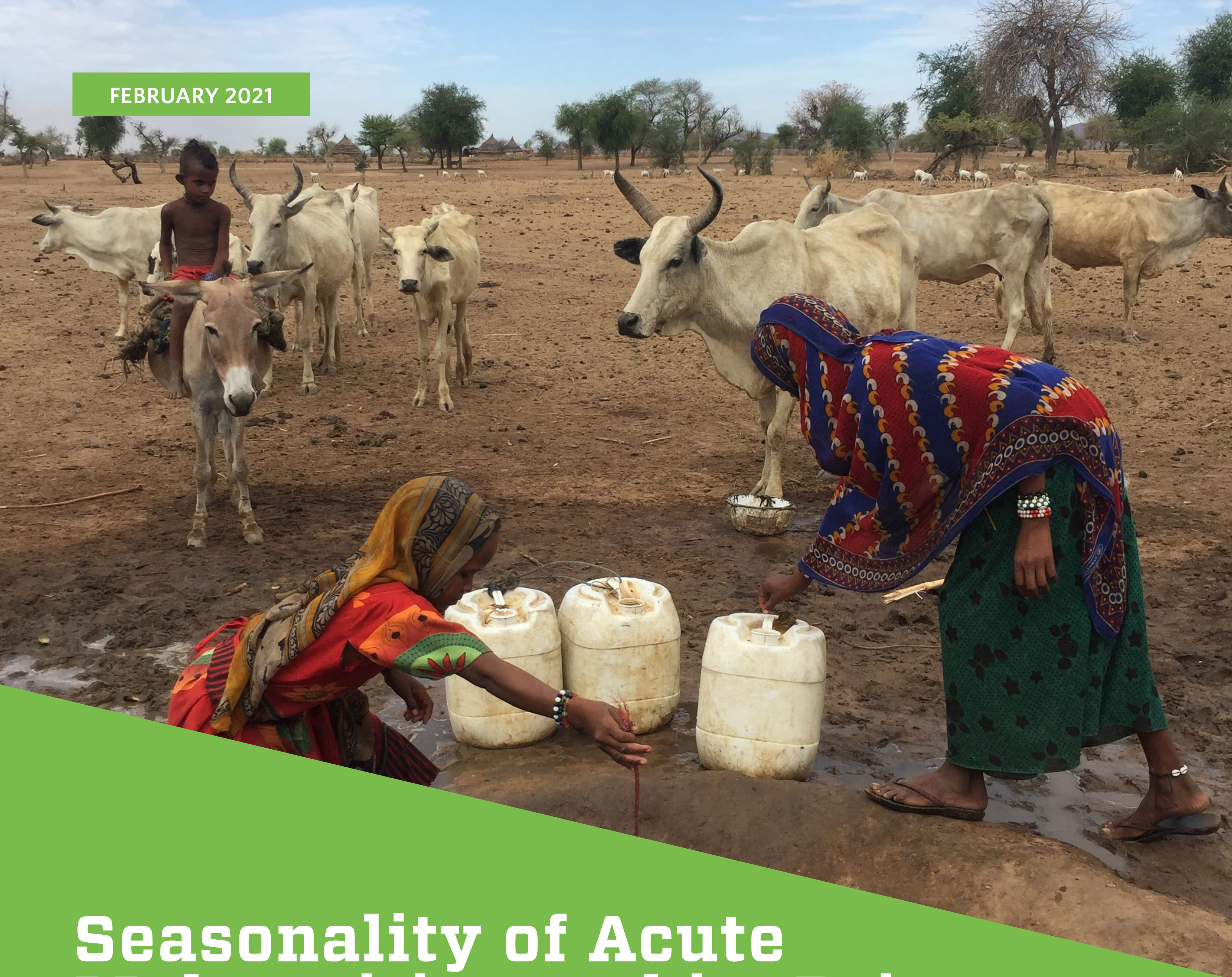

Seasonality of Acute Malnutrition and its Drivers in Sila Province, Chad: a mixed methods analysis

A CONCERN WORLDWIDE AND FEINSTEIN INTERNATIONAL CENTER PUBLICATION

Anastasia Marshak, Gwenaëlle Luc, Anne Radday, and Helen Young

Tufts University
Friedman School of Nutrition Science and Policy
Feinstein International Center

Irish Aid
Government of Ireland
Rialtas na hÉireann

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Corresponding author: Anastasia Marshak
Corresponding author email: anastasia.marshak@tufts.edu

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Feinstein International Center
75 Kneeland Street, 8th Floor
Boston, MA 02111 USA
Tel: +1 617.627.3423
Twitter: @FeinsteinIntCen
fic.tufts.edu

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Acronyms

BRACED	Building Resilience and Adaptation to Climate Extremes and Disasters
CGPE	Comité de Gestion des Points d'Eau (water management committee)
CI	Confidence interval
CRAM	Community Resilience to Acute Malnutrition
CRED	Center for Research on the Epidemiology of Disasters
DHS	Demographic and Health Survey
FAO	United Nations Food and Agricultural Organization
FEWSNET	Famine Early Warning Systems Network
FGD	Focus group discussion
GAM	Global acute malnutrition
HAZ	Height-for-age z-score
HH	Household
INGO	International non-governmental organization
IPC	Integrated Phase Classification
IRB	Institutional Review Board
MAHFP	Months of adequate household food provisioning
MUAC	Mid-upper arm circumference
ND	Negative deviant
NDVI	Normalized difference vegetation index
OLS	Ordinary least squares
OTP	Outpatient therapeutic feeding program
PD	Positive deviant
RCT	Randomized control trial
SAM	Severe acute malnutrition
SMART	Standardized Monitoring and Assessment of Relief and Transitions
UNICEF	United Nations Children's Fund
WASH	Water, sanitation, and hygiene
WAZ	Weight-for-age z-score
WHZ	Weight-for-height z-Score

Glossary

Achanai	Young child babysitting during mother's absence
Azaba	Proficient adult hired herders, (usually relative of the owner of herd)
Chaile	Milking cow that stays in the village during rainy season
Chamorokha	Derogatory term for a boy who behaves like a girl according to local gender norms
Damkoutch	Seasonal encampment for agricultural or market gardening purposes
Damre	Sedentary villages of communities with a pastoral history
Darat	Harvesting season/end of rains
Diarr	Seasonal practice where livestock are brought to field for fertilization
Dr. Tchoukou	Unlicensed street vendors of medicines. They examine patients and administer pills, injections, and infusions according to their "diagnoses". They are generally cheaper than qualified doctors
Hit	Pastoral deep well
Kharif	Rainy season
Machiche	Shallow well dug in the sand of a dry riverbed
Makhalaf	Place of encampment for cattle and herders (mostly men) during rainy season (July-November)
Rushash	Beginning of the rainy season (May/June)
Saraf	Shallow well dug in clay soil of a dry riverbed (wadi)
Seif	Hot dry season
Shita	Cool dry season
Talaaga	Signal of mobility for large herds, after harvest completed, to eat residues
Wadi	Sandy riverbed in a valley

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Executive Summary

This study describes seasonal patterns of and relationships between wasting, water contamination, and livestock management among communities around Goz Beida (the capital of Sila Province in eastern Chad) with the aim of informing and influencing programs and policies that address persistent acute malnutrition in the region. We explore hypotheses developed through research carried out by Concern Worldwide (Concern) and Tufts University as part of the Community Resilience to Acute Malnutrition (CRAM) and Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED) programs from 2012 through 2017. The CRAM/BRACED research found a direct and positive impact of the multi-sectoral programs on child nutritional status (Marshak, Young et al. 2020) and posed several hypotheses about the links between livestock, water contamination, and child malnutrition in Chad's Sila Province, and in dryland environments more broadly (Marshak, Young et al. 2016; Marshak, Young et al. 2017). In addition, and rather surprisingly, in the entire five years of CRAM/BRACED data collection, no relationship was found between different proxies of food insecurity and child nutritional status.

In order to better understand these seasonal patterns, Tufts and Concern carried out a two-year longitudinal mixed methods study focusing on child nutritional status and coliform contamination across the water chain. The quantitative portion of the study followed 89 households and their children from the ages of 6 to 59 months across 8 communities. Each month we collected data on child anthropometry, water contamination at the source and in transport and storage containers, and on water access and hygiene practices. The eight communities were purposefully selected for ease of access on a monthly basis during all seasons. We then selected all households with children under the age of five for which we already had CRAM/BRACED data. The qualitative portion of the study covers seasonal access to natural resources, mobility patterns linked to livelihoods (farming and livestock keeping), the history of livelihood specializations, and care and hygiene practices. This data was collected through focus groups and interviews. This report includes 23 months of longitudinal quantitative data and qualitative data gathered during two field studies conducted in August 2018 and May 2019, times that correspond to two hypothesized peaks of wasting.

The focus and analysis of this study are partially inspired by a recent paper that adapts UNICEF's (1990) conceptual framework on the causes of malnutrition to the context of Africa's drylands (Figure 1) (Young 2020). The adapted framework preserves concepts that are globally accepted and extensively tried and tested (nutritional outcomes, immediate and underlying cause), but puts renewed emphasis on the basic and more systemic drivers of wasting in drylands as well as on the synergy between the immediate and underlying causes. For the basic causes, the adapted framework highlights the importance of the role of environment and seasonality, institutions, and livelihood systems, thereby acknowledging the unique climatic and environmental conditions of drylands. This study borrows heavily from this thinking with a strong focus on understanding and further developing the role of these basic causes—environment and seasonality; climate variability; seasonal availability of water and other natural resources; livelihood systems; and gender, social and cultural norms—as well as some of the key immediate drivers (morbidity and food quality), and underlying drivers (food security, care practices, hygiene environment, access to health services).

While the study looks at seasonal patterns across multiple nutrition outcomes, the primary focus of the research is on wasting, defined as having a weight-for-height z-score (WHZ) less than negative two. The highest prevalence of wasting was the end of *seif* (the hot dry season) and into *rushash* (the first rains) (Figure 2). A slight improvement in wasting was observed in *kharif* (the rainy season) when the heavy rains are fully established, with a secondary peak observed immediately prior to the harvest (*darat*). The lowest prevalence was found in the cool, dry season (*shita*), followed by a gradual increase through the hot dry season (*seif*).

Figure 1. Acute malnutrition in Africa's drylands: a new conceptual framework (Young 2020)

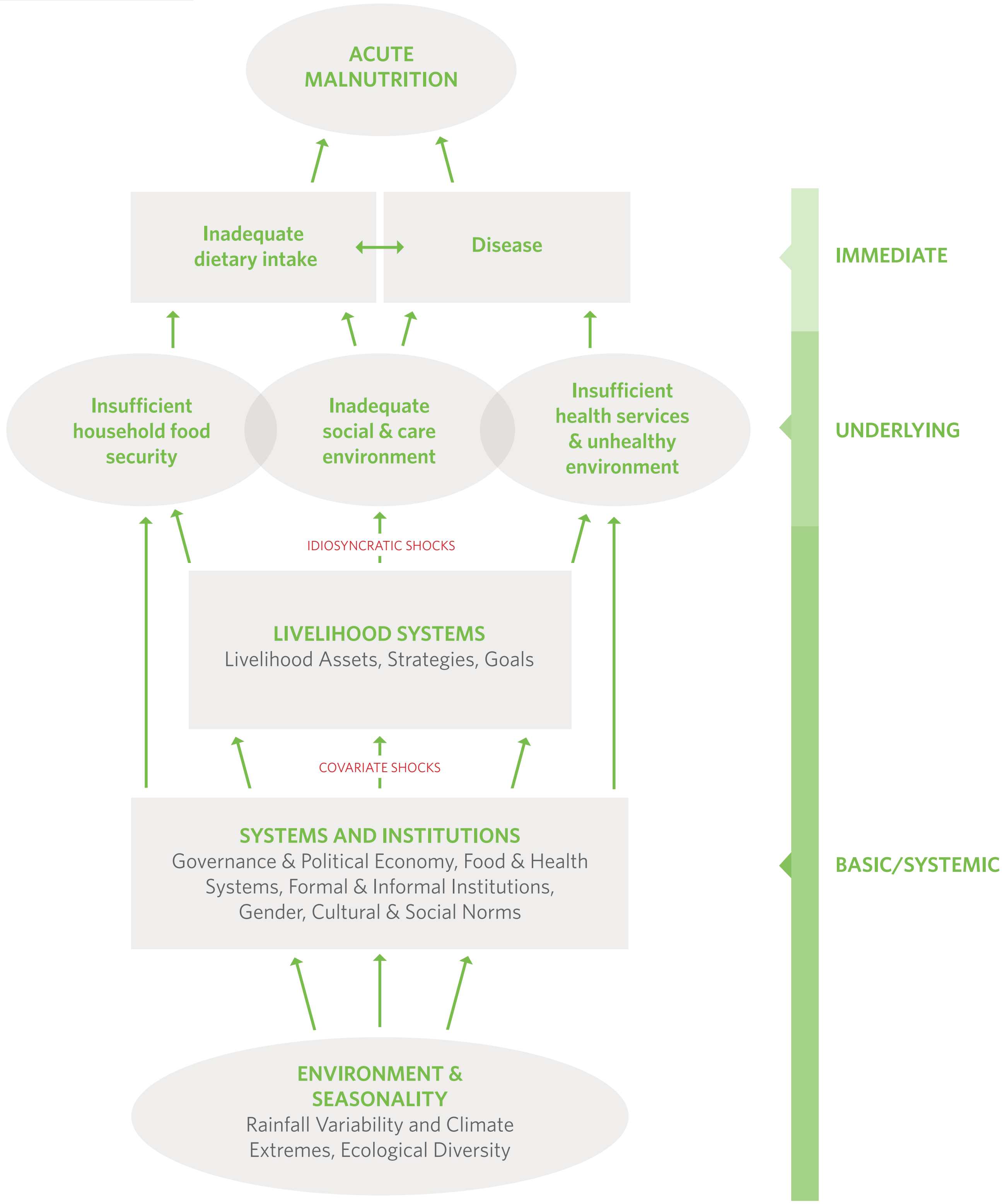
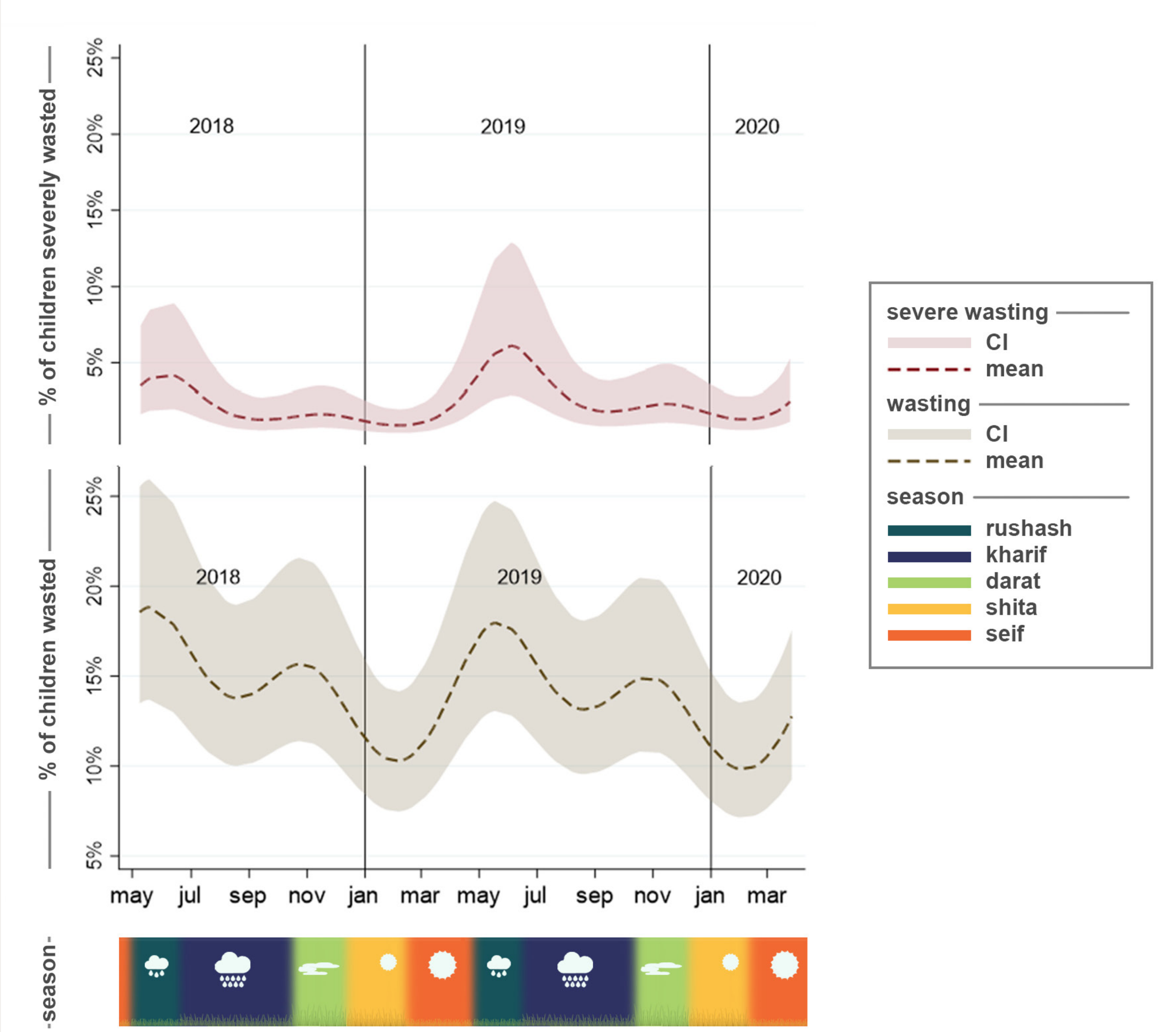


Figure 2: Predicted[1] prevalence of child wasting by season and year



The seasonal pattern of wasting points to a far more complex pattern than hitherto documented. The predominant narrative around the seasonality of wasting is that it peaks once during the rainy season—also called the "hunger gap" or "lean season" due to a combination of increased food insecurity and disease burden, particularly malaria (Chambers, Longhurst et al. 1981; Foeken and Hartog 1990; Ferro-Luzzi, Morris et al. 2002; Devereux, Sabates-Wheeler et al. 2012). The "lean season" assumption is so strong in the literature that it is more often assumed than documented. However, as is the case in Goz Beida, and likely in the Sahel more widely, this assumption is not accurate. Moreover, while the secondary wasting peak does correspond to the timing of high food insecurity and malaria risk, both the presence of the first peak and the improvement in wasting that occurs during *kharif*

1 In this report, the word "predicted" is used not in the sense of a forecast (of future trends) but rather to indicate what our regression analysis of data collected on a few specific days tells us about the nutrition outcomes (and their seasonal trends) that can be expected over the entire course of the research period. In other words, the predicted means are polished extrapolations of raw and "noisy" data.

(the rainy/lean season) indicate that food security and malaria cannot be the main driver of the *rushash* (first rains) wasting peak. Instead, this research and earlier work in Chad point strongly to water contamination by livestock as a critical driver of wasting during *rushash* (Marshak, Young et al. 2016; Marshak, Young et al. 2017).

Another important distinction in the seasonality of wasting was observed in relation to sex. Boys' nutritional status exhibits significantly greater seasonality than girls', driving the *rushash*/first rains/May and pre-harvest/end of *kharif*/October peaks. However, there were no significant differences in the prevalence of wasting between girls or boys (across the full sample). Moreover, in the adjusted regression analysis, girls had significantly lower WHZ and did not experience the improvement in wasting across the 24 months that the boys did. There is some evidence that this observed sex-distinct seasonal pattern is not restricted to Goz Beida, with similar seasonal differences by sex also identified in Mali and Gambia (Adams 1994; Schoenbuchner, Dolan et al. 2019). Overall, multiple studies have found boys to have significantly worse nutrition outcomes compared to girls (Svedberg 1990; Wamani, Astrom et al. 2007; Black, Victora et al. 2013; Development Initiatives 2018; Harding, Aguayo et al. 2018; Schoenbuchner, Dolan et al. 2019). The sex disparity identifying boys as worse off is so consistent that the Wasting-Stunting Technical Interest Group (WaST) highlighted it as one of seven key implications that need to be addressed: "in most contexts, boys are more wasted and stunted than girls. The reasons for this are unknown, but at a policy level this widespread finding indicates that common narratives around gender and heightened vulnerability of girls to malnutrition need to be revised" (WaST 2017). Seasonal differences might explain part (but not all) of the variation in nutritional status between boys and girls.

One possible explanation for the difference in seasonality of wasting between boys and girls has to do with gendered care practices. Through qualitative interviews we found that, due to cultural perceptions of masculinity, households were probably weaning boys much earlier than girls. Women reported that the community perception was that it was not good for boys to spend too much time with the mother and that the family and child would be stigmatized if they did. In addition, girls tended to stay closer to the mother, while boys were more likely to be raised by grandparents or older siblings. Consequently, boys might be experiencing lower frequency of breastfeeding, less supervision by and interactions with caregivers, lower focus on hygiene practice, and more direct access to contamination, which could explain the greater seasonality in nutritional status. Thus, paradoxically, gender differences likely benefit young girls, but later become detrimental to women.

The study found that child nutritional status was strongly correlated with the type of water source used for household consumption, which is extremely seasonal, being affected by the variability of rainfall and availability of open-source water. Across the sample and seasons, households reported using seven different sources of water: boreholes, *machiches* (traditional shallow wells), *hafirs* (man-made mud reservoirs), open wells, rivers/streams/ponds/wadi or other open sources, garden wells (private deep wells), and *hits* (traditional deep wells). Reported use of open-source water, *machiches*, and *hits* was significantly correlated with higher wasting. The same water sources associated with poor child nutritional status also had the highest coliform contamination: open sources, *machiches*, and *hits*. Boreholes and garden wells had the lowest levels of contamination. Weight-for-age z-score (WAZ), WHZ, severe wasting (WHZ<-3), and wasting all correlated with coliform contamination at the source (when relaxing some regression constraints), but not in transport or storage containers. One hypothesis is that contamination introduced into water between the source and consumption has less impact on child nutritional status compared to contamination found at the water source itself.

The density of cattle in a community correlated with both contamination at the water source and worse child nutritional status. Furthermore, the qualitative data identified seasonal patterns of livestock migration which suggest contact with cattle is greatest at the end of *seif/rushash* (when wasting prevalence is highest) when cows approach villages before leaving for more long-distance migration, although this trend varies by village and livelihood specialization. Based on the qualitative work, depending on livelihood specialization, size of cattle herds, as well as proximity to a wadi, certain communities have more contact with cattle than others and thus are at a greater risk of contamination and worsening child nutritional status.

Household food insecurity is also extremely seasonal in this context, peaking at the end of the rainy season just before the harvest. The quantitative data confirms that food security is extremely important for child nutritional status, with WHZ significantly and negatively correlated with household food insecurity (using the proxy Months of Adequate Household Food Provisioning). However, food security appears to be primarily correlated to shifting the entire WHZ distribution, meaning seasonal changes in food insecurity likely affect all households and children. Water contamination, on the other hand, was most strongly correlated to wasting (the left-hand tail of the WHZ distribution), meaning seasonal changes in contamination affect only a handful of children but lead to the most severe nutrition outcomes (severe wasting and wasting). Furthermore, across the 23 months of data collection, Sila Province remained at Integrated Food Security Phase Classification (IPC) Phase 1, with no change between 2018 and 2019. However, the prevalence of wasting surpassed the 15 percent emergency threshold both years (17 percent in Sila in 2018 (UNICEF 2018) and IPC Acute Malnutrition Classification Phase 4, which is considered "critical", in 2019), thus underscoring the need to look at other drivers alongside food insecurity to explain the difference in nutritional status across years.[2]

The seasonal patterns of child nutritional status adhere quite closely to the risks presented by the seasonal variability in rainfall and temperature in Sila Province. This variability affects almost all aspects of household livelihoods, including access to water and other natural resources, timing of rain-fed cultivation and market gardens, when and to where animals migrate, food security, and household child-caring practices. The May peak of wasting—end of *seif/rushash*—occurs at the time of year when water access is most limited; animals and humans are more likely to share the same water source; and, in some communities, the presence of large ruminants begins to increase, putting added pressure on water sources. These factors likely result in increased contamination, particularly from cattle possibly introducing into water sources the pathogen *Cryptosporidium parvum,* which is linked with environmental enteropathy (Rogawski and Guerrant 2017). In addition, this period was also associated with an increased workload for women in preparing the land and hence reduced time for care practices. NGOs and the government would therefore do well to adapt the timing and targeting of their nutrition (specific and sensitive) programming to align with these seasonal patterns of wasting and their drivers and to take more account of the heterogeneity of communities, which we observed even across our small sample of eight villages clustered around Goz Beida, Chad.

2 The IPC classification system (which separately measures food security, chronic malnutrition, and acute malnutrition) uses a 'convergence of evidence' approach and hence several indicators, not just acute malnutrition, have to meet the appropriate criteria to identify a region as facing a humanitarian emergency. For further details, see: http://www.ipcinfo.org/ipcinfo-website/faqs/en/

Background to the study

The prevalence of global acute malnutrition (GAM), when above 15 percent, is among the main indicators used to identify a humanitarian crisis (IPC Global Partners 2019). However, after the acute phase of a crisis and despite ongoing assistance, GAM rates frequently persist above the emergency threshold (Young and Marshak 2017). Chad regularly reports GAM rates above 15 percent (National Nutrition data) (Table 1) despite ongoing efforts by government, humanitarian, and development actors, and even in years when the country or region is categorized as food secure. This indicates that nutrition actors/stakeholders are probably not addressing *all* the key drivers of persistent GAM.

Table 1: Annual GAM prevalence in Chad and Sila Province, 1994-2014

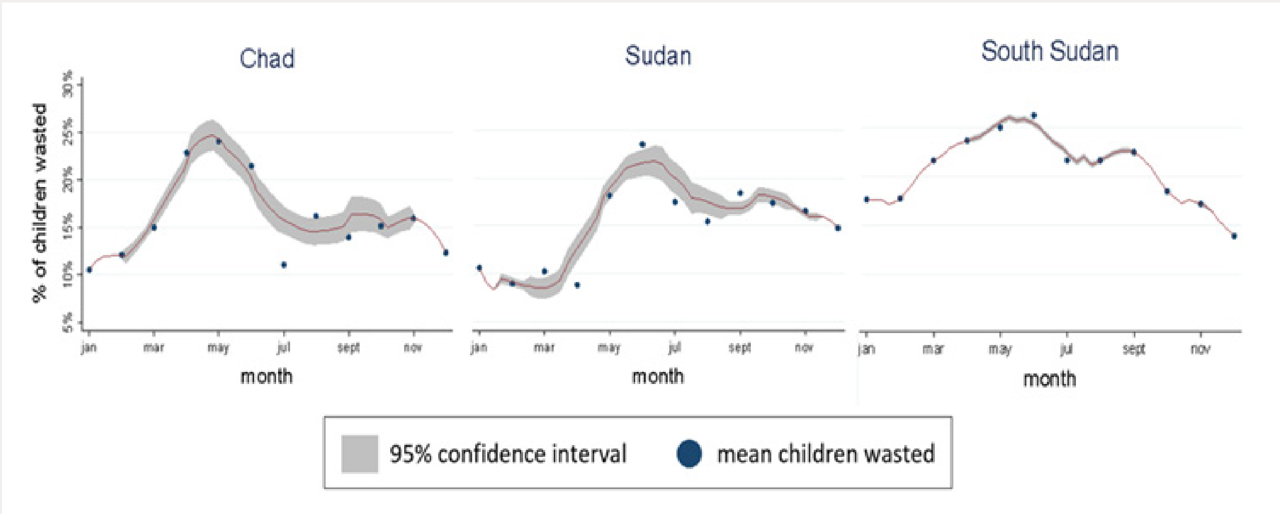
Year	Chad	Sila/Ouaddai
1994	20%	
1995	14%	
1996	22%	
1997	11%	
1998	36%	
2000	20%	
2001	21%	
2002	25%	
2005	18%	12%
2007	7%	7%
2008	6%	6%
2009	22%	22%
2010	20%	18%
2011	15%	13%
2012	16%	17%
2013	12%	15%
2014	11%	10%
2015	12%	14%
2016	12%	11%
2017	14%	17%
2018	14%	18%
2019	13%	16%
Aggregate	**16%**	**14%**

Note: green indicates years when GAM prevalence exceeded the commonly used emergency threshold of 15 percent.

Furthermore, previous studies point to the possible presence of two peaks of wasting: one at the start of the rains and one at the end of the rains (in an environment with one recorded annual rainy season), with possible improvement in between, indicating a strong role of drivers other than food insecurity (Bechir and Schelling 2010, Egata, Berhane et al. 2013, Grellety, Luquero et al. 2013). For example, one study in the Lake Chad region found that the prevalence of GAM was significantly higher at the end of the dry season compared to the end of the rainy season for both nomadic and sedentary communities (Bechir et al. 2010). Our own review of available Standardized Monitoring and Assessment of Relief and Transitions (SMART) data (aggregated from 1994-2014 by month) from Chad, Sudan, and South Sudan (same data as in Table 1) identified two peaks of wasting also at the beginning and end of the rainy season (Figure 3). A wider analysis of SMART data from all single-wet-season drylands in Africa identified the same two-peak trend (Venkat et al. 2020: in progress). The presence of twin peaks might therefore be a regional phenomenon, and not just specific to Goz Beida or Chad more broadly.

Several recent studies have explored what the "hidden" drivers might be in Chad. A recent evaluation in Chad identified inadequate household hygiene practices as significantly correlated with having a child with severe wasting (Dodos, Altare et al. 2018). Another research project found that adding a water, sanitation, and hygiene (WASH) package to outpatient therapeutic feeding programs (OTPs) shortened recovery times from severe acute malnutrition (SAM) and improved recovery rates (Altmann, Altare et al. 2018). Recent research further highlighted the importance of considering contamination from animal fecal matter; most current WASH programming is narrowly focused on contamination from human fecal matter (Headey

Figure 3: Seasonality of wasting using 20 years (1994-2014) of SMART data (Source: FAO and Tufts, 2019)



and Hirvonen 2016). Most importantly, evaluations of program impact carried out by Concern and Tufts in Sila specifically pointed to the presence of cattle in the community—along with poor access to potable water—as negatively associated with wasting (Marshak et al. 2016; Marshak et al. 2017). Further research from N'djamena, Chad found that SAM children who had *Cryptosporidium parvum* (a zoonotic pathogen frequently found in cattle) in their stool had a 72 percent greater risk of death (Akpako et al 2016, poster for DiDimas). Finally, a meta-analysis of the long-term consequences of *C. parvum* infection in children found the highest rates of disability-adjusted life-years lost to the pathogen in Chad (Khalil, Troeger et al. 2018).

Aim of the study

This study explores the seasonal patterns of wasting, water contamination, and livestock management and how these variables interact seasonally in the communities around Goz Beida in the Sila Region of Chad. Specifically, the study was designed to answer the following often-interrelated research questions to better understand the drivers of seasonal wasting:[3]

- What are the seasonal patterns of child malnutrition across multiple nutrition indicators?
- What are the seasonal patterns of coliform contamination along the water chain (source, transport, and storage)?
- What are the seasonal patterns in livestock management practices?

To do this, the Tufts and Concern carried out a small two-year longitudinal mixed-methods study on child nutritional status and coliform contamination across the water chain. In this report, we first briefly present the background and aim of the study, followed by its methodology, which includes information on study locations, sampling across the qualitative and quantitative data collection, procedures for data collection, and analysis. Next, we discuss findings, focusing on: seasons as described by the community; livelihood specialization and history; climate and shocks; livelihood-related seasonal mobility; gender norms; marriage and procreation; women's workloads; childcare feeding practices; animal health; water sources for human and animal consumption; contamination and hygiene practices along the water chain; and, finally, child nutrition and morbidity. We follow this with a discussion of the findings and their implications for programming. Qualitative and quantitative research findings are included throughout the report to illustrate key points.

3 While we look at seasonal patterns across all nutrition indicators, analysis linking nutrition to other outcomes is limited to wasting and WHZ given the research focus on the more acute forms of child malnutrition.

Methodology

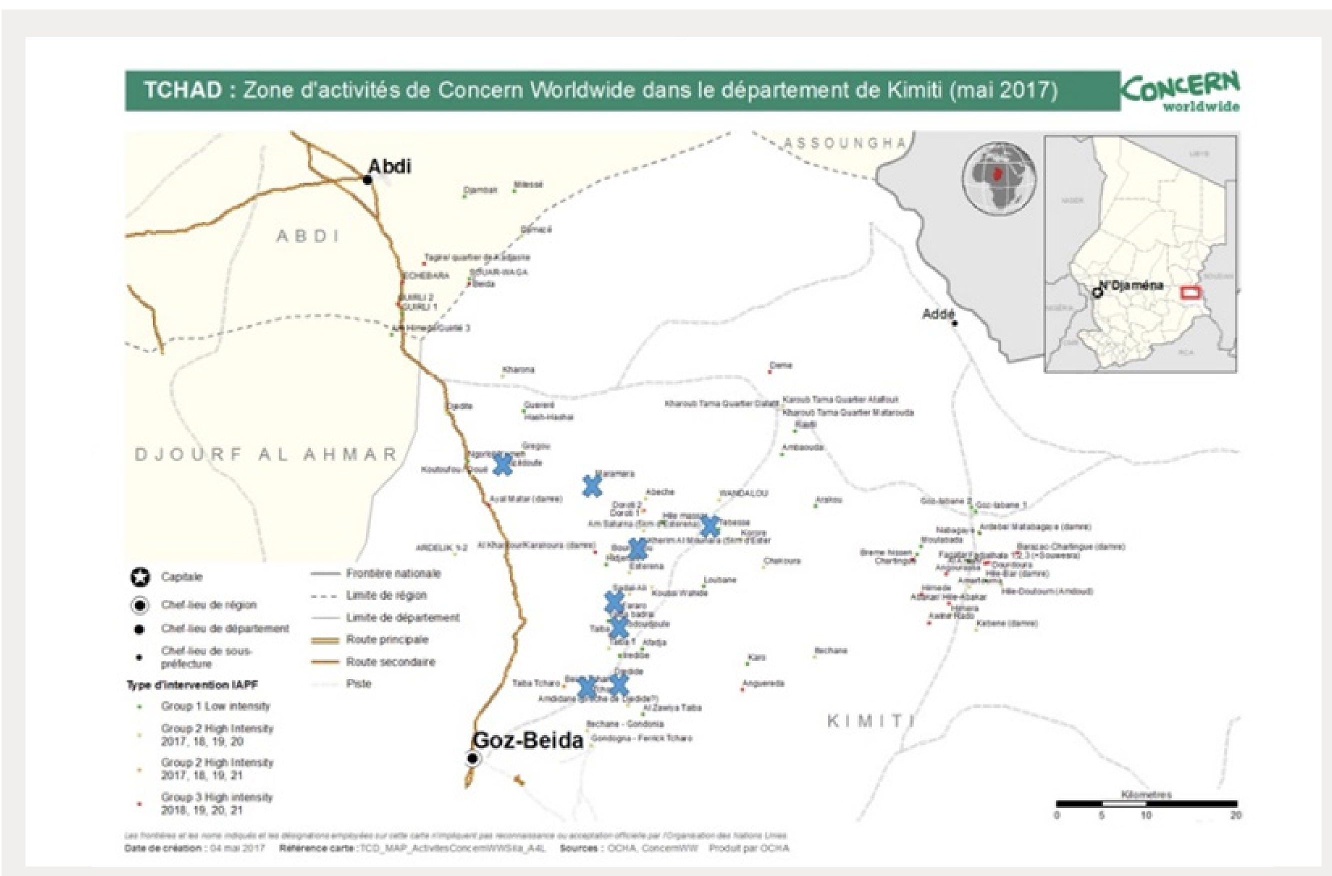
This study used mixed methods to follow children aged 6-59 months in the same 89 households in eight villages over 23 months, from May 2018 through March 2020.[4] We followed the same households and children to better identify intra-annual variability in wasting as well as start to understand how that variability might vary across two consecutive years. Over the course of the study period we gathered quantitative data on child anthropometry and morbidity; household water access and hygiene practices along the water chain; and coliform contamination at the water source, during transport, and in storage containers. In addition, qualitative research was carried out in August 2018 and May 2019 in an effort to understand more about seasonal access to natural resources; livestock mobility; household mobility patterns linked to livelihoods; the history of livelihood specializations, care and hygiene practices; and to draw comparisons across communities and households with the best and worst outcomes in child nutritional status and/or contamination across the water chain.

In this section, we discuss the study location, sampling, survey procedures, and analysis for both the quantitative and qualitative data. The study was approved by the Tufts Institutional Review Board (IRB).

Study locations

The study was conducted in the Sila Province of Chad in eight villages that received the multi-

Figure 4: Map of study locations



4 Originally the study was planned for 24 months, but we had to abandon data collection after March 2019 given the Covid19 pandemic and our desire to lessen risk to respondents.

sectoral CRAM/BRACED intervention from 2012 through 2017: Abdoudjoul, Al Kherim, Djedide, Maramara, Rizildout, Taiba Badria, Tcharo, and Tebesse. These villages were selected based on proximity to the Concern Goz Beida office and ease of access throughout the year (Figure 4).

While quantitative data was only collected from the eight selected villages, qualitative data was gathered from these villages and their environs, including nearby temporary settlements used by community members during times of farming and livestock migration activity, that lay outside the village boundaries[5] as well as neighboring villages. In the second round of qualitative research, we were also unable to conduct any interviews in Rizildout due to insecurity.

Sampling

Quantitative

The sampling frame included all households from the selected communities who had at least one child under the age of five years at the beginning of the study (May 2018). This list was compiled using the November 2017 data from the CRAM/BRACED program. We then randomly selected a total of 89 households from all the villages that met the criteria of having at least one child under the age of five. From the 89 households we enrolled 212 children in total because most households had more than one child in the appropriate age range (Table 2).

We followed the same children throughout the study. As children aged out (by turning five), they were removed from the study. Children in the enrolled households who turned six months during the duration of the study were added to the sample.

For the water testing, we tested the storage and transport container for every available household. However, the number of water sources per community was generally limited. Thus, we looked at what types of water source households in a specific village mentioned in the quantitative study and collected one sample from each type and merged it with the household data. Table 3 sets out the monthly number of coliform testing observations from different water sources. It is worth noting that generally our understanding of the diversity of sources increased in Year 2.

Qualitative

For the qualitative research, we purposively selected community members and key informants (Table 4 and Table 5). We use criteria from the first round of quantitative data collection to select individuals to interview. First, using the quantitative anthropometry and coliform contamination data,

Table 2: Research locations and sample sizes

Village	# of hh	# of children under 5	# of total child observations
Abdoudjoul	13	27	495
Al Kherim	5	8	104
Djedide	12	26	424
Maramara	10	21	358
Rizildout	13	35	607
Taïba Badria	15	39	585
Tcharo	8	21	316
Tebesse	13	35	523
Total	**89**	**212**	**3,412**

5 Data collection occurred in August 2018, during planting season and when cattle are kept away from field in pasture area. Therefore, on this season encampments are mainly: camping near farming field (*damkoutch*) and camping near herds (*makhalaf*, ferrik), and in May 2019, during diarr, *damkoutch* and *marchech* encampments.

Table 3: Number of water source samples by month and year of data collection

Month	# of different source observations	
	Year 1	*Year 2*[6]
May	13	17
June	11	9
July	11	23
August	7	19
September	8	16
October	11	17
November	7	17
December	19	22
January	20	-
February	15	18
March	20	-
April	17	-
Total	**159**	**158**

we identified positive and negative deviant[7] (PD and ND) households and communities in terms of both malnutrition and water contamination. Specifically, we selected households with: high coliform contamination along the water chain (ND for storage and transport); low coliform contamination along the water chain (PD for water contamination); no children ever malnourished in the last nine months (PD for malnutrition); and households where children were malnourished at least 25 percent of the time in the past nine months (ND for malnutrition) based on findings from the first nine months of data collection (see Annex B for list and sampling strategy). Second, to get a diverse spread of livelihood specialization and mobility patterns, we also selected:

- households who move seasonally to a *damkoutch*[8]
- households who move seasonally to a *makhalaf*[9]
- households with a history of semi-sedentary, pastoral livelihoods (key informants throughout the villages)
- households with a history of agricultural livelihoods (key informants throughout the villages)
- households and key informants with farming versus more livestock-based livelihood specializations (key informants throughout the villages)

The selection of individuals and households was achieved with the help of local informants and Concern Worldwide staff.

We interviewed the main caregivers/mothers, herders at water points, and women and girls at water points. For key informant interviews, we spoke with community chiefs, animal health workers, traditional birth attendants, imams and religious leaders, representatives of women in the community (*chouchie*),[10] the sultan of Goz Beida, and the canton chief of Tcharo.

We also conducted several focus group discussions using participatory methods in both 2018 and 2019. These were done with: women (mainly mothers of children under the age of five), men (mainly fathers of children under five), elders, owners of large herds, professional herders,[11] members of the water committees, as well as water source users across different types of source. Finally, we held a workshop to gather qualitative feedback from the quantitative enumerators in charge of the longitudinal data collection and from Concern Worldwide's operational team.

6 For the coliform data, we are missing both March and April data because the analysis of the coliform data was not allowed under Tufts IRB guidelines for human subject research during Covid19. The January data is missing due to a delay in data collection at that time.
7 Positive deviance is concept drawn from behavioral and social change based on the observation that in any community there are people whose uncommon but successful behaviors or strategies enable them to find better solutions to a problem than their peers, despite facing similar challenges and having no extra resources or knowledge than their peers. These individuals are referred to as PDs. Similarly, those who show negative deviance (by employing strategies that deliver worse outcomes than their peers) are termed NDs.
8 Seasonal encampment for agricultural or market gardening purposes
9 Place of encampment for cattle and herders (mostly men) during rainy season (July-November)
10 Either the wife or sister of the chief
11 Paid herders renowned for their expertise and skill.

Table 4: Qualitative data collection, by location (August 2018)

Village	Individual interviews: key informants	PD (5) and ND (3)	Damkoutch	Makhalaf	Focus group discussions: mothers of children < 5	fathers of children < 5	other
Tcharo	3	0	2	1	4	2	1
Rizildout	2	3	0	0	3	1	1
Maramara	1	0	2	0	4	1	1
Djedide	2	1	2	0	3	2	1
Tebesse	3	2	0	1	4	1	1
Al Kherim	2	0	0	0	3	2	1
Abdoudjoul	1	2	0	1	3	2	1
Taïba Badria	2	0	0	0	2	2	1
Goz Beida	-	-	-	-	-	-	11
Total # of ppl	**16**	**8**	**6**	**3**	**136**	**72**	**68**

Table 5: Qualitative data collection, by location (May/June 2019)

Village	Individual interviews: key informants	PD (8)/ ND (5)	mothers of children < 5	fathers of children < 5	Focus group discussions: mothers of children < 5	fathers of children < 5
Tcharo	3	0	3	1	2	2
Rizildout	0	0	0	0	0	0
Maramara	2	2	2	1	2	1
Djedide	3	3	2	3	3	2
Tebesse	1	0	2	1	0	0
Al Kherim	3	1	2	0	2	2
Abdoudjoul	2	4	2	2	2	2
Taïba Badria	3	3	1	2	2	1
Goz Beida	-	-	-	-	-	9
Total # of ppl	**17**	**13**	**14**	**10**	**82**	**58**

Procedures

Quantitative survey and anthropometry

A team of trained enumerators visited each selected household monthly for 23 months. Enumerators were trained on the survey tool, anthropometry measurements, and collection of water samples, with occasional refresher training in 2019. Each monthly visit entailed the completion of a short questionnaire on child anthropometry (MUAC, weight, height, and edema), morbidity, and hygiene practices along the water chain, as well as the collection of water samples (see Annex C for full instrument).

Water testing

Enumerators collected water samples at the same time (though perhaps by different individuals based on expertise) as the household quantitative questionnaire was completed. The enumerator first took a water sample from the main water source in each community (see Annex D for water testing procedure). This data was applied to each household in the community that used this source that month, as they reported in the quantitative survey. If a household reported using a different source, then a sample was also taken from that source and applied to that household. Then, the enumerator took samples from the water storage and transport containers of each household. If the households used the same container for both transport and storage, only one sample was taken. If a transport container was empty, the enumerator arranged a return visit. The data was then directly linked (using the same household ID) to the quantitative surveys. The water samples were then tested for total coliform.

Qualitative interviews

The field team consisted of one international researcher (female), three local assistants (two males and one female), one translator (male), and a field team supervisor (male). The supervisor provided contextual and seasonal information about the PD and ND households and water points as he visits them every month for the quantitative longitudinal data collection. We chose to work with three local assistants because they know the context and local languages and can identify bias in participant response and non-verbal information more effectively than professional researchers from other areas of the country. Exchanges took place in local Chadian Arabic and were translated into French by the translator.

This study used standard qualitative research tools including key informant interviews, individual interviews, focus groups (split by gender) (Photo 1), observation, and participatory tools and techniques. Specifically, the following techniques were used: storytelling, scoring risk games, daily activities charts, seasonal calendars, gender box, mapping, Likert scale, and interviews with PD and ND households. See Annex F for a detailed description of each approach.

Photo 1: Focus group discussion

Analysis

Quantitative data

We used two approaches to analyze the quantitative data. The first approach we used was mixed effects models for time series analysis with the inclusion of harmonic terms (sine and cosine) to explore whether there are non-seasonal trends. We used both 2π and 4π sine and cosine terms to test for multiple non-symmetrical peaks in the regression. Generally, when both terms are significant it means there is more than one non-symmetrical peak and nadir/trough in the seasonal pattern. In addition, in the mixed effects model we controlled for child and village-level fixed effects. Using the results of the mixed effects regression model we can identify the timing of the peaks. Because we used the precise day of data collection, the predicted peak timing provides a specific day rather than month. We present the predicted peak day throughout the analysis for illustrative purposes not because we are claiming that it is precisely on this day, every year, that we will see a peak, but rather to indicate whether that peak happens towards the beginning, middle, or end of the month for the specific time period of interest. One final point of clarification: while the regression analysis uses daily values for the purpose of understanding seasonal patterns, for the figures, data is averaged by month (for purposes of presentation), thus the predicted daily peaks or nadirs/troughs might differ slightly by a couple of days from what is in the figure.

In our second approach we relaxed some of the model constraints and ran an ordinary least squares (OLS) regression for continuous and normally distributed variables (such as z-scores) and a logit regression for binary outcomes (such as wasting, underweight, stunting, etc.). While the results from this approach are not nearly as robust as what we find using the mixed effects, they do allow us to make further hypotheses.

Only relationships (across all regression analysis) with a p-value less than 0.10 were considered significant. The p-value is the probability of seeing a relationship between these two variables if the relationship did not actually exist (the null as opposed to alternative hypothesis was true). The lower the p-value the more confident we are in the observed relationship. In most of the tables we report on either the sample mean or sample prevalence for a certain indicator as well as the 95 percent confidence interval (CI). The CI tells us that there is a 95 percent probability that the population mean falls between the two specified values.

Qualitative data

For the qualitative data, we used content analysis to analyze and interpret verbal, behavioral, and observational data. All coding was done manually in Excel. We analyzed the content descriptively or interpretatively through the following steps:

1. **Review.** Reviewing all data, writing down impressions, looking for meaning and determining which pieces of data have value.
2. **Data coding and categorization.** First, data from each community and informant was coded by themes related to the research questions (e.g. health-seeking behavior, water source management, daily activities for women in May). Then, we did a second level of coding to stratify the first categorization for specific groups (e.g. villages, livelihood specialization, PDs and NDs, wealth of the household, gender of the respondents, age of respondents, households who go/do not go to a *damkoutch*). Finally, we classified responses by seasons or years (e.g. main water source for human consumption changes by season).
3. **Identification of patterns and connections.** We looked for relative importance and occurrence of responses received and identified relationships between themes or respondents and themes and seasons.
4. **Interpretation of data and findings.** After themes, patterns, connections, and relationships were identified, we analyzed meaning and significance and linked this to the research questions and objectives. We identified noteworthy quotations from the transcripts to highlight major themes within findings and possible contradictions.

Limitations

There are several limitations to the study methodology.

Data on children is not consistent across months: While the quantitative study aimed to follow the same children over the course of 23 months, not all children are available monthly. Of the children in our sample, 5 percent of the time the children were reported too sick to be measured, 16 percent of the time the children were not present (and too far to reach), and 11 percent of the time the entire household was missing from the sample. By not including children who are "too sick to measure," we positively biased the anthropometry data. On the other hand, children who were absent from our study tended to be significantly ($p<0.001$) older than those present (38 months vs 34 months). Since older children are significantly less likely to be wasted ($p<0.001$), we expect this to negatively bias our anthropometry data. Together it is difficult to estimate the overall direction of the bias, if any.

Children's ages might not be completely accurate: Children in Goz Beida are extremely unlikely to have official documentation that testifies to their age. Thus, enumerators had to use seasonal calendars and events to try to pinpoint the age of the child in months, likely leading to some discrepancies.

The study is not set up to identify causality between nutrition outcomes and drivers: The main aims of the study and associated design was to understand the seasonality of nutrition outcomes and drivers and to see where those seasonal patterns overlap. While we looked at the relationship between these indicators, we can only claim association and not causality. Although having a temporal and child level association strengthens our hypothesis around causality, it does not in itself directly *establish* causality.

Coliform data is only a proxy for animal-related contamination: The water contamination data covers information on coliform, a bacterium found in the feces of warm-blooded animals. Coliform itself does not necessarily cause serious illness, but its presence indicates that other pathogenic organisms of fecal origin might be present. We cannot link the presence of coliform to specific animals, distinguish between animal and human fecal presence, nor identify which disease-causing bacteria, virus, protozoa, or parasite might be present. This does significantly hinder our interpretation of the coliform data. Consequently, we can only use the coliform data as a proxy for possible pathogens. Follow-up research using stool samples would allow us to identify specific pathogens and their associated risk to child malnutrition.

Data on open defecation was not collected: The study was designed, and its variables were selected based on which variables came out as relevant and significantly correlated to wasting and WHZ in the CRAM/BRACED study. Open defecation, at the individual or village level, had no relationship to child or village-level wasting, thus it was not included in the seasonality data collection (Marshak, Young et al. 2016). However, that omission makes it difficult to assess whether the contamination in the water comes from animals or humans. Furthermore, the lack of a relationship between open defecation and child nutrition outcomes in the CRAM/BRACED data might be an artifact of the timing of the data collection (harvest period). Thus, open defecation could still be critical in regard to child nutrition during other seasons, such as the dry season or the start of the rains. Unfortunately, we did not pursue this line of inquiry and thus cannot say anything in this study in terms of the contribution, or lack thereof, of open defecation on child nutrition outcomes.

Inclusion of variables drawn from 2017 CRAM/BRACED data: Given the frequency of quantitative data collection, we made the survey as short as possible to limit the burden on the respondents as much as possible. Thus, for some variables, because the sample was pulled from a previously surveyed population (CRAM/BRACED) we used available 2017 data. Specifically, we use dated livestock (cattle ownership) and food security (Months of Adequate Household Food Provisioning (MAHFP)) data. While this increases survey efficiency, it does mean there could be discrepancies between the 2017 information and the current reality. As our interest is mainly about relative variability in food security and presence of livestock, the variability in the values over time does not matter as much as the variability in the variables across households. However, if some households improved while others got significantly worse, it could throw off our interpretation. While we hoped to remedy this by collecting food security data using the MAHFP variable in the last planned month of data collection (April 2020) we were unable to do so due to the Covid-19 pandemic requiring all human subjects research to cease in March 2020.

Short duration of qualitative research: We collected qualitative data in the villages for only 21 days in total (11 days in August 2018 and 10 days in May 2019), which is a short period to gain a deep understanding of the dynamics and heterogeneities of the area. Also, the design included multiple types of key informants, yet only a couple could be interviewed in each village. In addition, we had originally planned a third qualitative field trip in May of 2020 that was cancelled due to restrictions related to the pandemic on travel and human subject research.

Timing of qualitative research analysis: The qualitative data collection took place in August 2018 and in May 2019 (to correspond to the timing of the hypothesized peaks of wasting). We were therefore unable to include nomadic households with large cattle herds as they had not yet arrived at the research location. Furthermore, despite the use of seasonal calendars, it was difficult to catch seasonal variations for other times of the year, as the study team relied only on participants' testimonies to get an idea of changes in other seasons. Seasonal calendars and daily chart tools can be challenging for participants and some things will be forgotten because they are so habitual or not reported because they are not socially discussed. Additionally, during the May 2019 field trip, the team was not able to visit Rizildout for security reasons. Furthermore, due to restrictions on human subject research and travel in 2020, we were unable to return to Chad to do an additional qualitative inquiry in May that would have allowed us to further pinpoint some of the differences observed across the two years of data collection.

Positive Deviant and Negative Deviant methods are highly context specific: PD and ND methods have some limitations, as the attributes of a PD and ND household or child are highly context specific and cannot be applied to other communities (e.g. a PD household in Tebesse could be very different from a PD household in Maramara), or even between different seasons of the year. Also, as communities change over time and become more heterogeneous, behaviors that were considered positive in one community may eventually be considered negative in another (e.g. the presence of men/proximity to husbands). While we used the same methods to identify PD and ND households across all research locations, the specific drivers of what makes a household PD or ND varies by community.

Association with Concern Worldwide might have biased some responses: Carrying out this study under the banner of the INGO Concern Worldwide, which intervenes in the area, is likely to influence some of the testimonies and survey responses. The villages selected for the study were those that had previously benefitted from Concern projects. We suspect that the direct association with Concern did have an impact in the honesty of some initial responses on both the quantitative and qualitative survey with respect to inputs provided by Concern, specifically borehole function and use. We found that at the start of the survey a little over 60 percent of households reported using boreholes built by Concern Worldwide that we later discovered to not be functioning.

Findings

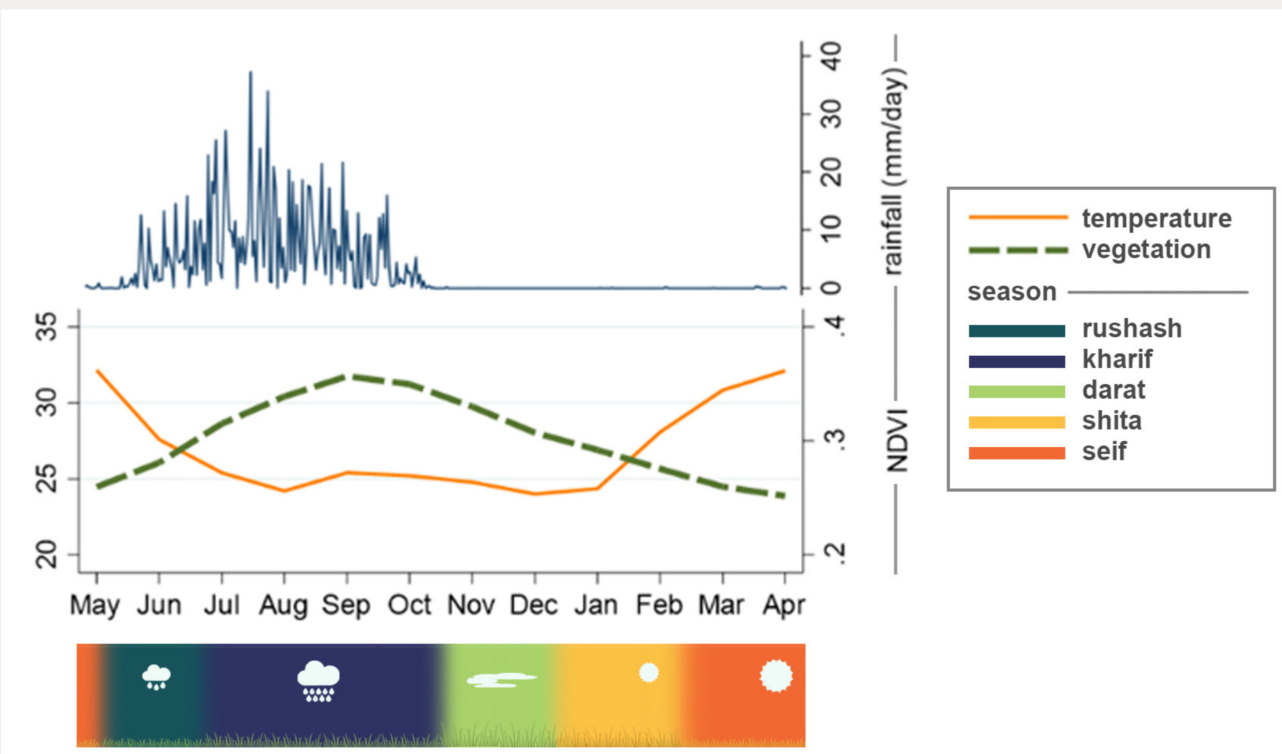
In this section, we briefly outline the seasons in Sila Province and then describe the livelihood systems and associated history, livelihood shocks, livelihood-related seasonal mobility, gender norms and their potential impact on our outcomes of interest, water sources for human and animal consumption, contamination of water sources and along the water chain, and child nutritional status.

Seasons as described by the community

Sila Province corresponds to the Sahel climate zones of Chad and is located between the 450mm and 600 mm isohyets. Rainfall varies from 200 to 600 mm annually, 90 percent of which is obtained in July and August. The transition from one climate type to another is sometimes very abrupt.

Communities in Chad distinguish between multiple seasons (Figure 5) beginning with *rushash*, the start of the rainy season. *Rushash* is an extremely short season, usually lasting between three and five weeks sometime between late April and early June and corresponding to the first weeks of intermittent rainfall. *Rushash* is followed by the rainy season *kharif*. In *kharif* the temperature drops and rainfall increases, usually lasting through the end of September. As the rains subside after *kharif*, we enter another short season, *darat*, when seasonal rivers, or wadis, are full but begin to dry out, and vegetation has reached its peak. *Darat* is followed by *shita*, the cool, dry season usually occurring around January and February. As temperatures begin to climb, access to surface water declines, and vegetation is at its lowest. This is the period of *seif*, the hot dry season. *Seif* is then interrupted by

Figure 5: Local seasons in Goz Beida, Chad



the start of the rains and we are back at *rushash*. It is worth noting that while we generally assign calendar months to these seasons, the precise dates are extremely variable. What is far more important than the calendar month is the corresponding changes in precipitation, temperature, and vegetation.

The seasonality in Figure 5 corresponds to previous work done around seasonality in Sudan with slight distinctions in the start and end of the rains depending on the latitude of the location (Saverio, Eldirani et al. 2013; FAO and Tufts 2019; Young and Ismail 2019).

We will primarily use the local names for these seasons for the entirety of this report.

Livelihoods specialization and history

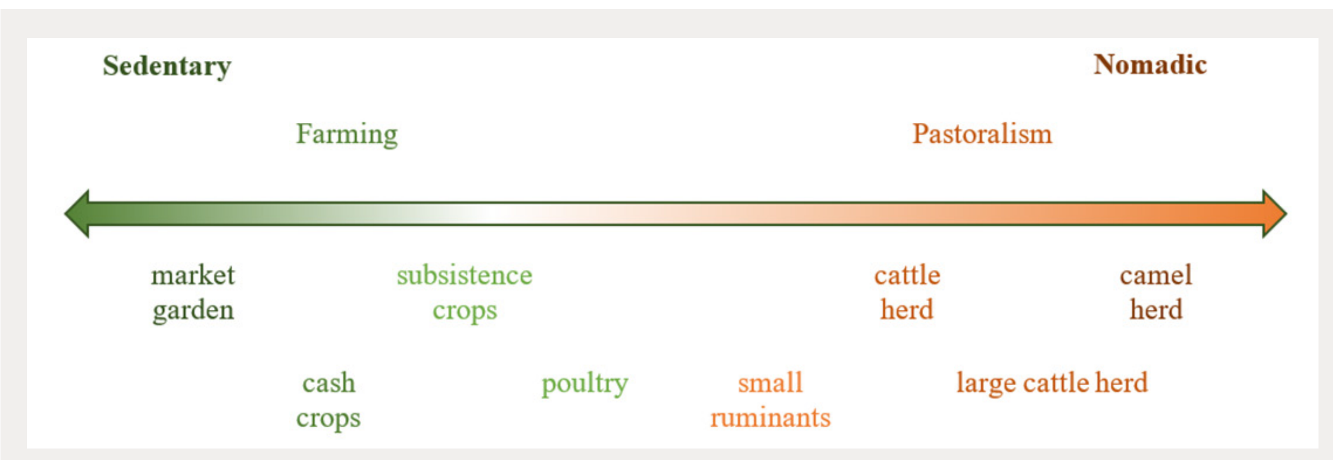
Our eight communities lie on a spectrum of prioritization and practices of farming and pastoralism (Figure 6) with households generally doing some farming and owning some animals irrespective of their livelihood specialization. For example, people in Djedide and Rizildout consider themselves mainly farmers, while those in Taïba Badria, Tebesse, and Al Kherim are more likely to define themselves as pastoralists, with the other villages falling somewhere in between on the agro-pastoralist spectrum. Livelihood specialization is also linked with the mobility of households and their livelihoods (which we discuss in the section on "Livelihood-related seasonal mobility"). In households that prioritize livestock keeping and have medium-sized to large herds, males must move with their livestock to consistently get sufficient access to water and pasture.

Livelihood specializations are ecologically adapted to their dryland environment. Communities take advantage of the seasonal distribution of natural resources. They also have a long history of specialist knowledge/skills being handed down from one generation to the next. In this sense adaptation is a long-term positive process, in contrast to the more marginal short-term coping strategies people have to adopt in order to have access to sufficient food or income for food.

These specializations are broadly associated with particular modes of living: farming is a more sedentary lifestyle in villages, while pastoralism is associated historically with nomadism but also practiced by settled pastoralist communities in which only livestock and their herders migrate.

Livelihood specialization—where households lie on the spectrum of farming to pastoralism—is closely linked to access to natural resources, which in turn is associated with ethnicity and community history. Many different ethnic and tribal groups have cohabitated in the Sila region for decades. The most populous groups are:

Figure 6: Simplified spectrum of livelihood specialization and mobility



- Dadjo: the historical inhabitants of Dar Sila. Dadjo have a history of agriculture-based livelihoods.
- Ouaddaï: historically farmers from Ouaddaï region, "most of whom arrived after the drought in 1984".[12]
- "Arabs:" a term that encompasses many tribes: Mimi, Zaghawa, Badria, Masirié, Alouadrachit, Salamat, and Hemat. These communities historically specialize in pastoralism. "Some groups came in 1968 (when the government started to tax animals), others in 1973 (after conflicts with Ouaddaï groups), in 1982/1984 (drought), in 1985 (rinderpest). Arab tribes often have larger herds, with cows."[13]

Tcharo, Djedide, and Rizildout are the oldest villages in our study, while the communities of Tebesse and Taïba have settled more recently. Older villages, that are primarily Dadjo—Djedide and Rizildout—have access to land at the foot of the mountains and near a wadi. Newer villages have poorer soil. Even in older villages, population pressures have led new villages to spring up. For example, because of diminishing land access in Rizildout, some households moved seasonally to Maramara to find fields to cultivate. After some years of seasonal movement, they settled down year-round in Maramara. Maramara is located on a mountain; "the land is very hard to farm, and apart from the boreholes there is no other water point in the dry season".[14] Al Kherim, on the other hand, is located near a wadi, so has relatively good access to water all year long for cattle but its soil is stony, which is not optimal for agriculture.

Access to water is linked to access to land. The historic inhabitants of Sila (Dadjo communities) own most of the land around wadis where it is possible to dig wells during the dry season to access water. Traditionally, the Dadjo (farmers) and pastoralist groups made customary arrangements that allowed the pastoralists to access the Dadjo-owned land and dig wells to water their animals during the dry season. Patterns of reciprocity between farmers and pastoralists also entailed soil fertilization by livestock as they fed on residues, and the transportation by animals of crops to market.

Most households across all communities carry out rain-fed cultivation, mainly focused on pearl millet, sorghum, sesame, beans, peanut, and okra. Cereals are the main subsistence crop while the other crops are mainly grown for sale (cash crops), although a small amount is normally kept for consumption by the household. Crops from the previous year are used as seed. Fallow methods are rarely used because of the low availability of arable and productive land.

Agricultural activities begin at the end of the dry season (usually around May), with the preparation of fields by women, eventually with the help their husbands (ploughing). Planting of millet occurs at the first, second, or third rainfall (usually around June) depending on the quantity of rain and the quality of the soil. For example, "Some households in Tcharo, with very fertile land are planting just before the first rain, but some households in Maramara or Taïba Badria have clayey land, they have to wait for the third rain".[15] About three weeks after seeding, "when the millet starts to come out of the ground", the woman of the household will weed the field (June/July). The weeding is mainly done by hand with a hoe; households that have a "good quality donkey" or horse will use them for ploughing. Around August, just after weeding, households sow sesame and peanuts, most often on the same fields as the millet. Around September, women do the second weeding. To reach maturity, millet takes four to five months and peanuts and sesame take about three months. Harvesting generally happens two months after the second weeding (November/December).

Historically millet is sown before other crops so that they can all be harvested at the same time. However, in response to climate variability and fearing an early end of rainy season that would result in poor maturation of crops, some households now sow peanuts, sesame (etc.) at the same time as millet.

12 Key informant in Goz Beida, August 2018
13 Key informant in Goz Beida, August 2018
14 Woman interviewed in Maramara, May 2019
15 Key informant in Goz Beida, May 2019

"If the millet does not reach optimal maturity, at least I will have the peanuts."[16] "It is a risky practice: if peanuts are sown earlier, but if the rainy season is normal or long, you need to harvest very quickly in August, otherwise the plants will reproduce, and you will get a poor yield." "In 2018, planting groundnuts earlier was a failure because of the very long rainfall." Food-insecure households will risk planting millet and other crops earlier, using their remaining stocks as seeds instead of eating them. This also helps them harvest as early as possible.

Some households are able to practice market gardening during the cool dry season. The work of market gardening is primarily done by women. Market gardening plots are different from rain-fed crop fields, as they require more fertile alluvial soils and water for irrigation. They are located close to wadi beds, where water can be found during the dry season by digging a deep well. Market garden plots are also smaller, relatively rare and coveted due to their greater productivity/fertility. However, not all households practice market gardening for different reasons:

- They do not own suitable alluvial land or do not have the money to rent a suitable plot.
- They have land suitable for a market garden, but the woman of the household does not have help from a man to dig a well. "Digging a well is a man's job, women don't have the strength".[17]
- Land suitable for market gardens is very often attacked by wildlife or livestock that destroy crops or damage the land, or the land is near pastoral wells, which discourages women from investing in a market garden.
- Women have other sources of incomes for the dry season, such as making millet beer.

However, market gardens have contributed to conflict between farming and pastoralist communities (see Box 1). As the use of market gardening has increased, competition for land with water access has grown, with pastoralists being pushed back and forced to find another place to water their animals during *seif*.

The majority of households reported owning some type of livestock. The most common species of animal reared are poultry, donkeys, horses, goats, sheep, cows, and camels. The qualitative data

Box 1: Conflict over access to *hits* near market gardens in Djedide/Tcharo

In the large wadi between Tcharo and Djedide (located in Djedide perimeter) more than 10 *hits* with 25 water troughs for livestock were dug and functional in May 2019. *Hits* are located very close (200 meters) to Djedide's market garden. More than six neighboring communities come here with their animals and to get water for household consumption during *seif*. These are the main water sources for Tcharo communities. A minority of Djedide communities use these *hits* as they prefer using their traditional garden wells. Households from surrounding villages come here, as do the communities moving with their animals. In May 4,000 to 5,000 animals get their water at the *hits* each day. In *darat*, more than 6,000 animals come every day. However, in the last five years, there has been a decrease in the number of herds coming to water here during *seif* for several reasons. First, the market gardens in Djedide reduce access to the *hit* area and cause conflict between herders and market gardeners. Second, the overcrowding of animals in a shrinking space contributes to the spread of animal diseases, so herders have begun to move away from the area.

Since the development of market gardening (in 2003, with the arrival of INGOs), competition for water during *seif* has disadvantaged communities with a pastoral history as the land around the wadi belongs to the sedentary communities. Historically, access to *hits* is free, but access to the market garden wells and wadis is lucrative. Therefore, the communities of Djedide opt to rent out their land. To avoid conflicts with herders, they prefer to lease the market gardening land to ethnic groups that are close to the Chadian government (Zaghawa), so they are protected.

16 Woman in Tcharo, May 2019
17 Women during individual interview in Djedide, May 2019

highlights a spectrum of different practices for managing livestock according to access to and use of natural resources, livelihoods history, and specializations. Livestock has important social and financial value for communities. When households have a financial need, they sell agricultural stocks (beans, sesame, millet, etc.) before selling livestock because livestock are seen as an investment that will reproduce. Economic and cultural preferences vary with livelihood specialization, but in general, poultry will be sold first, followed by small ruminants. Breeding females and then large ruminants will be sold as a last resort. The main reasons for selling animals are: lack of food, health expenses, ceremonies (marriage, baptism, religious celebrations, etc.), or when households no longer have the ability to keep their animals healthy. Livestock are mainly sold at the end of the dry season or at the start of the rainy season to overcome their poor access to water and pasture or their vulnerability to zoonotic epidemics. Since animals are thinner at this time of year, they sell at lower prices. Our understanding is that this is the case for mixed faming households or poor pastoralists, who cannot afford to be mobile. Pastoralists will not want to sell at the end of the dry season, as they will have the opportunity to fatten their animals and make more money by expanding their herds during the imminent rainy season. Low prices generate losses for sellers, but potentially big gains for buyers. Other sources of income from livestock production include:

- Milk and dairy products: cow and goat milk are the main types of milk consumed. Milk is mostly available and sold during *kharif* and *darat*. The trade of milk is an arrangement between communities who have large herds and those that do not. Milk is sold at the market and could be exchanged or sold between neighboring communities. For example, during the rainy season, women from neighboring communities bring milk to market to trade for cereals, okra, sesame, and use of the flourmill in Rizildout.
- Tallow, used for cooking, is sold year-round in markets.
- Lamb, beef, goat meat and (more rarely) camel meat is sold in markets all year long, with an increase after *darat* and for religious festivities.
- Women make and sell leather products during the dry season, but only specific groups tan the leather.

Some households have different livelihoods specializations due to their genealogies. For example, blacksmiths, butchers, potters, and tanners come from specific families and their skills are passed down the generations. These groups are highly stigmatized and are treated as inferior. They sell their products in dedicated and peripheral areas of marketplaces. They can only marry within the same category of livelihood and are usually—but not always—excluded from village social activities. This stigmatization creates vulnerabilities and resilience capacities distinct from those of households involved in a mix of farming and livestock keeping. The trade-off for this lack of social support is exclusive rights to certain livelihood activities.

Throughout this report, livelihood specializations impact key hypothesized drivers of wasting, including water sources and access, presence and mobility of livestock and gender norms. For a summary of community livelihood practices and ethnic background see Table 6.

Climate and shocks over the study period

In this section, we will briefly discuss rainfall patterns and livelihood shocks during the research period. Using area-averaged remote-sensing precipitation data,[18] we can get a picture of the rainfall patterns in the Goz Beida area for the period of January 2018 through March 2020 (Figure 7). Rainfall in both years appears normal, with 2019 rains starting a bit earlier with heavier rainfall in August. The 2018 rainfall appears to be most consistent with the five-year average (April 2015-March 2020).

The duration and amount, as well as the spatial and temporal distribution of rainfall directly impacts agricultural production. Households reported that 2018 was a good year for agricultural yields.[19] This

18 https://giovanni.gsfc.nasa.gov/giovanni/
19 Women during FGD in Tcharo, May 2019

Table 6: Livelihood summary by village

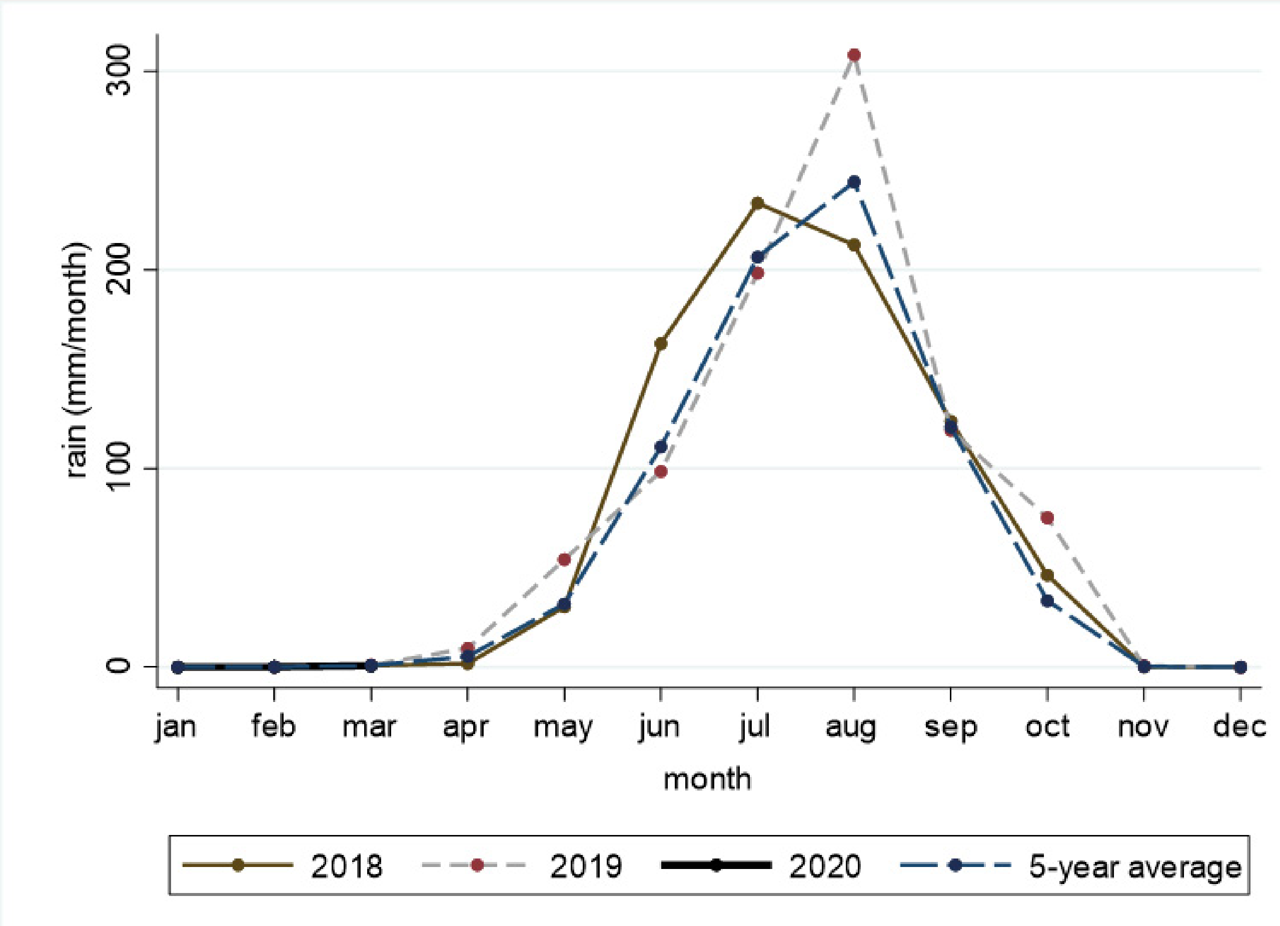
	Rizildout	*Djedide*	*Tcharo*	*Maramara*	*Tebesse*	*Al Kherim*	*Abdoudjoul*	*Taïba Badria*
Main ethnicity	Dadjo	Dadjo	Dadjo	Dadjo and Ouaddai	Missiria	Zaghwa	Mimi	Badria
Range of crop production	+++++	+++++	++++	+++	+	+	++	+
Market gardening	+++++	+++++	+++	+ (by Rizildout)	+	-	-	-
Millet productivity	+++++	+++++	++++	+++	++	++	+++	+
Goats and sheep in the communities	+	++ 1,200 big herd: 40-50 medium herd: 10-12 small herd: 4-5	++	+++ 1,600 big: 50-60 medium 30-25 small 1-10	+++ only sheep (no goats)	+++ 1,300	++++ 2,400 big herd 50-100 medium herd 20-40 small herd 5-10	+++++ big herd: 400, medium 100 small 10-25
Cattle number owned by community average size of herd by household	-	-/+ 28 cows/ bull/steer	++	-	+++++ 7,000 cow/ bull/steer	+++ 3,000 cow/ bull/steer	++++ 4,000-5,000 cow/ bull/steer big herd: 100 medium: 50 herd: small: 30	++++ 5,000 cow/ bull/steer big herd: 250 medium: 100 small herd: 50
Camels	-	-	-	-	+++	+	++	+++++ big herd/ household: 150 medium herd/ household: 75 small herd: 20

+ indicate a positive amount (the more + the greater the amount) and – indicates the absence of this livestock in the community

corresponds to the Famine Early Warning Systems Network's (FEWSNET) classification of Sila as showing "minimal food insecurity" for June through September 2019. Similarly, according to FEWSNET (we do not have qualitative data after August 2019), "national cereal production [in Chad was] slightly above the five-year average" as of November 2019 with Sila categorized as IPC Phase 1: Minimal Food Insecurity. In May of 2020, FEWSNET reported that "food security continues to deteriorate as a result of COVID-19 measures", however Sila remained at IPC Phase 1.

While 2017 was not mentioned as a food insecure year by research participants, FEWSNET classified western Sila and Ouaddai as "stressed" from June through September 2018. We can therefore assume that food security following the 2019 and 2018

Figure 7: Total recorded rainfall (Jan 2018-March 2020) and five-year average, by month and year (mm/month)



harvest was better than food security following the 2017 harvest. However, despite the study villages all being close together, not everyone reported doing well following the 2018 harvest.

One of the main shocks that was mentioned throughout the interviews, especially by female respondents, was an epidemic of a (unspecified) disease that killed a lot of donkeys during *seif* in 2019. Women, especially those in more remote communities, reported that this had serious consequences on their workload, making it harder for them get to markets, fetch water, collect wood, and bring their children with them while working. Households also reported that their cattle, while not struck by an epidemic, were very vulnerable to disease during *seif* in 2018.

Weak local governance as well as competition for scarce natural resources—particularly water, land, pasture, forage, etc.—occasionally results in conflict between farmers and households with larger livestock herds. Conflict can occur when camels, cows or other animals eat crops or crop residues without authorization or when market gardens block livestock access to water points (Kratli, Sougnabe et al. 2018).

In May of 2019, clashes were reported between the Arab Zakwa ethnic group (different from Zaghawa) and the Ouaddaians in Abdi. Tension between the two communities was a result of the Arabs wanting to graze their camel on land belonging to the Ouaddaians, who refused. In response, the Arab group set the land on fire and both parties began using their knives and firearms. It was reported that many people died, and several were wounded.

Livelihood related seasonal mobility

Households across the livelihood specialization spectrum reported practicing different types of mobility to deal with the temporal and spatial distribution variability in access to natural resources. In this section, we briefly describe these different practices as they pertain to both cultivation and livestock management. We first discuss the temporary *damkoutch* and *diyar* settlements. Then, we briefly cover livelihood mobility, distinguishing between sedentary, medium-, and long-distance livestock mobility systems. Finally, we provide a brief discussion of the factors that influence choice of mobility and distance.

Damkoutch

Many households leave their villages seasonally and move for agricultural purposes to protect their land or because they only have land far from the village:

> *If you have a large household, you would need a large field to cultivate. My husband has two wives, and eight children. His first wife has a field near the village, but it is too small for both of us, so he had to ask the chief to rent another plot for me and my children, which is located about five kilometers from the village. During planting season, my children and I move to live in our field to save time and to make sure animals will not ravage our crops.*[20]

These seasonal settlements for agricultural purposes (either during *kharif* for rain-fed agriculture or during the dry season for market gardening activities) are called *damkoutch* in the local language (Photo 2). *Damkoutch* are usually located between 1 and 10 kilometers from the village. According to participants of the focus groups, the practice and duration of going to a *damkoutch* varies according to:

- **The distance of the plot from the village:** if the field is very far, the household will stay in the *damkoutch* for the entire planting season; if it is "relatively far" the household might go to the *damkoutch* only for periods of intense agricultural work (seeding, plotting, and harvesting).
- **The proximity of the cultivated field to animals and wadi:** households who have land located near the path of animals or are involved in market gardening in the wadi (close to animal water points in the dry season), are more likely to stay in the *damkoutch* to protect their crops from damage. "Before it was possible to build pens to protect gardens or fields, now it is forbidden by law to cut wood, so we must be careful that animals do not come to eat our crops".[21]
- **Household size and cultivation support:** larger households who need more land and have the capacity to cultivate large areas will stay longer in a *damkoutch*. If the woman has help to cultivate (from her husband or older children), it saves her time to stay in the *damkoutch*. Women and their children move together to the *damkoutch*:

  > *In the damkoutch, you won't find many men, most of them have migrated for work, or are not really interested in agricultural work. My husband was in Libya for two years, he is now back. He is polygamous, so he spends about three days with me in the damkoutch to help me, and then will go to another village to help his second wife in the field for three days.*[22]

- **Food security:** "Very vulnerable households won't stay too long in the *damkoutch*, as they would need to find daily work. So, in the agricultural season, they will split their time between their own fields and the fields of the wealthiest farmers who employ them daily."[23]

Participants in focus group discussions recognized that vulnerabilities and environmental risks might worsen when the family move to the *damkoutch*.

20 Woman in Rizildout, August 2018
21 Woman from an FGD in Rizildout, August 2018
22 Woman in Tcharo, August 2018
23 Women in Rizildout, August 2018

Photo 2: *Damkoutch* encampment

They see changes in their children's health, type of water sources, and in care and hygiene practices:

> *There is no borehole in the damkoutch, we are all using machiches or wadis. Those who are doing market gardening are using the traditional wells in their garden.*[24]
>
> *We are very busy with agricultural work. We don't have much time to look after and take care of the children. Younger children (under two) will stay in the field under a tree while we work; older children go with their siblings playing or herding goats in the surroundings.*[25]
>
> *Children are sicker when they are brought to a damkoutch. They don't drink safe water, and nobody is watching them.*[26]
>
> *Health centers are far from the damkoutch, [so] the mother has no time to go. When someone is sick, they prefer to buy medication from Dr. Tchoukou*[27] *or during market day.*[28]

Some animals might also be brought to the *damkoutch*: donkeys, chickens, and goats if the households have only a small herd. Small herds near the *damkoutch* are tended by children aged from six to nine years old; children 10 years and older work in the field with their mothers. Communities in Rizildout, Tcharo, and Maramara are the most likely to have a *damkoutch*, while in Tebesse and Taïba Badria it is very rare for communities to move to a *damkoutch*.

Diyar

Another type of seasonal temporary settlement for cultivation purposes is called *diyar* (Photo 3), which appears to be a relatively new phenomenon linked to the increasing sedentariness of pastoralist communities. Households with medium and large herds take their animals to spend some time on their fields to fertilize the soil. Households might stay in a *diyar* settlement from a few days to several months during *darat* and *rushash*. In Tebesse and Abdoudjoul, many households practice *diyar*. "In Abdoudjoul, women do *diyar* from *darat* to the first ploughing. The whole family moves in on the field with some of their cows and small ruminants from *darat* to *rushash*."[29] In Al Kherim, households mainly use a *diyar* in *darat* while animals eat crop residues: "Herds are too big and the fields too small to be left for too long in *diyar*. Those with small herds might do a second *diyar* at the time of sowing millet."[30] In Maramara between December and March, some women do *diyar* with their small ruminants.

There are also arrangements between households that have cattle and those that do not. Owners of large herds of cattle can rent them to fertilize the fields of cultivators in May and June. However, this practice depends of the quality of relationship between communities. "This practice has become less common because of the conflicts between herders and farmers that happened during harvesting season."[31] "Farmers are using goat and sheep dung to fertilize gardens. They store the manure in their compound and bring it to the fields in May."[32] Similarly, crop residue can be sold to herders to feed their cattle (5,000-10,000 FCFA (8 to 17 USD) per hectare of residue) during *darat*.

24 Woman in Maramara, August 2018
25 Woman in Rizildout, August 2018
26 Men in Tcharo, August 2018
27 *Tchoukous* (also called "*tchoukou* doctors" or "*Dr Tchoukous*" despite their lack of medical qualifications) are unlicensed street vendors of medicines. They examine patients and administer pills, injections, and infusions according to their "diagnoses". They are generally cheaper than qualified doctors.
28 Key informant in Goz Beida, August 2018
29 Key informant in Abdoudjoul, May 2019
30 Women in Al Kherim, May 2019
31 Men in Rizildout, August 2018
32 Women during FGD in Djedide, August 2018

Photo 3: *Diyar* settlement

Livestock mobility systems

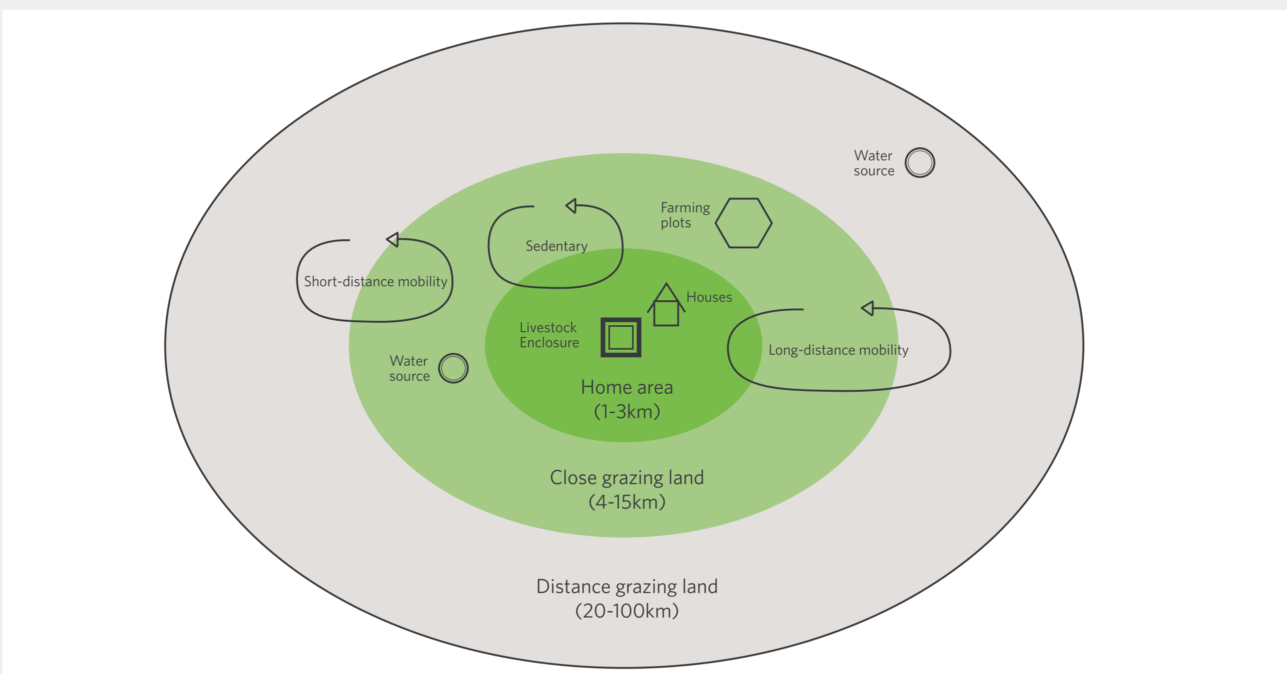
Consideration for livestock mobility is extremely important when trying to understand potential animal-related water contamination, as mobility patterns determine when there is the greatest presence of livestock in Goz Beida. Mobility patterns of animals are associated with livelihood specialization and the number and species of animals owned. The spectrum of livestock mobility falls into three major categories: sedentary systems, short-distance mobility, and long-distance mobility. Households can use one or more of these mobility systems (see Figure 8 for an example of mobility systems in Sudan).

Sedentary livestock systems

In communities adopting sedentary livestock systems animals tend to be kept within a 1-5 kilometer radius of the village. Rizildout and Djedide mainly use this system as they do not have many animals. Sick animals, baby animals, lactating cows (*chaile*), pregnant animals, animals that have recently given birth, favorite cows,[33] goats, chickens, and beasts of burden such as horses and donkeys, are also kept close to the household.

During *rushash*, animals mainly access water from natural sources such as ponds and wadis near the village. In *seif*, animals drink from the same sources as humans and from surface water during *kharif*.

Figure 8: Mobility system example



Source: Sulieman, H. & Young, H. 2019. Transforming pastoralist mobility in West Darfur: understanding continuity and change. Boston, Feinstein International Center, Friedman School of Nutrition Science and Policy at Tufts University.

33 A favorite cow is a cow given in memory of a loved one. A household will take extra care of it and keep it close to the household.

Water will be brought home to very sick animals and poultry, as well as small ruminants if the household owns just a couple. During the day, these animals graze around the village (outside the cultivated areas, which are generally guarded by women, or children over six year of age) and come back to sleep in the house plots at night. When pasture is no longer available around the village, or if they are very sick, these animals will be fed sorghum stems and hay that is stored for them. These animals are often also brought into the *damkoutch* and *diyar* with the household members. "When we are moving to the *damkoutch*, we bring our few goats with us; the children will watch them and keep them away from the farm."[34] "We will stay with our small ruminants and cows in *diyar* from *darat* to *rushash*."[35]

Medium-distance livestock mobility systems
Medium-distance mobility covers animal migration from 20 to 50 kilometers from the village and is mainly used by households with medium-sized herds. In *darat*, animals will stay around the community and their agricultural fields to eat crop residues from November for few months. They are then guarded by children, who are supervised by an older and more experienced herder, or *azaba*. At night herds will stay on the fields around the village under the watch of the *azaba*. A*zabas* can be paid in cash or be given animals in exchange for their work.

Around November, these animals drink surface water, then as surface water depletes (December), they use the *hits*. When water from the *hits* and/or available pasture is no longer sufficient to water and feed the livestock (between February and April depending on the size and species of herds), the herd will migrate south or east about 20 to 50 kilometers away (*marchech*). The herd will move with the whole family (father, mother/favorite wife, and children) or with an *azaba*. The herd will be back in the village in *rushash* to stay in a *diyar* for one to three weeks: from ploughing to first planting. Children will herd them during this time. Livestock will drink surface water produced by the first rains.

Rushash is perceived as the most vulnerable time for livestock as "surface water from first rains is really contaminated, and pastures are destroyed by first rain."[36] Households will keep dry crop residues to feed livestock at this time. If stocks of stems and hay are not enough, animals will leave the *diyar* quickly to find pasture in areas where the rains have already come, and the grass has begun to grow.

After *diyar* (about July), the animals will be brought to an encampment for cattle and herders (mostly men) called a *makhalaf*, located two to eight kilometers from the village in a non-cultivated zone for about three months (July-September). Few women will stay in the *makhalaf* because they are working in their fields:

> *It is mostly young single men [azabas] and teenagers from communities with a history of pastoralist livelihoods who go in the makhalaf.*[37]
>
> *Women from households that own large herds will go back and forth from the village to their field and to the makhalaf every day to milk the animals.*[38]
>
> *Some polygamous herders can bring one of their favorite wives to the makhalaf; the other wife will be responsible for cultivation for the whole family.*[39] *(Photo 4).*

In October/ November, days or weeks before the harvest, livestock will be brought back near the cultivated fields to wait for the harvest to be finished to access to crop residues. This practice, called *daratir*, is used to make sure that the field owner's animals will get the crop residues before long-distance herds arrive.

No authorization seems to be needed to access grazing land if there are no cultivated fields nearby. Grazing livestock near cultivated fields is allowed at only specific times of the years. "The chief of the canton and chiefs of villages are responsible for giving the signal: they tell farmers they should finish harvesting. From this date, cattle can go in

34 Woman in Rizildout, August 2018
35 Woman in Abdoudjoul, May 2019
36 Herder in Tcharo, May 2019
37 Woman in Tcharo, May 2019
38 Man in Al Kherim
39 Man in Abdoudjoul

Photo 4: Woman at a *makhalaf* (left) and cattle in pasture in August (right)

the cultivated fields."[40] The Sila Province sultan is responsible for delineating *makhalaf* areas with the chiefs of the canton.

Long-distance livestock mobility systems
This type of mobility is mainly used by large herds of cattle (in Tebesse) and camels (in Taïba Badria) and requires travel of approximately 50 to 100 or more kilometers from the village, south-north migration in the rainy season and back again after the rains. These animals only return to areas near the village twice a year: during *rushash* after the first rains (one to three days before ploughing) and during *darat* to eat crop residues (for a week to a month). These animals will mainly drink surface water during *darat*. When they return, they only stay for short periods, for example, about three days in *rushash* and a two to four weeks at *darat*.

During *seif*, animals will move 50 to 100 kilometers south (camels travel farther) or east (less common, because of conflicts) to look for water and pasture. One of the most radical changes in water access happens at *rushash*. From the very first rains, most of the livestock (especially cattle) will leave *hits* and start drinking from the rainwater pools. They will move to find pasture in locations where water was not available during *seif* before but where pasture remains (example, near the hill of Maramara). Rainwater is the preferred water source for animals, especially for large and medium-sized herds, as it is entails less effort for the herders. During *kharif*, livestock go north (50 kilometers or more) to get away from farming areas and because the conditions further north are better for animals—grasses are more nutritious and there is less exposure to disease.[41]

Household members divide up their activities. Some will stay in the village for agricultural activities, while others will follow the animals. Most often, these households are polygamous; men can travel with one of their wives and leave the other to farm for the whole family. If a man has other livelihood activities, he will hire a male relative or friend to herd his cattle.

Additionally, households with small herds can arrange with households with large herds (*serha*) so that their livestock can join the larger herds. "In exchange, he [the owner of the smaller herd] will give the herders a certain number of animals or newborns each year or pay him by animal."[42] This is a common practice in Djedide, for example.

Decisions on the timing of long-distance livestock migration are made by the provincial sultan together with canton heads and village chiefs. They give dates and signals for when animals should depart in *kharif* and return after *darat*. For transhumant (*murhal*) mobility, the provincial governor and cantonal chiefs (government officials) are responsible for the timeframe of *talaaga*, the traditional signal

40 Key informant in Djedide
41 Risk, Resilience, and Pastoralist Mobility
42 Key informant in Goz Beida

for animals to eat crop residues after harvest is complete. However, in recent years, pressure on natural resources (water and pasture) and climate variations have led to increasing conflicts involving long-distance mobility animals. "The time for *talaaga*, is no longer respected; animals are brought into the field before harvest is completed."[43] In May 2019, many people were killed in one of these conflicts near Rizildout. These conflicts are managed by tribal and cantonal chiefs, the governor and sultan of Sila Province, and government ministers.

Factors that influence the choice of mobilities and distances

There are several factors that influence the way households manage their herds. These include:

- Species and number of animals owned
- Water access in *seif*: "If there's not enough water in the *hit*, too many people using it, or too much market gardening around we have to go further to find another *hit*."[44]
- Access to pasture and land: "if there is no space close to the village for a *makhalaf* in the rainy season, herds will move farther and we will keep few *chaile* [milking cows] and their babies, and some animals in case of financial need in the village."[45]
- Agricultural production: "If we don't have enough crop residues from last seasons, we cannot keep animals close to the village during dry season."[46]
- Conflicts: "When there is a conflict, we need to move farther away."[47]
- Access to income: "It is necessary to keep animals close to the village to be able to sell them in case of emergency."[48]
- History of livelihoods specialization: "I entrust my cattle to my wife's brother because he knows the areas to the south well and is able to find water and pastures. He is used to it."[49]

Gender norms, marriage, and procreation

Gender norms

During qualitative fieldwork, we explored societal expectations of gender roles and qualities and behaviors for each gender. This method helped to understand social organization and identify barriers to, and potential levers for, women empowerment. In this section we describe gender norms in Sila, and how they affect everything from marriage to women's workload and resulting childcare and feeding practices.

Social relationships and roles between genders are clearly to the disadvantage of women. Men are the heads of households and the decision-makers, while the women have very little decision-making power. A "good woman" was described[50] by both men and women as: "docile," "quiet," "obedient and respectful to her parents, husband, and husband's relatives," "resilient and hardworking," "making her husband proud," "producing good income," "managing household income well, prioritizing children and husband when spending money," "taking good care of her husband and children," "respecting traditions, conventions, and customs," "submissive to her husband," "keeping a clean house," "willing to deprive herself for her man and children," "having good relationships within the community," "always asking her husband before making a decision on the use of resources," and "helping her husband to be respected in the community by finding money for her husband to eat lamb at the weekly market with other men".

Characteristics of a "bad woman," on the other hand, include: "taking decisions alone," "not working enough to feed her children and husband," "hiding money from her husband for herself," "disrespectful to neighbors, family and friends," and "having conflict with members of the community".

43 Key informant in Djedide
44 Man in Tcharo
45 Man in Tebesse
46 Woman in Abdoudjoul
47 Man in Djedide by *hit*
48 Woman in Taiba
49 Man in Tcharo
50 All quotes in this and the subsequent two paragraphs are taken from the gender box participatory tool in Djedide, Maramara, Al Kherim, and Abdoudjoul, in May 2019

A "good man" was described by both men and women as: "successful and wealthy," "clever and daring," "respected by his wife and other members of the community," "very social, spending time with other men, sharing his meal, tea, and meat at the weekly market," "powerful, and listened to by the community," "having a large family." Conversely, a man will be mocked if he helps or is substituting for his wife: "when we see a man doing household duties, he will lose respect from his peers".

Spatial and social roles are well delineated and agreed upon between the sexes: women must take good care of their husband and children while men should prioritize community cohesion. These social norms in turn affect women's workload as well as childcare practices.

Marriage and procreation

The quality of relationships between spouses is connected to a man's financial support to his wife/wives. Domestic violence against women is socially widespread and accepted. "Most marital conflicts happen during the rainy season, which is the lean season when grain stocks run out."[51] Women accuse men of not contributing to household daily expenses, while husbands accuse women of "always asking them for more money"[52] and of secretly building their own capital. Women confirmed that they do sometimes hide goods and income from their husbands to have more autonomy or resilience. Men frequently prioritize spending money on things that increase their social status, instead of investing in items or food that might benefit nutritional outcomes: "If a woman earns something, it is for the family; if a man earns something, it is to take a second wife, or to spend it on himself, buying a motorbike for example."[53] While men are responsible for occasional household expenses (clothes, parties, ceremonies, healthcare, etc.), most of men's income goes into external signs of his social success (livestock, a leg of lamb at the market for the husband, horses, motorcycles, clothes, jewelry, telephones, herds, additional wives, etc.). Men recognize that most of them do not help their wives in the field and spend money made from that fieldwork without their wife's consent. They explain this behavior stating that they do not trust women with money. They suspect them of wanting to get rich behind their backs, not managing money and wanting to become independent. Some participants said that if they gave their wives more than others on market day, they would be teased throughout the village: "If someone gives more to his wife, he'll get scolded by other men." "Other women will start comparing their men and asking for more if one starts to change habits."[54]

Domestic conflicts were perceived to be more common in communities with a history of farming specialization. Women in Tebesse explained: "Girls from this village are not marrying men from the farming communities [because] they are not good husbands; they're not helping their wives."[55] The level of responsibility men have for sharing financial burdens varies by livelihood specialization. In communities with an agricultural livelihood history (Djedide, Tcharo, Rizildout, Tcharo), "many cases of conflict and divorce are linked to men's consumption of alcohol. They spend a lot of money on millet beer or other alcoholic beverages. It's less the case with Arab communities, [where] few are drinking alcohol."[56] Furthermore, men in pastoral societies are also viewed as "more religious" and were reported to drink alcohol less frequently. The latter is likely related to the prohibition of alcohol consumption under Islam.

A man can marry up to four women. Having several wives is socially valuable. For men, the main reported advantage of polygamy is to maintain peace within the household: "When women start asking their husbands too much or start to disobey, he will take another wife, so she will have to obey, work well and treat him well. Otherwise he will prefer the other woman and no longer help her at all, or worse, he will divorce her."[57] (See Box 2 for an example of the perceptions of the negative consequence of divorce on child nutrition.)

51 Woman in Djedide, August 2018
52 Key informant in Djedide, August 2018
53 Male FGD participant in Tcharo, August 2018
54 Male FGD participants in Tcharo, August 2018
55 Woman in Al Kherim, May 2019
56 Female FGD participant in Djedide, August 2018
57 Man in Djedide, August 2018

Box 2: Consequences of divorce in a negative deviant household (children malnourished more than 25 percent of the time over previous nine months)

The mother has been divorced since the last rainy season, *kharif*. Her ex-husband drank a lot and spent all the family's money on alcoholic beverages with friends and other women, and there was a lot of conflict between them.

She is very poor, and her house is in very poor shape. She has 8 children between 7 months and 17 years.

She is a farmer and mostly relies on rain-fed agriculture. She has a market garden during *seif*. Her mother left her the land near the wadi for market gardening and her oldest boy dug the garden well for her.

She doesn't have any animals. Her only donkey died in April 2019, and since then life has been even more difficult for her: she carries water on her head from the well in her garden and makes more round trips. She is also now unable to get wood to repair the fence of her garden and the structure of her house.

She noticed that her seven-month-old baby is unwell. She explains that it is because she "does not have enough breastmilk," her breastmilk is "not nutritious," and that she is "very tired and not eating enough." When her children are sick, she prefers to use traditional plant porridges and says the health center is too expensive. The qualitative study researchers referred her child to the health center. She says she went three times, but either the nurses weren't there or there was a shortage of medicine. She got discouraged and never went back because she felt it was too much time wasted.

Another strategy used to prevent spousal conflicts is early marriage of girls: "If you marry a little girl you can educate her in your own way. She will never question your actions."[58] Early marriage is much more common in communities with a pastoral specialization history, where girls can be married from eight years of age. When girls are married at a very young age, they will wait until they reach 17 or 18 years old to live with their husbands. In the meantime, they stay with their parents or in-laws. To notify the community of their marital status, girls will bear distinctive signs: henna only on the right foot during ceremonies for young married girls not yet living with their husband and henna on both feet for married women living with their husband. Other married young girls wear a jewel on their nostril.

In the Dadjo communities, girls can be married from 14 or 15 years of age. Early marriage is mostly used as a strategy to avoid the social shame and stigmatization of an extramarital pregnancy: "You can't trust girls anymore, they might have a child before marriage, so parents rush to marry them."[59] There is strong social control over early marriage of girls: "Parents of unmarried 15-year-old girls are mocked, everyone says that no one wants their daughter."[60] Finally, for some households, the early marriage of a girl is an opportunity to reduce household expenses or for the economic attractiveness of the dowry.

In years when agricultural production is good, men do not leave the village for economic migration (to Sudan, Abéché, N'Djamena, etc.): "Men come back from migration for harvest/*darat*, and usually, there is a peak of births in May and June."[61] The presence of the husband results in more sexual intercourse and more babies. 2018 was a good year for agricultural production, so communities with an agricultural specialization (Maramara, Djedide) noticed an increase in pregnancies and births in May 2019. Also, woman perceived that in years of good harvests, they are healthier and hence more likely to get pregnant compared to years with a bad harvest.

58 Man in Al Kherim, May 2019
59 Man in Tcharo, August 2018
60 Woman from Al Kherim, May 2019
61 Women in Maramara, May 2019

This potentially brings about an unexpected inverse relationship between food security and birth spacing, with years of good production leading to shorter birth spacing, which can have a negative impact on breastfeeding practices (see below).

Women's workload

The high workload of women was mentioned in nearly every qualitative interview with both men and women. Women described being overworked and tired. All year long, they are responsible for fetching water and firewood, preparing food, cleaning the house and food utensils, cleaning clothes, feeding and bathing children, pounding millet, and supplying food. In addition to these household duties, women are in charge of providing income for their households' daily expenditures: fees for water and household food. The intensity and nature of women's workload varies according to their livelihood specialization, access to natural resources, seasons, and their level of social support: "Water fetching and looking for firewood can take more time during *seif*." "Women of households who own large herds of cattle will milk the cows in rainy season in addition to agricultural work."[62]

Because women are the main labor force for subsistence rain-fed agriculture, the rainy season (from *rushash* to *darat*) is the time women are busiest in all communities. As the rainy season is also the time when food stock are at their lowest, most vulnerable women also need to find sources of income to feed their children when food stocks run out, and this further increases their workload: "More vulnerable women would find daily employment on big farms."[63] "When their husbands do not help, women need to multiply their activities to find food for their children."[64]

During *seif*, the women's activities and sources of income are more differentiated between communities and livelihood specialization (Table 7). Djedide, Rizildout, and Tcharo women have more access to incomes during *seif* (from market gardening and selling of cash crops), while women from Tebesse, Al Kherim, and Taïba Badria have more access to income during the rainy season (milk, petty trade). Key informants identified women in Maramara and Abdoudjoul as busiest in all seasons, as they have less access to income:

> *Women of Maramara cannot just rely on agriculture. Their land does not have a good yield, they cultivate less diverse crops and do not practice market gardening [with a few exceptions who go to Rizildout for market gardening]. They also have many goats to look after and they multiply the activities to earn money.* [65]

This type of diversification is frequently associated with poorer, less food secure households who must take up marginal activities to survive.

Day-work is mainly used to cope with food shortages during the rainy season, when women are employed by wealthier households for ploughing, weeding, sowing and threshing, and filling *hits*. The table below sets out women's main income sources by seasons and by livelihood system.

The main source of income for men comes from agricultural production, livestock, migration outside of Sila, brickmaking, trade, and daily wage work. Financial support from men is one of the main determinants of a woman's workload: "Women with husbands who are nice to them and provide financial assistance have fewer problems than women whose husbands spend their money on drink or elsewhere."[66]

When a husband migrates, he does not systematically send money back to his wife (or wives). He may leave for a few months to four or five years. During this time, his wife supports the needs of the family as best she can. If the husband has animals, he may leave her a few goats,[67] making the workload for the wife even heavier. Responsibility for the family is entrusted to the brother or the father of the migrating husband, or sometimes a neighbor. The woman must have permission from her husband

62 Women in Al Kherim, August 2018
63 Female FGD participants in Djedide, August 2018
64 Female FGD participants in Tcharo, August 2018
65 Key informant in Goz Beida, May 2019
66 Woman during FGD in Tcharo, August 2018
67 This practice varies by wealth groups and communities

Table 7: Sources of women's income by season and specialization

Livelihood activity	*Rushash*	*Kharif*	*Darat*	*Shita*	*Seif*
Women's workload	+++	++++	++++	++	++
Agriculture	Selling small amounts of their own crops Brewing millet beer	Daily wage labor on big farms	Selling small amounts of their own crops	Selling small amounts of their own crops Market gardening Brewing millet beer Making soap	Selling small amounts of their own crops Market gardening Weaving Brewing millet beer Selling oil Making soap
Pastoralism	Petty trade (of cereals, salt, sugar, and other condiments)	Selling milk Petty trade	Selling milk, preparing and trading dairy products (butter, curdled milk)	Preparing and trading dairy products (butter, curdled milk)	Leather work Importing goods from Sudan (gas, oil, sugar, salt) Weaving
Other	Selling poultry and eggs Selling wood	Selling poultry and eggs	Selling poultry and eggs	Selling poultry and eggs Selling wood	Selling poultry and eggs Selling wood

by telephone or from her brother-in-law to sell an animal. The period when a husband returns from migration is known as "watering." His return is sumptuous. With pride, he distributes gifts, buys more livestock, takes a new wife and, if he can afford it, buys a motorbike or a horse with the money he earned while away.

When a woman does not have enough resources to feed the family, she may ask her husband for help. During the rainy season, grain stocks run out and additional income sources are scarce because women are overworked and cannot carry out other money-making activities. It is therefore most common that a woman will ask her husband for help during the rainy season. If he refuses, there are disputes between the spouses. Communities perceive a difference in husbands' assistance according to their history of livelihoods: "Pastoralists help their wives much more than men with an agricultural history."[68] They explain that this arrangement is related to women's empowerment: "Pastoralist women are really dependent on their husbands, while farming women might have independent access to land by inheritance; they can manage without her husband. [...] This is why we see divorced women in farming communities and none in pastoralist communities."[69]

Childcare and feeding practices

In this section, we look at differences in care and feeding practices by sex due to the gender norms described above, in breastfeeding and feeding practices, and in health-seeking behavior.

Differences in care and feeding practices by sex

Social construction of gender starts at birth and gradually increases in the first years of a child's life: "Girls should learn early how to be a good wife by staying close and imitating their mothers, while boys should learn how to be men from their older brothers and father."[70] "Mothers have to be ruder with their boys, to encourage them to leave their

68 Key informant in Goz Beida, August 2018
69 Key informant in Goz Beida, August 2018
70 Woman during interview in Djedide, May 2019

sides, otherwise they'll start acting like women."[71] Women must keep their daughters next to them, while boys will be (emotionally and physically) kept at a distance:

> *A boy must be initiated into tough things from the day he is born.[72]*
>
> *If a boy is too pampered by his mother, he will become a worthless man: he will not have strength and courage, he will always be dependent on his mother.[73]*
>
> *Boys should not be too close to their mothers, as they will become a chamorokha, a thing between woman and man. Everybody will mock him and his family.[74]*

Social constructions of gender thus unconsciously (through social reproduction) affect care, health, and feeding practices of boys and girls.

According to traditional beliefs: "Girls have two intestines while boys have only one, which explains why it is normal for girls to eat more than boys," and: "Boys prefer porridge and soup rather than breastmilk."[75] Boys are often breastfed less frequently, less exclusively, and for a shorter duration than girls. Moreover, boys are more likely to be watched by their older siblings (*achanai*) than girls. According to the UNICEF Global Database (2019), girls in Chad are more likely to be exclusively breastfed and boys are more likely to have a minimum acceptable diet.[76] Moreover, in the 2014 Chad Demographic and Health Survey (DHS) boys were reported to be exclusively breastfed for a shorter period of time than girls (4.7 months vs 5 months) (ICF International 2016). It is also possible that girls, who stay with their mothers more, will be closer to food and therefore eat more often than boys.

Differences in care practices between sexes might also lead to differences in hygiene and contamination: "Boys are always playing outside, being dirty."[77] Communities reported that "boys are sicker than girls," "girls grow up healthier," and that "the girl is more resistant to illness."[78] However, communities did not make any link between boys' sickness and their feeding, breastfeeding, or outdoor play practices: "That's the way it's supposed to be, girls and boys are different."[79]

Parents explained they have less control over vulnerability to disease than in the gender construction of their children: "If our child is sick, it's a misfortune, whereas if they become one *chamorokha*, the whole community will mock and accuse the parents, especially the mother."[80] Paradoxically, gender differences likely benefit young girls, but later become detrimental to women. When it comes to gender inequality, Chad ranks 187th out of the 189 countries on the Gender Inequality Index. The index is compiled using several measures on which Chad performs poorly, including maternal mortality (856 deaths per 100,000 live births), adolescent birth rate (161.1 births per 1,000 women aged 15-19, and access to education (1.7 percent of women aged 25 and older have at least some secondary education compared to 10.3 percent of men).[81]

Breastfeeding practices

According to World Health Organization recommendations, women should breastfeed their children until they are two years old. However, that is usually not the case, with Chad having one of the lowest prevalence of exclusive breastfeeding in the world (0.2 percent of all children under two years of age according to 2014 Demographic and Health Survey) (ICF International 2016). The first reason for early weaning an infant, is when a mother gets pregnant with a new child. "During pregnancy, breastmilk becomes *labane akhdar* (green milk that causes diarrhea)." To avoid the "green milk" perceived as harmful for the child, a pregnant woman

71 Woman during interview in Abdoudjoul, May 2019
72 Woman during FGD in Al Kherim, May 2019
73 Woman during interview in Djedide, May 2019
74 Woman during interview in Djedide, May 2019
75 Women during FGD in Al Kherim, May 2019
76 https://globalnutritionreport.org/resources/nutrition-profiles/africa/middle-africa/chad/
77 Man in Tcharo, May 2019
78 Women in Abdoudjoul, May 2019
79 Women in Abdoudjoul, May 2019
80 Women in Taïba Badria, May 2019
81 http://hdr.undp.org/en/composite/GII

Box 3: Negative deviation household (child malnourished more than 25 percent of the time over previous nine months) short birth spacing

The grandmother has been raising her grandson alone for three years (the child is a little over three years old). He is her daughter's son. Shortly after his birth, the mother became pregnant again and so weaned the child very early and sent him to her mother about 40 kilometers away (in Abdoudjoul).

The grandmother explained that the child has always been very weak because of early weaning, but that he is not sick (malnutrition is not a disease for her). When the child was sick months ago with a fever and respiratory problems, she gave him boiled millet water and oil. She did not bring him to the health center because it was "too far away to bring him there."

She did not report any problems with food security and said that her children help her when she has financial difficulties. The grandmother's (millet, sorghum, and groundnut) field is near her house. She has some goats around the village. Her 12-year-old granddaughter fetches water for her twice a day.

will suddenly wean her child upon the discovery of a new pregnancy. The child is weaned not just off breastmilk, but also of physical attention from the mother. As to not "tempt" the child being weaned, s/he is entrusted to a grandmother or another child during the new pregnancy and no longer stays with his/her mother. The child is fed with the family meal of porridge or *boule*, regardless of his/her age (sometimes a few months' old). Poor birth spacing between children therefore negatively impacts the breastfeeding practice of the older child. See Box 3 for an example of a ND household due to short birth spacing.

Another reason for early weaning is associated with the nutritional status of the mother. If a mother has poor health, her milk is perceived as not nutritious enough for children: "When women are tired, exhausted, [or] not eating well, they do not produce good milk for children." "When I am tired and overloaded, I can't breastfeed my children all day long; I have to reduce the frequency."[82] One likely interpretation is that this belief is a combination of the perceptions that not enough is milk available during seasonal periods of hardship and that the reduction in milk production is due to the lower frequency of breastfeeding resulting from the multiple demands on women's time.

Giving a child water while breastfeeding is a common practice that begins at childbirth. After a child is born, a traditional birth attendant administers a boiled plant infusion "to prevent the child from having diarrhea"[83] before putting him or her to the breast. Infants are often cared for by an older sibling while the mother is busy. When a newborn cries during the mother's absence, siblings will provide water or porridge to calm the infant. This untreated water increases the risk of exposure to waterborne diseases in younger children.

Mothers tend to take children who they are breastfeeding with them during their daily activities (such as fieldwork and collecting water or wood). Children from two years of age are more frequently left behind to be cared for by older siblings. Before leaving for their daily activities, mothers leave food for the children staying in the village.

Feeding practices

From the age of four months, children often consume porridge in addition to breastmilk. The porridge is mainly made of millet flour, water, sugar, and salt. From July to December, milk is sometimes added to this porridge. In *darat*, crushed peanuts and oil are also added to this porridge.

82 Women in Djedide during FGD
83 Key informant in Djedide

At approximately 12 months, the main household meal, *boule*, a kind of porridge, is introduced to the child's diet. Daily, households eat cereals, oil, vegetables (okra, leaves), condiments (chili, garlic, onions, dry meat) and sugar. Fresh meat is only eaten occasionally. Dairy products are included from July to December in wealthier households. Groundnuts or sesame can be added in the post-harvest season. During the rainy season, *boule* will include less food diversity. Children do not eat fruit until they are one year old.

Households will eat two to three meals a day. In addition to the seasonality of food availability, feeding practices of young children will also be influenced by the seasonality of the women's workload: "I don't have time to prepare three meals a day during rainy season." "I prepare the *boule* for the children in the morning; they will eat it during the day while I am gone in the field".[84]

Cow and goat milk is frequently given to the child. Cow milk is mainly produced and sold in *kharif*, while goat milk is available in *darat* and *seif*. Access to milk differs by season and by livelihood group. Djedide and Tcharo are communities with less access to goat milk, while Abdoudjoul and Al Kherim communities have more access to goat milk in *kharif*. Tebesse, Abdoudjoul, and Al Kherim have good access to cow milk during the rainy season, while Djedide, Maramara, and Tcharo have less access: "Children have good access to milk during rainy season; we always leave a milking cow for young children in the village or in the *makhalaf* before moving north with our large herd of cattle."[85]

Access to milk is also partially dependent on the arrangement with communities who have large herds. Milk is sold at market during the rainy season and could be exchanged or sold between neighboring communities. For example, every Friday, households from nearby *damres* (sedentary villages inhabited by former pastoralists) and *makhalafs* bring milk to trade for cereals, okra, sesame, and use of the flourmill when they come to Rizildout to pray in the mosque: "We have good relationship with the *damres* nearby. They have been here for 10 years, so we exchange milk for the use of our flour mill."[86]

Health-seeking behavior

According to the communities, children are more frequently sick during *rushash* and *darat*. The treatment of the child is based on what the mother and other care givers perceive the disease and symptoms to be. Parents also consider the price of care or transport, the distance to health centers, and seasonal barriers when considering treatment options.

When a child falls sick, the first recourse is self-medication. The child's mother gives him/her herbal or root infusions or makes the child fast. Then a traditional marabout or sorcerer is consulted. The child must be examined as soon as possible: "When our child becomes like this, we go to a marabout that is an hour's walk from here, so he can do the treatment. Prices vary from 500 to 20,000 FCFA (USD 0.9–36)." The marabout "attacks" the supernatural cause of the disease and treats the child with verses of the Koran selected according to the specific symptoms. In the case of diarrhea, the marabout uses several techniques. He will recommend boiled plants, scarifications, or burning the anus with a lit millet stem. In the event of fever, the marabout often recommends burning the forehead and scarification "to bring out or kill the bad blood".[87] According to one woman's account, in case of breathing difficulties, the sick child's uvula is often removed through unhygienic surgery. The marabout also gives his diagnosis of the disease. If he can't cure it, he sends the parents to another type of care, another marabout, *Dr. Tchoukou*, pharmacist, or local health center. The marabout therefore has an impact on decisions made about the course of treatment for the sick child.

Marabouts are frequently consulted for the following ailments:

- "Evil eye" (suspected curse)
- Fractures
- Toothache (treated by incision of the gums or using two needles)
- Swollen belly and fever (treated as "bad blood" through incisions of the abdomen and the forehead, letting out the "black" blood)

84 Woman in Rizildout, May 2019
85 Man in Tebesse, August 2018
86 Woman in Rizildout, August 2018
87 A Mother in Djedide, May 2019

- Malnourishment (also treated with an incision of the abdomen)
- Stomach aches and diarrhea (treated with incisions and emetic infusions of traditional plants)

In addition to marabouts and other traditional healers, people consult unlicensed sellers of uncertified individuals called *Dr. Tchoukou* who examine patients and administer pills, injections, and infusions according to their (unqualified) diagnosis. Most *Dr. Tchoukou*s are trained by an elder *Dr. Tchoukou* relative. People prefer to consult a *Dr. Tchoukou* rather than visit a health center as they are seen as cheaper and easier to access because they make house calls or attend markets. They tend to sell products for headaches, malaria, body aches, tension, fever, and sore kidneys that are acquired via networks trading in fake drugs (from India and China) or drugs intended for veterinary use. Market pharmacies are also a flourishing trade (see Photo 5). Drugs (certified or not) are sold by traders without a prescription, usually based only on the information/drawings on the packaging. Unlike *Dr. Tchoukou*s, market pharmacists do not make diagnoses, but just sell drugs.


Photo 5: Market pharmacy

Some participants in our focus groups made no distinction between *Dr. Tchoukous*, unlicensed market pharmacists, and nurses from the local health center. This confusion is fueled by the fact that some health center personnel set up pharmacies in markets to prescribe/sell cut-price drugs which are taken from the health center.

The local health center is often the last resort of the therapeutic course. Mothers know that in cases of headache, stomachache, fever, malaria, diarrhea, and respiratory infection, the child should be taken to a health center. Yet resorting to health centers is not yet systematic, nor is it a priority. To get to a health center, a woman must have her husband's approval or, in his absence, of that of his brother or father. A male figure's authorization is less likely to be needed for *Dr. Tchoukou* or traditional healers as they are more likely to be trusted given that they come from the same community. Health centers are not numerous and are sometimes located far from villages.[88] In the rainy season, the centers can become inaccessible for villages isolated by floods. The seasonal move to a *damkoutch* leads the distance to health centers for these communities to vary. The seasonal nature of the use of health centers is also due to seasonal changes in financial resources of the household and the workload of women. However, even if communities identified the price of healthcare and the distance to health centers as factors limiting their access to care, some participants in our focus groups explained that they prefer healers specializing in the treatment of worms and who are tens of kilometers away from their villages. In our study area, the main factor in the non-use of formal health services is a preference for and the traditional use of marabouts and other healers.

Study participant and key informant descriptions of health-seeking practices in Goz Beida led us to

88 There is a system of weekly mobile village health units (UVS) for remoter villages (those located more than five kilometers from a health center). The health district of Goz Beida has 15 UVS clinics, covering multiple villages. Djedide, Abdoudjoul, Taïba-Badria, Maramara, and Tebesse are served by UVS units, while Tcharo, Rizjildoute, and Al Kherim are linked up to health centers.

conclude that the delays and potential harmful practices and medication experienced by patients could complicate simple illnesses that would be effectively and economically addressed by health centers. A child's condition often worsens during the above procedures. When he/she finally gets to the health center, treatment is often difficult and more expensive than it would have been if the health center had been the first step. In the worst cases, treatment may be impossible.

Another important consideration around health-seeking behavior is household mobility related to livelihoods. Communities described how their use of health centers varies based on seasonal access to resources, women's workload, and mobility, as well as their history of livelihood specialization: "When we are in the *damkoutch*, we are far from health centers and very busy with field work. If the child is sick, I will try other options before taking him to the health center."[89] "*Dr Tchoukous* and marabouts are very much appreciated by Arabs; they are even visiting *makhalaf* to sell medication."[90] Communities with a pastoral history use health centers less than agricultural communities.

Animal health

According to the United Nations Food and Agriculture Organization (FAO), animal diseases are a serious threat to food security and water contamination. Animal diseases can reduce the quantity and quality of food (such as meat and milk), livestock products (such as hides and skins), and animal power for transport.[91] Moreover, sick animals can contaminate communities and especially children via children's direct exposure to fecal matter or through the water chain. The focal point of veterinary services in Goz Beida explained that animals are more vulnerable to diseases at the beginning of rainy season, given that the period of greatest food deficit for livestock is *seif* (the hot dry season) when access to pasture and water is reduced. In addition, the first rain destroys remaining pasture and animals and herders need to wait for two to three weeks for new pasture to grow. This time of the year is therefore also the seasonal peak of livestock disease. Community perceptions confirmed that livestock are sicker at the end of the dry season and the beginning of the rainy season: "The first rains drop on dirty soil and the water become contaminated… [the animals] are tired and hungry from the dry season."[92] Also, communities perceived that cows are more vulnerable to diseases and that goats are more resistant.

Sick and weak animals are brought closer to the house, so the household can more easily take care of them. Men supply and administer medication and women oversee food and water for the sick animal. People treat sick animals similarly to how they treat humans or perhaps even better: "When a cow is sick, I will buy medication in the market, or get advice from *Dr. Tchoukou*. Also, I will ask the marabout to protect the animal."[93] Some key informants explained the risks of such behavior: "Drug sellers in the markets or *Dr. Tchoukou*s use amoxicillin or tetracycline [antibiotics] in the wrong way. They mix up sub-muscular, intramuscular, and intravenous injections, which is very dangerous."[94] Official veterinary services are often the last resort for treatment: "Communities are suspicious of governmental or INGO services for animals; they believe that those services are disguised to count animals and tax them."[95] Over recent decades some INGOs have trained livestock support workers (*auxiliares d'élévage*). While veterinary legislation does not allow auxiliaries to administer vaccines without going through the state agency for the livestock sector, some do so regardless as well as providing other services. Key informants reported some questionable practices among *auxiliares d'élévage*, including one who sold the vaccine that he had been given for free by the government or an INGO, and one who "diluted the vaccine with water so he could sell more".[96]

89 Woman in Tcharo, August 2018
90 Key informant in Goz Beida, August 2018
91 http://www.fao.org/emergencies/emergency-types/transboundary-animal-diseases/en/
92 Key informant in Abdoudjoul, August 2018
93 Herder in Abdoudjoul
94 Veterinary services focal point in Goz Beida
95 Key informant in Goz Beida
96 Key Informant, May 2019

Table 8: Summary of water sources and their characteristics

	Borehole	Garden well	*Hit*	*Machiche*	River/stream/ pond
Description	Built by NGO or government, usually using concrete, in the village	Located inside garden fencing; built with straw.	Dug by large herd owners in/next to a wadi, built with wood and straw; not fenced	Small hole dug by hand in the sand in a wadi	Surface water
Depth		From 50cm in December to 3-4m in April/ May	From 1m in January/ February to 5m in May/ June	15–50cm	n/a
Season	All year	*Seif* to *rushash*	*Seif* to *rushash*	*Rushash* to *darat*	*Rushash* to *darat*
Months of usage	All year	Dec to Apr/May	Dec/Jan to May/Jun	Jun to Dec	Jun to Dec/Nov
Photo					
Main users	Nearby households, some animals (goats, sheep, horses, donkeys) during *seif*	Households who do market gardening	Humans and livestock	Humans and donkeys	Humans and livestock
Main purpose	Drinking, bathing, cooking, washing clothes, watering sedentary animals (*seif*)	Irrigation for market gardening	Watering animals during *seif*	Household purposes (mainly drinking and cooking)	Watering animals, bathing, swimming
Authorizations and ownership/ institution	Village chief	Owner or renter of the land	Historical arrangement between village chief and owner of large cattle herds	No authorization needed	No authorization needed
Arrangement for access and use/ governance	Monthly fees paid to CGPE[97] by women in households)	Privately owned; dug by male members of households; some rent land near wadi for 5,000 to 10,000 FCFA per year	The person who digs the *hit* has priority for his household and animals in the morning; in the afternoon others in the community can use it; separate area for animals; most users own large herds	No specific arrangement	No specific arrangement
Perception of quality (cleanliness and taste)	Good quality but bad taste (salty and iron-y), perceived as too "light"	Good quality, medium taste	Better taste in the evening, some wood used in construction gives it a bad taste in the morning	Very good taste, medium quality; favorite source of water; perceived as "heavy" water but quality not optimal because of contamination	Bad quality, medium taste
Human-use preference by season	*Rushash* ++ *Kharif* + *Darat* + *Shita* ++ *Seif* ++	*Rushash* ++ *Shita* +++ *Seif* +++	*Rushash* ++ *Shita* +++ *Seif* ++++	*Rushash* (only after first rain) ++ *Kharif* +++++ Darat +++	*Rushash* (only after first rain) + *Kharif* ++ Darat +

Note: + indicate preference. The more + the greater the relative preference

97 CGPE = Comité de gestion des points d'eau (local water committee)

Water sources for human and animal consumption

There are multiple types of water points in the Sila region. Each has characteristics that influence its use and users, including livestock, which in turn relate to water contamination (see next section). In this section, we will first describe the types of water sources available, then present their seasonal use for human and animal consumption, and finally identify the times of year when water sources are most likely to be shared by people and animals.

Water sources

The range of available water sources in Sila includes boreholes, traditional garden wells, *hits*, *machiches*, and the open well found only in Djedide. For a summary of the different types of water sources and their main characteristics refer to Table 8. For a summary of the water sources by village refer to Table 9.

Boreholes

All eight sampled communities have at least one borehole, built by NGOs (mainly Concern) or the

Table 9: Summary of water sources by village

	August 2018		May 2019	
	Borehole	Main sources for human consumption	Borehole	Main sources for human consumption
Rizildout	2 managed by CGPE (1 is not functioning) plus 1 by parents of student (total of 3)	Borehole and *machiche*	n/a (researchers didn't visit)	n/a
Djedide	1 borehole with a very poor water flow, 1 open well with high risks of contamination (hole in the structure and animals nearby)	Open well and *machiche*	Open well was dry, and borehole not functioning	Garden well and *hit*
Tcharo	4 boreholes: 3 not functioning; 1 is private (water sold 50 FCFA for 2 jerrycans)	*Machiche*	Only the "private" borehole was functioning (one of 4 boreholes)	*Hit* and borehole
Maramara	3 boreholes: 1 with solar powered pump (functioning), 1 for school, 1 not functioning	Borehole (solar), and *machiche*	Both boreholes were functioning	Solar borehole
Tebesse	1 borehole not functioning	*Machiche*	Borehole functioning but with low flow	*Hit*
Al Kherim	1 borehole not functioning	*Machiche*	Borehole functioning but not used for human consumption	*Hit*
Abdoudjoul	1 borehole not functioning	*Machiche* and *wadi*	Borehole not functioning	*Hit*
Taiba Badria	2 boreholes not functioning for 1 and 3 years	*Machiche*	2 boreholes not functioning	*Hit*

government (the Ministry of Environment and Fisheries), but in six of these village boreholes were not functioning during our field visits. Only boreholes in Rizildout and in Maramara were functioning and in public use. Our own observations of borehole usage did not fully correspond to the qualitative and quantitative data, but it is hard to say which approach was more biased. Given that qualitative researchers were able to physically look at boreholes, we tend to believe that there is more bias in borehole reporting in the quantitative data. For example, in Al Kherim and Abdoudjoul, during the August 2018 visit, all participants in the study told us that they were currently exclusively using the borehole, but when the team went to inspect the boreholes, they discovered that they were not functioning. One reason participants may not have disclosed this information could be that the research team worked under the banner of Concern, and the community were reluctant to admit that the boreholes supported by Concern were not functioning. Moreover, while the quantitative survey collects information on "boreholes" generally, there are multiple varieties reported in the area. Foot-pump boreholes are the most common type. In Maramara, there is also a borehole with a solar-powered pump, and in Tcharo there is a motorized pump borehole (see Photo 6).

NGOs promote the management of boreholes by water committees, known as *comités de gestion des points d'eau* (CGPEs). As well as managing boreholes, CGPEs collect contributions from the community for maintenance. Water committees are reportedly composed of one president (coordinator), one cashier, one guard (who controls access for animals and children), two controllers (responsible for cleaning and hygiene at the borehole and the functioning of the committee), one secretary (in charge of collecting user contributions), and one artisan repairperson. Monthly contributions vary between 250 and 500 CFA.[98] Women pay the water fees out of their own pocket/income as they are the one responsible for providing water to their households.

In each of the communities, there were different reasons why boreholes were no longer functioning or utilized, including privatization, poor management, taste preference, conflict, and seasonal availability of household funds. We briefly discuss each case below.

In Tcharo, one of the four available boreholes (constructed by Concern) was privatized and privately rented out. Key informants explained reasons for this privatization:

> *The CGPE was not functioning, [so] the chief gave the management of the borehole to a tradesman who has installed a generator to pump water. The tradesman rents the borehole to the chief*

Photo 6: Solar-powered borehole in Maramara (left) and motorized pump borehole in Tcharo (right)

98 Women and men from all eight villages.

for 10,000 FCFA [monthly], and he oversees the maintenance. He sells the water by jerrycan.[99] The price of the water fluctuates with the price of fuel for generator.

One other borehole in Tcharo had not been working since *darat* 2017. Respondents explained why:

> *The chiefs[100] dissolved the water committee to manage the borehole themselves, but then the borehole went down, and chiefs did nothing to fix it.*
>
> *In Tcharo there are a mix of different ethnic and tribal groups, so there is poor governance and it has an impact on access to water. In addition, there is a large weekly market, which means there are a lot of users, both human and animal, that is why the maintenance of the borehole is challenging and the queue can be off-putting.[101]*

But poor organization of the CGPE is not only a problem in large communities, like Tcharo. In Djedide, water committee members complained that "community members stopped contributing so the pump has not been repaired." One woman there said: "the reasons for the outage is that that the CGPE is poorly organized and ineffective."

In Al Kherim, though the borehole was functioning (albeit with low flow) no human users were observed. The borehole is in the wadi and *hits* are located next to it. Households from Al Kherim prefer fetching water (for human consumption) from the *hit*. "The water from the borehole is very 'light' and 'salty'. This is very good for ruminants, it can replace a salt cube, but not for us, we don't like to drink it. The water from the borehole gives urinary stones. We prefer the water from the *hit*, it tastes better."[102] A similar reason was given in Tebesse and Djedide. In Tebesse: "The borehole has a very low flow and requires a lot of effort to pump, so it is not used. During dry season, households prefer using *hits* around the village."[103] In Djedide: "The borehole has been malfunctioning since June 2018 and has very low flow, so *machiche* are preferred."[104]

In Taïba, the borehole had been out of service for 18 months at the time of the field visit. The inhabitants explained that "the borehole was causing conflicts with the neighbors; they came to use it without paying fees. If we repair it the problems will start again."[105]

Access to household income and availability of other water sources were mentioned across several villages as reasons why boreholes might not be utilized. In Al Kherim, one of the chiefs explained that "the community have contributed [to the CGPE] but as there is water everywhere in rainy season, we are using the savings from the water committee to invest in petty trade, and earnings will be given to the water committees." Boreholes tend to break down during *seif*, as demand is greatest during that time. They are usually not repaired until after *kharif*, when the communities have more income to pay fees as well as a greater need for additional water sources to replace the shrinking wadis.

Maramara is the only community that reported the use of a borehole throughout most of the year, primarily due to a lack of other options nearby, such as seasonal rivers (see Box 4).

Traditional garden wells

Traditional garden wells (*zagir birr*) are (mostly) private wells used to irrigate market gardens during the dry season (see Photo 7). They are generally protected by a fence, with no animals allowed nearby (Click here for video). Land for market gardening is rented from individual owners or village chiefs/ canton heads to individual households (for around 5,000 CFA per season). This agreement includes permission to dig a well on the land. A garden well can be used by multiple households from the same

99 Two jerrycan-loads of water sell for 50 CFA. Prices for small ruminants: 2,500 CFA/month for 100 head; 1,250 CFA for 30–50 head; 50 CFA/month for a horse.
100 Tcharo is a large village divided into four sections, each with its own chief.
101 Key informant in Goz Beida, August 2018
102 Man in Al Kherim during FGD, May 2019
103 Girl using the hit in Tebesse, May 2019
104 Key informant in Djedide, August 2018
105 Man during FGD in Al Kherim, May 2019

Box 4: Water use in Maramara, a positive deviant community with the lowest water contamination across all communities

Maramara is the only community among those studied that uses a borehole as the main source of water all year long. It happens to be a PD community, with the lowest recorded water contamination of any of the villages we studied across all reported water sources, not just boreholes. Maramara has two functioning boreholes, one with a foot pump, the other a solar pump. The solar pump is the main source of water for the entire community: "The foot pump is for the school, rarely used by the community as it requires more effort to pump."[106] "We use the foot pump sometimes during the rainy season, when there is not enough sun to run the solar pump. But there are also *machiches* that people use instead of the solar pump during rainy season."[107] According to the community, the solar borehole breaks down less often than the foot pump and is less expensive to maintain: "On average the solar system breaks down only once a year; the last breakdown cost us only 20,000 CFA."[108] However, it is worth noting that this is just the perception of the community. In the long-term, a solar pump could be as costly as they have high capital maintenance costs with solar panels needing to be replaced every 10–15 years.

Both boreholes are managed by a CGPE, whose president the chief of the village. His deputy is the marabout, and they are responsible for fees and savings. All households contribute all year round, except during the rainy season when no one wants to pay monthly fees of 500 CFA "because there is water everywhere we won't pay, machiche water is free."[109] Thus, during rainy season borehole water is free.

Maramara is located on a hill. During *seif*, the closest location where it is possible to dig a traditional well is very far from the village (10–12 kilometers): "The borehole is the only source we have in dry season."[110] "I prefer the taste of water from a hit or machiche to prepare the tea, but we don't have the choice."[111]

In Maramara, the solar borehole is connected to several taps and a separate water trough designed for small ruminants. As a result, water points are not shared between humans and animals. Moreover, fewer animals are present in Maramara in the first place given that there is no wadi nearby. During *seif*, no cattle come to the vicinity of Maramara because of its lack of water.

family, especially polygamous families. If a man has more than one wife, they will share the same well and land with each cultivating her own plot.

Zagir birrs are dug by men or boys during *seif* and shored up with branches and timber. They are deepened every two weeks during *seif*. Women are the main user of this type of well, as men are rarely seen gardening. Water is collected with an open container. Wealthier households use a motorized pump to draw water from the garden well, which is mainly used to irrigate crops, but also for household consumption. Households who have garden wells will use them as their main source of water during *seif* in Djedide and Rizildout.

However, there is an important limitation to the use of traditional market gardens. Households complain about national legislation restricting the cutting of wood. This makes it difficult to fence their gardens from animals and obliges them to work or stay in the *damkoutch* to keep livestock away.

106 Woman in Maramara
107 Woman in Maramara
108 Key informant, Male, Maramara, May 2019
109 Woman in Maramara, May 2019
110 Women in FGD, Maramara, May 2019
111 Women in FGD, Maramara, May 2019

Photo 7: Traditional garden well (*zagir birr*) in May 2019

Photo 8: Hit in May 2019

Hits

From January/February to *rushash*, it is difficult to find surface water in the Goz Beida area. During *seif*, pastoralists who need to water their large herds will dig traditional pastoral wells called *hits* (Photo 8). *Hits* are mainly used to water cattle (see Photo 9). Clay water troughs are usually built next to *hits*; herders collect water from the *hit* and pour it into the water trough through a water filtration system made of straw and stems. *Hits* are dug by owners of large cattle herds in dry wadi sand (*djourouf*, a former *machiche*) or just next to the wadi in clay soil (*torodja*) (Click here for video). The depth of a *hit* will increase gradually during the dry season until it reaches four or five meters deep. (Herders will dig deeper every week or two to find more water).

As the dry season progresses, water points become rarer, but communities with a pastoral history will know where to find water. *Hits* are only dug by men with a history of pastoralism specialization. Even though wadis are supposed to be for everyone, locations to dig a *hit* are transmitted from generation to generation within the same family. There is no official documentation of this, rather it is an historical arrangement/custom between primarily (village chiefs in) Dadjo communities and former semi-sedentary pastoralist communities. For years, the same family digs their *hit* in the same location:

> *Hit wells are located at the same place every year; there is no need for authorization to re-dig a hit that existed last year, as arrangements have existed for decades. However, authorization is needed to dig a hit in a new place. The chief of canton and the sultan will allow digging new hit if the location is far enough from gardens land.*[112]

> *Arrangements to dig a hit are free of charge, but you have to ask the chief.*[113]

112 Key informant in Tcharo
113 Herder around Hit in Djedide, May 2019

Photo 9: Cattle waiting to be watered at a hit (left) and water trough/man-made reservoir for animals next to a *hit* (right)

A *hit* can be shared between several households of the same family. Each household will then have its own water trough for livestock around their *hit*. *Hits* are built after *darat*. Village chiefs, imams and marabouts will sacrifice a small ruminant at a ceremony that signals permission has been granted to start digging *hits*.

Customary rules defining the use of *hits* are established between the cattle-owner who dug the *hit* and other potential users. The family of the herder who dug the *hit* has priority: he waters his livestock—large herds of cattle, goats, and sheep—there between 8.30 and 10 am, then the animals leave the *hit* for pasture, coming back at 3 pm. After the owner's livestock have been watered, other herds may use the *hit* by order of arrival. Large herds of cattle might come from 10 to 12 am, small ruminants will come in the afternoon. At 4 pm, all animals have gone to pasture, so neighboring communities with an agricultural livelihood history come to the *hit* to fetch water for their livestock. Although it is possible to fetch water from the *hit* for household consumption anytime during the day, it is easier for neighboring communities to fetch water after 3 or 4 pm, when livestock have finished drinking, and the *hit* is less crowded. However, access to *hits* near areas where market gardening occurs might be a source of conflict (see Box 1).

Communities prefer to drink water from the *hit* in the evening, as animals empty the *hit* during the day and it refills itself by filtration and thus tastes better: in morning *hit* water has "stagnated during the night is not clear and tastes like wood[114]".

Hits are destroyed by the first rains (Click here for video).

Machiches

At the beginning of the rainy season, water is easily accessible, rainwater flows into the wadi bed and communities begin to dig *machiches* next to it. *Machiches* are shallow wells hand-dug in the sandy soil of the wadi (see Photo 10): "We dig *machiches* because the water is filtered by sand, it is much better and less contaminated than the surface water in the wadi."[115] At the end of the rainy season, it is necessary to dig a deeper *machiche* by hand to find water, so the depth of *machiche* varies from 15 centimeters in August to 50 centimeters in December/January.

Water quality of the *machiche* is perceived as having a "good taste, but you have to be careful as there is dirt all around. You don't know who used it before you, and it can be an animal. So before fetching water from it you must first empty the *machiche* and wait 30 seconds for it to refill."[116] The *machiche* is

114 Women in Djedide, May 2019
115 Women fetching water at a *machiche* in Tcharo, August 2018
116 Women from Tebesse, August 2018

Photo 10: *Machiche*

Photo 11: Open well in Djedide (left) with hole (right)

used as a way to treat water through sand filtration. Water flows through the sand to fill the *machiche* and is therefore considered by communities to be good quality. While communities recognize the good quality of water from boreholes, the water from *machiche* was mentioned as being tastiest: "The water of the borehole is light: it does not hold on in the belly and one is always thirsty, you can sense the iron because of the pumping accessories. The water of the *machiche* is saltier, it's just water and sand, there is no other smell."[117]

Open wells

One open well was used in Djedide (and in no other community) during our field visit in August 2018 but it was in poor condition (Photo 11). In May 2019, the open borehole was dry. People wanted to repair the open well rather than the pump as "it is less expensive, and then it doesn't break down."[118] Part of the wall collapsed two years ago, and during *rushash*, surface water runs off inside the well. Due to poor management of the CDGE, the collapsed wall has not been repaired. Users fetch water with their own container, which is placed on the ground before being immersed in the open well. Women from Djedide explained that they preferred the quality and the taste of the *machiche* water to the open well water but noted that the *machiche* was further away from their houses.

Seasonality of water source use for human consumption

As the previous section has described, households use different water sources depending on the season and where they live (Figure 9). The seasonal variation is directly related to the availability of water in seasonal rivers as well as to taste preferences. The clearest seasonal pattern is observed in relation to the use of *hits* (deep man-made wells) and *machiche* (shallow man-made wells). *Hits* are primarily used after a wadi has partially dried out and before there is sufficient rain to refill the seasonal water ways: from January to June. Once water is freely available again in the rivers, households switch to either using a *machiche* or getting their water directly from the riverbed or a man-made mud-walled reservoir (*hafir*).[119] In the qualitative data, some households reported that *hits* are destroyed by the first rains and households transform the destroyed hit into a *machiche.* Borehole use is inconsistent throughout the year and peaked towards the end of the rainy season (August to October) in both years of our study. The peak in borehole use could be associated with households having greater access to funds during this time to fix or rebuild the well combined with less pressure on the well due to the availability of water in the wadis. Thus, trends in borehole use are a mix of functionality, taste preference, and access to income.

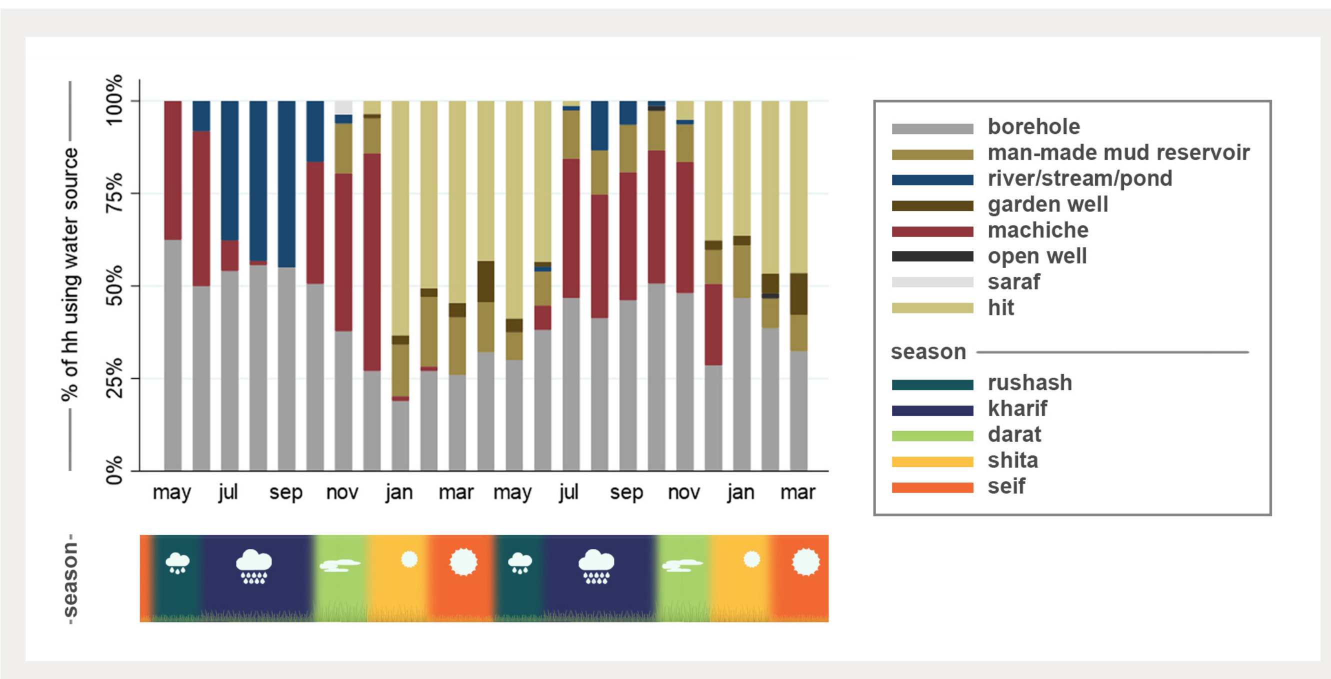
117 Women in Tcharo, August 2018
118 Man in Djedide during FGD, May 2019
119 We did not collect detailed information on man-made reservoirs during the qualitative work. However, they seem to be reported more in year two of our quantitative data collection. They are described as a basin made from mud in a circular shape with a depth of 20–30 cm and are usually built near a well from which people can fill it with water. They are generally associated with water consumption for animals.

On its own, the quantitative data suggests that during the first year of data collection households primarily used water directly from the riverbed during the rainy season, but in year two they appeared to switch to mostly using a *machiche*. It is difficult to determine whether this was a genuine switch linked to Concern's programming coupled with the dissemination of our research findings, or more the result of how our understanding of the different types of water sources (and how they are used) improved from year one to year two of the study thanks to the closer collaboration between qualitative researchers and enumerators in May and August 2018. Thus, we feel confident in the accuracy of the water source data for the second year of data collection, with the understanding that there is likely more "noise" in the first year of data collection.

Gradually, during the first three rains (which could occur within a two-to-four-week timespan), all traditional deep wells (*hits* and traditional garden wells) collapse as the river fills up and floods them. In the month after the first rain (between the first rain and the third rains), households will gradually start using *machiches* or surface rainwater. Remaining pastoral *hits* and garden wells are preferred to surface water for human consumption. The surface water during the first three rains is perceived by communities as being of worse quality for both animals and humans and corresponds to seasonal peaks in animal diseases. In fact, the first rain will drain all the dirtiness from the dry season (animal cadavers and fecal matter) into the riverbeds or ponds. The relationship between the first rains and increased contamination has been supported by previous research. The start of the rains and warmer temperatures have been associated in other studies with peaks of total dissolved solids in water[120] (Kulinkina, Mohan et al. 2016), as well as with *Cryptosporidium*[121] (Molbak, Hojlyng et al. 1990; Perch, Sodemann et al. 2001; Jagai, Castronovo et al. 2009), and bacterial enteric infections[122] (Kelly-Hope, Alonso et al. 2008). However, surface water is more accessible and timesaving for women who are busy with planting at this time of the year.

In the large wadi near Djedide, there is a significant change before and after the first rain (see Photo 12). In 2019 the researchers witnessed the changes. After the first rain, most of the *hits* have collapsed; only

Figure 9: Type of water source for household consumption by month



120 Any minerals, salts, metals, cations or anions dissolved in water
121 A parasitic coccidian protozoan found in the intestinal tract of many vertebrates, where it sometimes causes disease
122 Bacterial infections in the intestinal tract resulting in diarrhea or other symptoms

Photo 12: *Hit* in Djedide before (left) and after (right) the first rains in 2019

3 out of 15 remained. Uses and users of the three remaining *hits* were radically different just one day apart: thousands of cattle and their male herders were replaced by women from neighboring villages (including Tcharo) who were collecting water and doing their laundry. One of the interviewees we met at the *hit* after the first rains explained she preferred collecting water here rather than in rivers formed by rainwater:

> *After the first rain, the surface water is very bad quality. It is very contaminated by cadavers of animals. All the dirt from dry season is cleaned by first rain, so the smell is really bad, and people will get sick when they drink it. A lot of people will prefer to collect water from the few hits that haven't fallen, so there's a queue. People prefer to continue collecting water in hits as long as possible because the water is of better quality, so they wait for several rains before they start using the machiche or wadi. However, others will collect surface water, as they are busy planting millet and don't have the time to go to the hit*[123]

Gradually, the garden wells are also abandoned at the end of *seif*. The women abandon their gardens and begin to prepare their fields for planting.

Water source for human consumption by village

There are considerable differences in water access between the communities we studied (Figure 10). In Taiba, Abdoudjoul, and Al Kherim, borehole use is the most limited, with a much greater reliance on *hits* and *machiche*. Rizildout consistently stands out as a community primarily utilizing boreholes for its water needs. Maramara and Tebesse showed a distinct shift in utilization between the two years, but in opposite directions, with Maramara households reporting borehole use at a much lower level after November 2018 and Tebesse households reporting borehole use to a greater degree after March 2019. Both changes relate directly to borehole availability. As of May 2019, people in Maramara reported that the borehole there was broken and that the fees were too expensive. In addition, some respondents said that the chief and marabout were keeping the fees. In Tebesse during the May 2019 field work, households reported that their borehole had previously been broken.

Seasonality of water source use for animal consumption

Water sources for animal consumption also follow a clear seasonal pattern (Figure 11). During the rainy season (*kharif*), open source water (from wadis) is most commonly utilized. The use of wadi water is replaced by machiche water during the first couple of months after the end of the rainy season when water is still widely available (October, November, and December). Once the wadis and *hafirs* dry out completely, households switch to the *hit* for animal water consumption.

We also looked at how water use for animal consumption varied by village (Figure 12). There is generally much more consistency across the communities when it comes to water for animals, with a few outliers. The lack of a nearby seasonal

123 Key informant, Female, Djedide, May 2019

Figure 10: Water source for human consumption by village

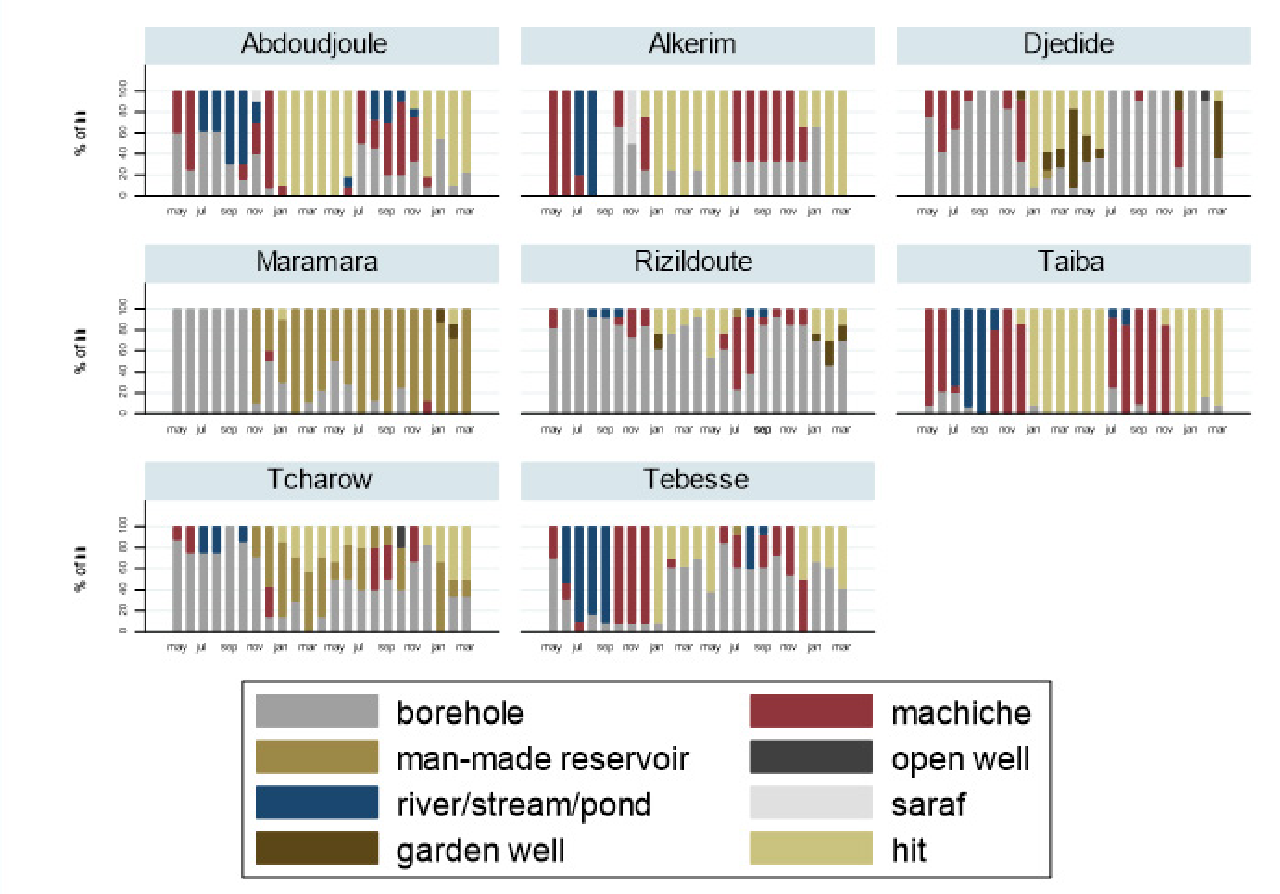


Figure 11: Type of water source for animal consumption by month

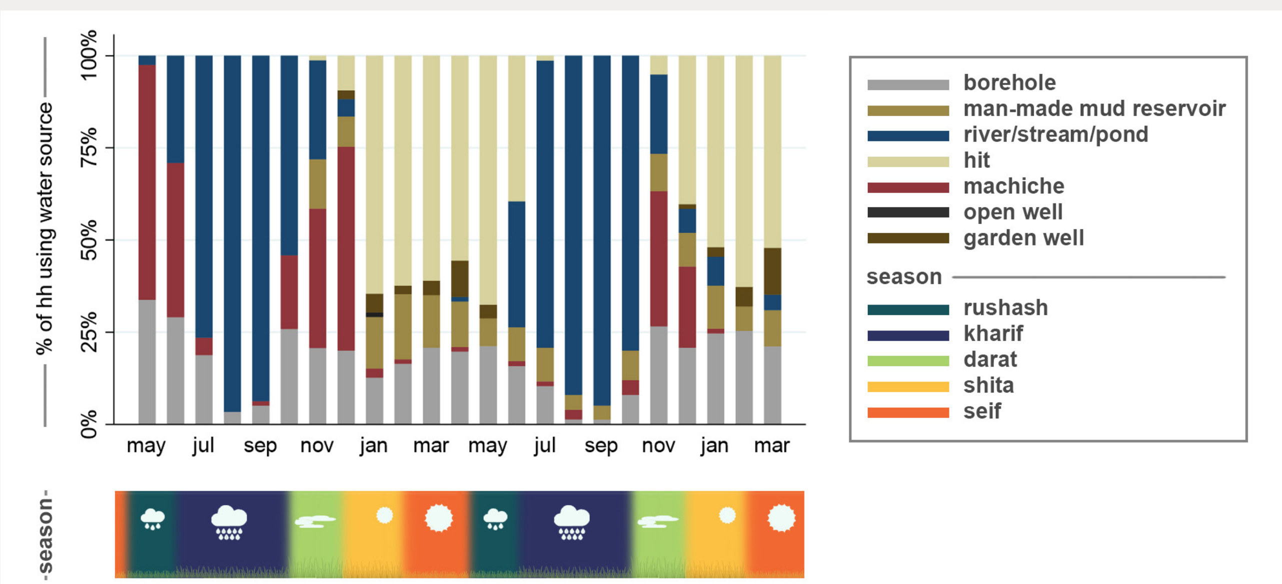
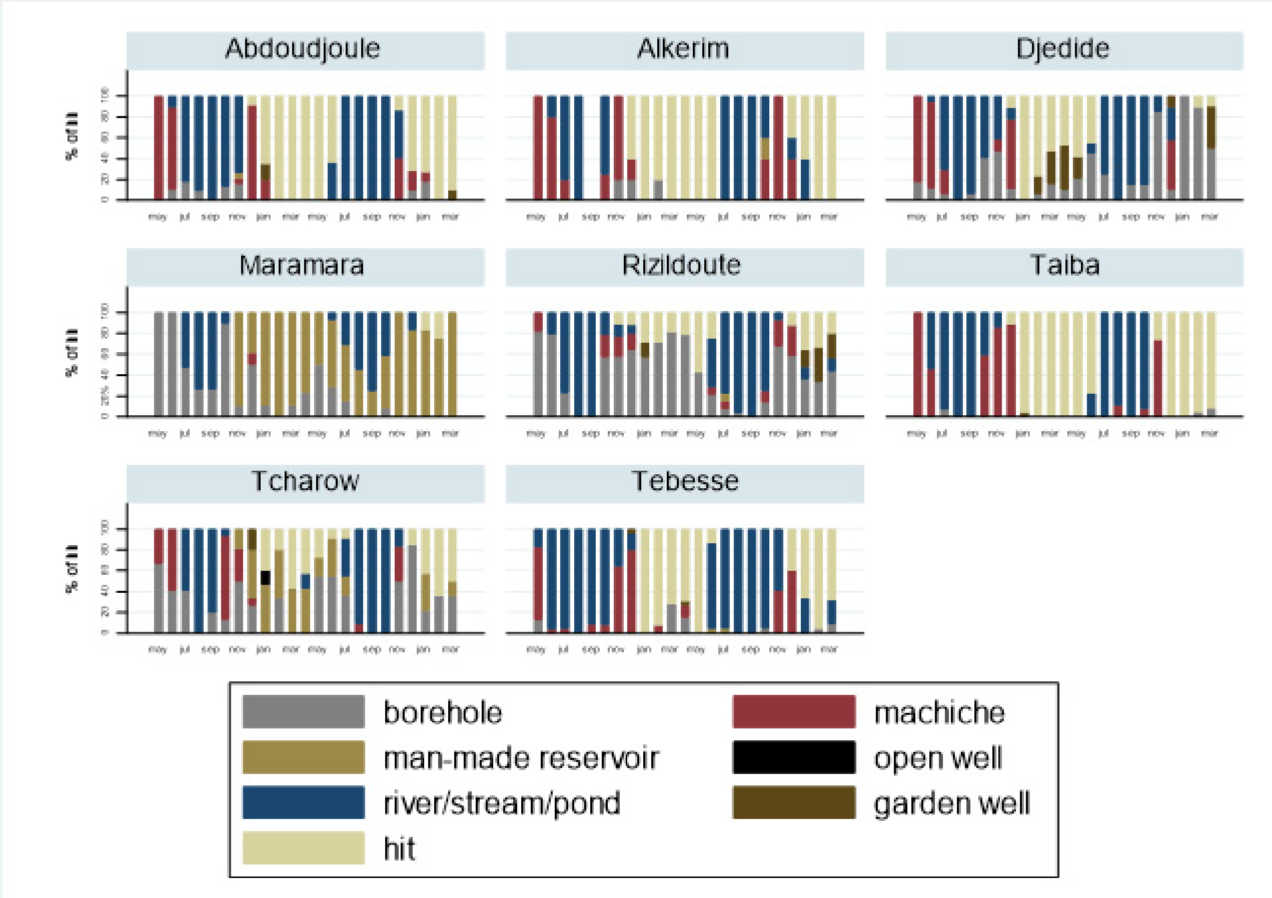


Figure 12: Water source for animal consumption by village



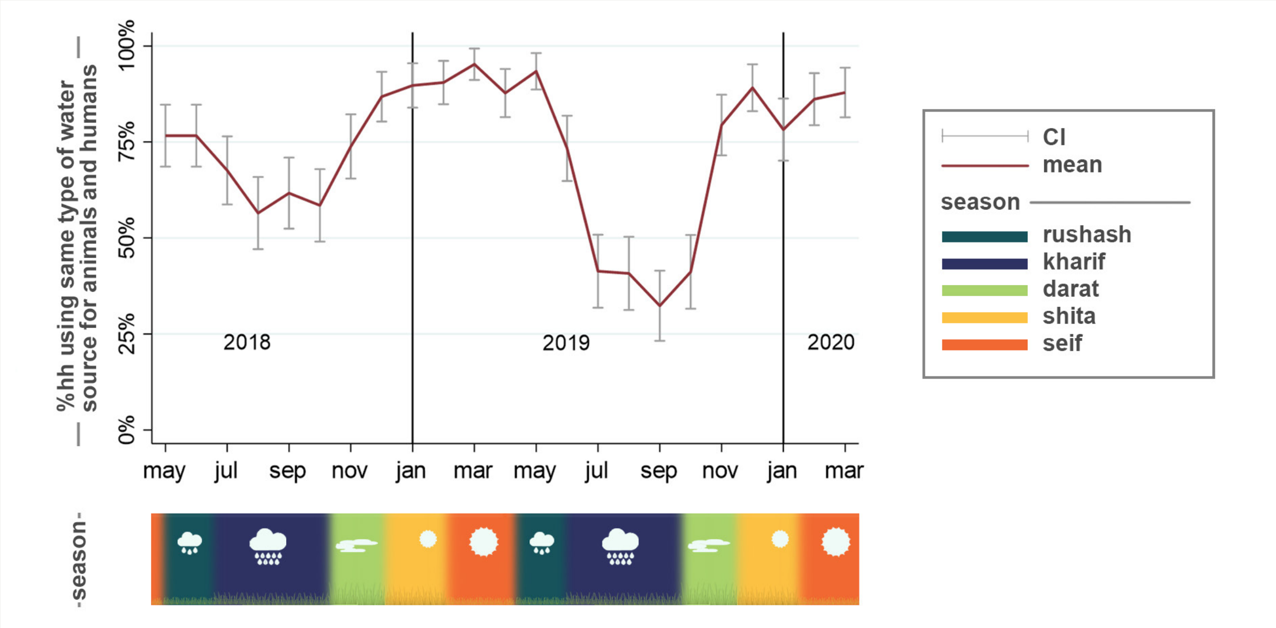
river is obvious in Maramara, where the smallest proportion of households reported using open source water, and which instead showed a strong reliance on man-made reservoirs.

Seasonality of shared water use by humans and animals

The result is a clear seasonal pattern of shared use (by type) of water sources between animals and humans (Figure 13). Animals and humans are most likely to share water sources from December to May (*seif*), when both primarily rely on *hits*: "The time of year when we share the water source with livestock the most is at the end of dry season. In May, communities are only fetching water from one *hit*, the same one for humans and animals who stayed in the village during dry season."[124] *Seif* corresponds to a decrease in available water sources and thus to a greater concentration of animals and humans at those sources: "The further we progress into the dry season, the more we share the same source with the animals that remain in the village."[125] The only time of year when there is a greater distinction between the type of water source used predominately by animals and by humans is the rainy season (*kharif*) from July through October. We again saw a distinction between the first year and second year of data collection in terms of shared use during the rainy season. This difference is primarily caused by an apparent shift in households from using open source water in 2018 to a *machiche* in 2019 during *kharif* (the rainy season). As noted above, this shift is likely due to our improved understanding of different types of water sources—particularly in terms of distinguishing between open source, *machiche*, and *hits*—rather than to genuine (and positive) changes in habits.

124 Man in Taiba
125 Man in Abdoudjoul

Figure 13: Households using the same type of water source for animal and human consumption



Practices along the water chain and water contamination

In this section, we present findings about practices along the water chain (from water source to transport and storage) and about water contamination. We start with a description of water handling practices, followed by a discussion on hygiene practices and how they vary by season, and end with an analysis of coliform water contamination across communities, the water chain, by source, and over time.

Water handling practices

Gender roles along the water chain are clearly distinguished. Women and children are responsible for fetching and carrying water for all household purposes from all types of water sources. Men are responsible for digging and building traditional shallow wells (*hits* and garden wells), and for watering large herds at the *hit*. Water collection is mainly done by children (girls) and women in a clay jar (canari) or a plastic jerrycan (see Photo 13). Water is stored in the house in a clay jar to keep it fresh (see Photo 13). To drink water, one dips a cup into the water and drinks from the cup (Photo 13), causing contact between hand, mouth, and water stock. In some households, we observed the cup left on the ground, causing contact with the dirt there also.

A game in which participants scored risk along the water chain showed that communities understand potential risks of contamination and of how to avoid them: "Animals cannot be around the borehole." "Water containers for storage and transportation need to be regularly cleaned and should be closed." "Cups should be clean before fetching water in the jar." "Children's hands should be washed before eating."[126] The communities seem to have learned key messages from Concern's sensitization activities, which is a good indicator of the process of behavior change. Lack of knowledge is not what is keeping people from adopting better hygiene behaviors:

> *I know that drinking water from borehole is a better option, but when I am working, my children are in charge of fetching water, and I cannot control where they actually fetch the water. They are playing with their friends in the wadi, they will take water on their way back.*[127]

126 Quotes from various FGD with women in August 2018
127 Women in Tcharo, August 2018

Photo 13: Jerrycan for water transport (far left); clay jar for storage (second from left); cup for drinking (second from right); clay jar for transport (far right)

> *In dry season I don't have time to queue for water [at the borehole], I will fetch water in the traditional well.*[128]

One reported barrier to better hygiene is poor access to water during the dry season: "We wait for the first rain to wash our clothes, carpets, sheets, or others household utensils."[129] During rainy season (especially at the end of the rainy season) women's heavy workload and lack of income was also reported as a barrier: "We don't have time to wash containers and we don't have any money to buy soap."[130]

Women recognize that hygiene practices have seasonal variations: "Being hygienic is easier when you have the time, lots of water, and the money to buy Omo [a common brand of soap]."[131] "During the dry season, we need to save water, so children do not take a bath every day."[132] "Hygiene is difficult in the *damkoutch*; we have no soap, and no time."[133]

Communities believe that water contamination is worst at the beginning of the rainy season (*rushash*):

> *The children are sicker when the first rains come; they have a lot of diarrhea.*[134]

> *At the first rain, children from two years old, especially boys, will play in rainwater ponds. This is when the contamination happens as the first rain flushes all the bad things from the dry season into the pond.*[135]

> *Best to wait two or three rains to drink rainwater.*[136]

The quality and taste of water during *kharif* is perceived as the best: "There is less contamination in *kharif*, water flows from everywhere and cleans everything."[137] In May 2019, our observations of water sources showed that those in Abdoudjoul and Taïba (*hits* shared with animals) were dirtier than the source in Maramara (a solar-powered borehole with a separate area for small ruminants).

Poor food hygiene also poses a risk of contamination. When the mother leaves in the morning, she takes food with her for the children during the day. She will also leave food in the household for the older children. The food is kept in the kitchen, which is located outside the hut, and dishes are not systematically covered. Some women in the focus groups also indicated that poor hygiene with kitchen utensils posed a risk to children's health. Indeed, the pots and dishes are not systematically washed between each meal.

128 Women in Tcharo, August 2018
129 Woman in Tcharo, May 2019
130 Woman in Djedide August 2018
131 Woman in Rizildout
132 Women in Maramara, May 2019
133 Woman during FGD in Maramara
134 Woman in Tcharo, May 2019
135 Woman in Tcharo, May 2019
136 Woman in Tebesse, May 2019
137 Woman in Al Kherim, May 2019

Moreover, young children are frequently in contact with fecal matter that is left on the ground in the villages. Children, mostly those under two years of age, crawl on the ground and put their hands to their mouths and are at risk of contamination from animals kept near the house. This includes chickens and goats, but also sick animals, calves, and milking cows, which are kept near the house (where they easier to take care of) throughout the year. Personal hygiene practices also vary by season. In *seif*, women and children usually bathe once or twice a week, alternately. From the first rains, hygiene practices improve with better access to water: "We wait for the first rain to do the laundry of clothes, carpets, sheets."[138]

Tebesse was identified as a PD community for hygiene practices through qualitative observations.[139] During data collection, Tebesse's borehole was not functioning, so the community was using *machiches* in *kharif* and *hits* in *seif*. Qualitative observations and FGDs highlighted the following characteristics in the Tebesse environment that differed to other villages (see Photo 14):

- No livestock or traces of fecal matter were observed in the village, as households in Tebesse mostly practice medium and long-distance migration with cattle.
- Water containers were closed.
- Cooking utensils were washed and stored above ground-level.
- Women were well dressed and seemed more empowered as they were able to have deep and informed discussions with the research team.

There seem to be two factors here—wealth through livestock, and the influence of the urban on the rural—that have implications for both income and behaviors. One of our key informants explained:

> *If it was not for livestock, Tebesse communities wouldn't live in the bush. They have a lot of social networks in town, with rich people. They have a lot of cattle, they are wealthier. They know how city dwellers behave and they apply the same practices in the village.*

Photo 14: Environment in Tebesse (May 2019)

According to this key informant, the social networks with better-off and educated people could be an enabling factor in behavior change.

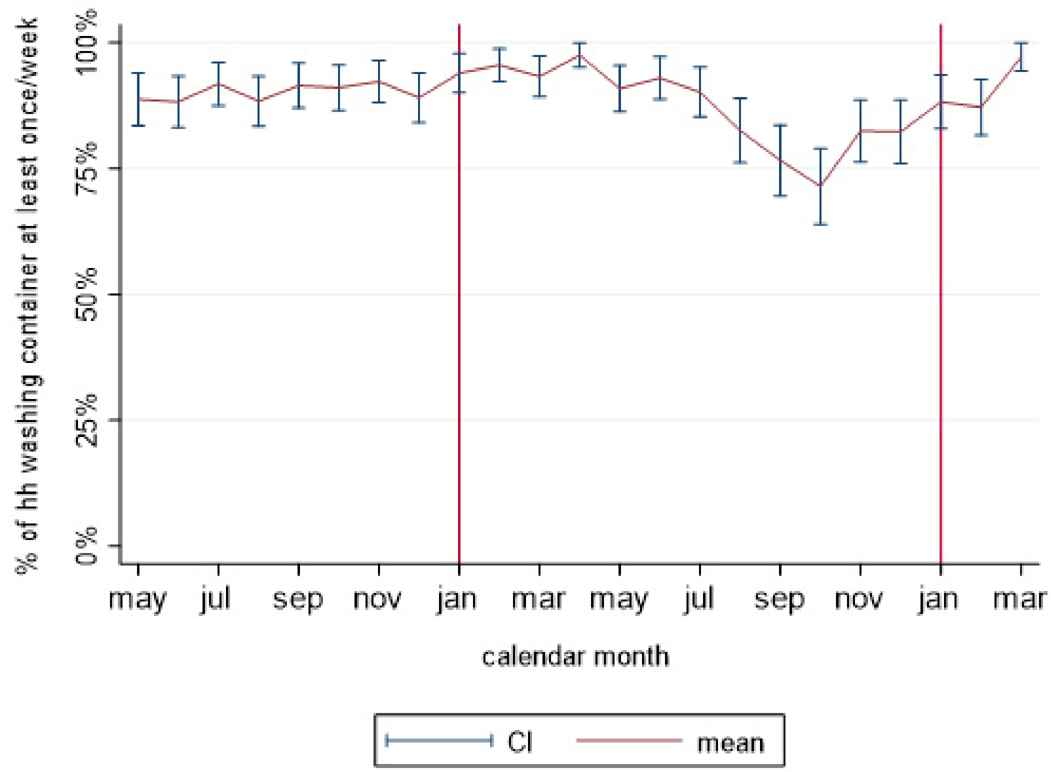
Seasonality of hygiene practices along the water chain

Almost 90 percent (CI: 88-91 percent) of surveyed households said they clean their storage container one or more times a week. Despite the large proportion of households who practice this, a seasonal trend is apparent in the data (Figure 14), with households less likely to wash their container as frequently during the rainy season (see Table 20 in Annex A for regression table). For example, the proportion of households washing their storage container one or more times a week in April 2019 is 98 percent, which then steadily drops to 71 percent in October of 2019, to then steadily increase back to 97 percent in March of 2020. Interestingly, that means access to water and use of water for washing a storage container have an inverted relationship.

One third of households (CI: 31–35 percent) said they washed their storage container with soap or ash, 36 percent (CI: 34–38 percent) reported using crop residues (*habile/kebeche*), 26 percent (CI: 24–28 percent) said they used sand and small stones, 3 percent (CI: 2–4 percent) said they used water alone, and 1 percent (CI: 0–1 percent) said they used bleach or chlorine. Enumerators reported that 86 percent (CI: 85–88 percent) of storage containers were closed and 55 percent (CI: 52–57 percent) looked clean. Households who reported either washing their containers with sand and small stones or using only water were significantly more likely to have a container that did not look clean (according to the enumerators). If the container was closed it was

138 Woman in Tcharo, May 2019
139 In Tebesse, a traditional well had zero coliform contamination

Figure 14: Proportion of surveyed households that wash water containers at least once a week by season



also significantly more likely to look clean, with 59 percent of closed containers looking clean compared to 26 percent of open containers. It is worth noting that the recommended practice (according to Concern) is to put pebbles in soapy water inside the container, shake it, and then remove the pebbles.

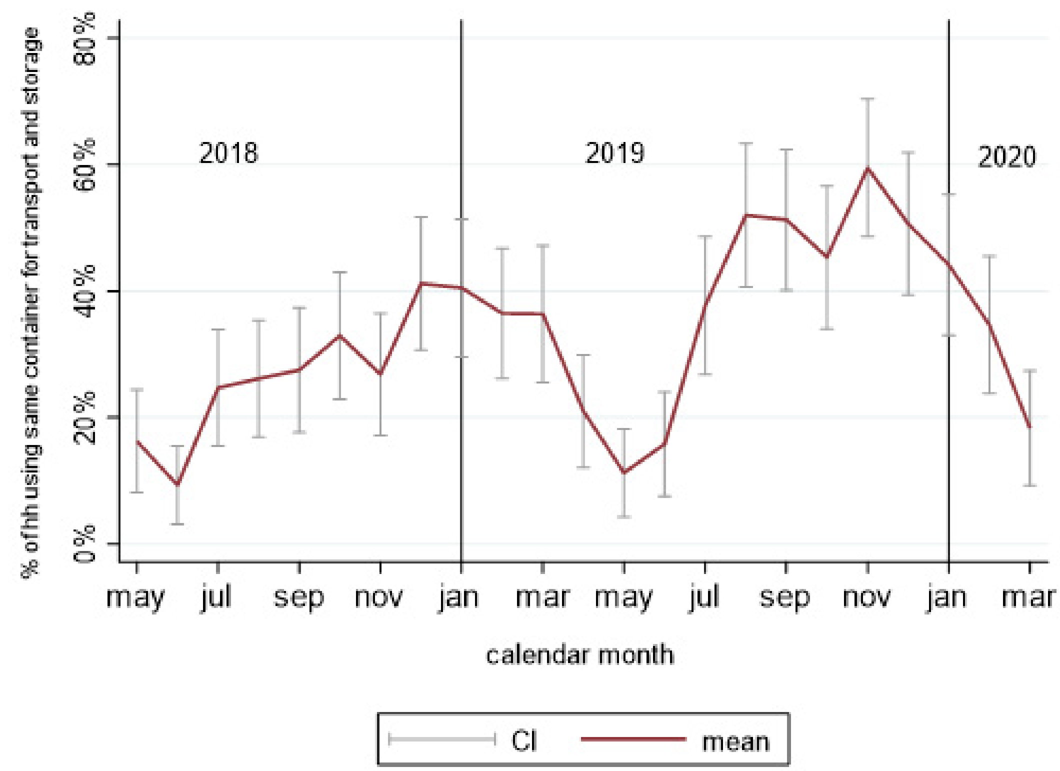
The proportion of households who said they used the same container for storage and transport varied seasonally (Figure 15). During the dry months, going into *rushash,* households are very unlikely to use the same container, but have separate containers for storage and transport. However, as the rains begin, households are much more likely to have only one container. This is likely an indication of the availability of water and hence the necessity to store more water when it is less available.

Coliform contamination

According to the fourth edition of the World Health Organization (WHO) Guidelines for drinking water, a source or container is considered non-contaminated (in relation to coliform) if zero coliform colonies are present (WHO 2011). We looked at coliform in several different ways, including average coliform as well as a categorization based on the following criteria taken from a previous water analysis done in Chad (Bauby and Flachenberg 2014):

- No contamination: 0 coliforms/100 ml
- Low contamination: 1–10 coliforms/100 ml
- Medium contamination: 11–50 coliforms/100 ml
- High contamination: >50 coliforms/100 ml

Figure 15: Proportion of surveyed households using the same container for water storage and transport, by month and season



Across communities

In this section we will present information about coliform contamination of water by community. From the aggregated village-level data, we found that Abdoudjoul, Taiba Badria and Al Kherim had some of the highest overall contamination, while Maramara and Rizildout had the lowest (Table 10). We discuss some of our hypotheses around the village-level differences in the discussion.

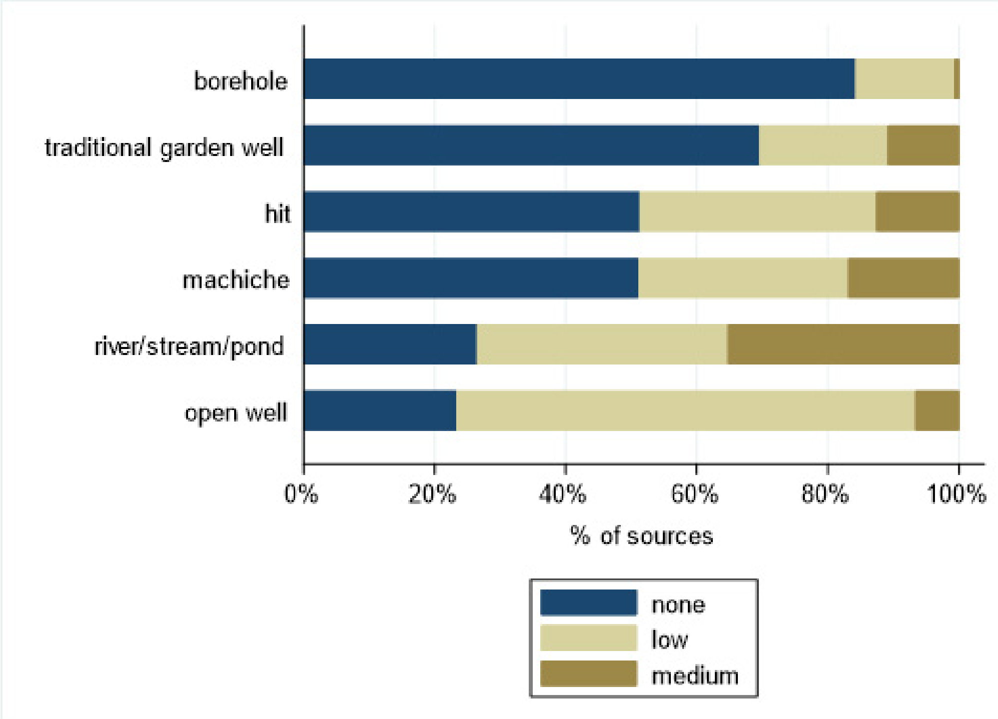
Across the water chain

As expected, we saw a significant increase in contamination across the water chain. Across the study area, the mean number of coliform colonies per 100 milliliters of water was 2.1 (CI: 1.9–2.3 colonies) at the source, 3.3 (CI: 3.1–3.5 colonies) at transport, and 4.3 (CI: 4.0–4.5 colonies) at storage. Or put another way, 69 percent of households got water from a source that was not contaminated

Table 10: Uncontaminated water storage, transport, and sources by village

Village	Storage	Transport	Source
Abdoudjoul	43%	48%	54%
Al Kherim	47%	56%	58%
Djedide	48%	61%	74%
Maramara	51%	68%	87%
Rizildout	54%	63%	85%
Taiba	36%	41%	51%
Tcharo	47%	61%	72%
Tebesse	41%	51%	62%
All villages	**45%**	**55%**	**69%**

Figure 16: Extent of coliform contamination by type of water source



(zero coliform colonies per 100 milliliters), 55 percent had a clean transport container, and 45 percent had a clean storage container (Table 10).

Across water source

Contamination significantly differs by water source (Figure 16). The greatest contamination was found in *machiches*, open wells, and *hits* and the least found in boreholes and man-made reservoirs. However only two communities, Maramara and Tcharo, reported using a man-made reservoir. We know from the qualitative data that there is a significantly lower prevalence of livestock in Maramara and so it is not completely surprising that we found that there was significantly ($p=0.06$) greater contamination in the man-made reservoir (which is mainly intended for animals) in Tcharo.

Across time

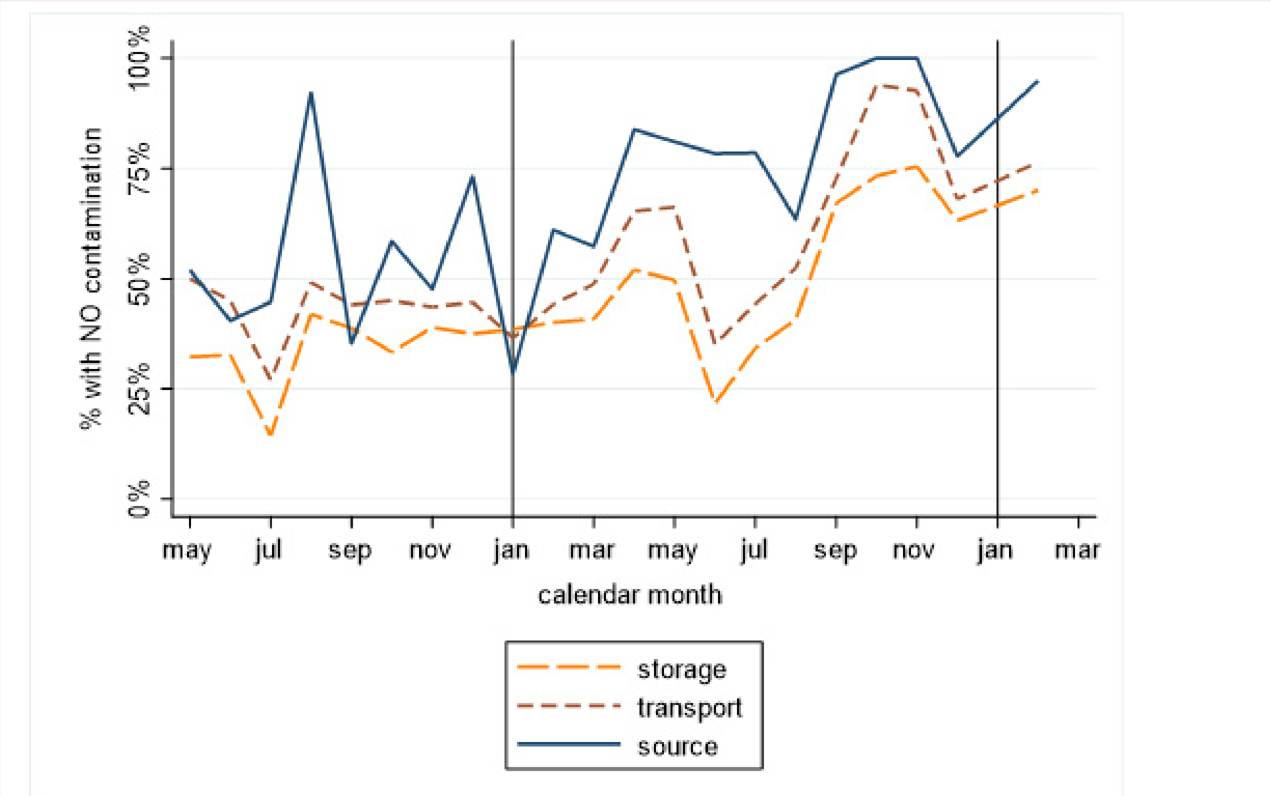
The coliform data shows a decrease of contamination over the course of the study period (Figure 17) with evidence of seasonality. We ran a negative binomial mixed effects regression with harmonic terms on our storage container coliform variable and found evidence of a pronounced seasonality (Table 21 in Annex A).

In order to get a clearer picture of the seasonality, we plotted the predicted values in Figure 18. The predicted values clarify that the two seasonal peaks of coliform contamination occur in July and January and that contamination initially declines during *seif* but increases during *rushash*.

What is associated with coliform contamination?

In this section, we review what is correlated with water contamination at the source and in transport and storage containers. As discussed in the methodology section, we wanted to also test the relationship between contamination and two variables for which we did not collect data during the two-year study but did do so in November/December 2017 as part of the CRAM/BRACED endline survey. The first variable is the total number of cattle owned by all households sampled in each of the villages, which we use as a very rough proxy for

Figure 17: Absence of coliform contamination across the water chain, by month and season

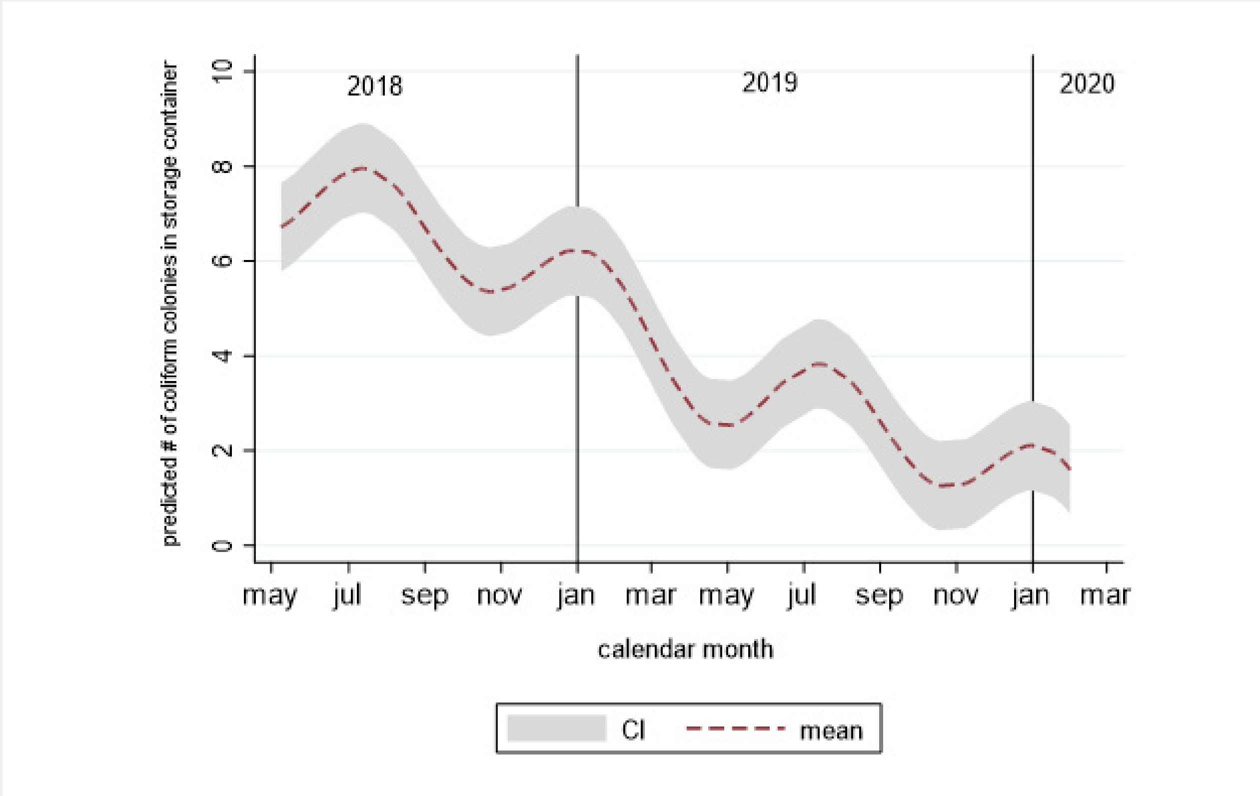


the relative presence of cattle in the community. The second variable is household wealth, measured as tropical livestock units (TLU) per capita. To convert individual livestock ownership into TLUs we used the following conversion factors (based on relative value of the livestock): cattle = 0.7, sheep = 0.1, goats = 0.1, pigs = 0.2, chicken = 0.01 (Harvest Choice 2015).

The type of water source was significantly correlated with contamination across the entire water chain. Compared to water from a borehole, water from all other sources, except *hafirs*, was significantly more likely to be contaminated (Table 22 in Annex A). Both our village cattle proxy and households reporting using the same type of water source for both animal and human consumption were significantly correlated with greater contamination at the source. To get a better sense of the magnitude of impact, we ran the same regression model but using the outcome "no coliform contamination." Given that running a mixed effects model on a binary outcome (no coliform contamination vs some coliform contamination) is more complex, we could only run it on the level of contamination at the source (Table 23 in Annex A). According to the model, the odds of getting non-contaminated water from a *machiche* are 85 percent lower than they are from borehole; they are 97 percent lower from an open well (vs a borehole); 75 percent lower from a traditional garden well; 85 percent lower from a hit; and 39 percent lower from a source shared by both animals and humans. The number of cattle was not significant in this model.

It should be recalled that the "coliform" variable is a measure of the amount of fecal coliform—bacteria that is found in warm-blooded animals, including humans—and thus covers contamination from multiple sources, not just cattle. Interestingly, neither sharing a water source with animals nor the number of cattle in the community are significant in relation to transport and storage containers (on the outcome:

Figure 18: Predicted number of coliform colonies in household storage container



number of coliform colonies). In other words, it is very likely that animals play a role in contamination mainly at the water source; subsequent levels of contamination—i.e. of transport and storage containers—are likely linked more with poor post-defecation hand-washing practices than with the presence of animals, or at the very least cattle.

We also looked at whether individual livestock wealth, hygiene practices along the water chain (measured by recording whether containers were closed, clean, regularly washed, and what they were washed with), and climatic variables (rainfall, temperature, and normalized difference vegetation index (NDVI)) were correlated to contamination at the source and in the transport and storage containers. We found no significant relationships. While the lack of a relationship with hygiene practices does not mean that these aspects are not crucial, it does indicate that their role in contamination is much smaller than some of the community-level factors such as type of water source and whether there are animals (particularly cattle) nearby.

Understanding child nutrition and morbidity

In this section, we look at the seasonality of multiple nutrition indicators (defined in Table 11), irrespective of whether we expect to see seasonal changes in the nutrition indicator (i.e. stunting). Since the main focus of this study is on child wasting, we start by looking at wasting (WHZ<-2), severe wasting (WHZ<-3), WHZ, and MUAC. We then move on to underweight (WAZ<-2) and WAZ, followed by stunting (HAZ<-2), HAZ, and child morbidity. We end this section by exploring which variables are associated with wasting and WHZ. While we measured the presence of bilateral edema in the survey, only 11 children across the whole sample had edema and all 11 of those measurements were later discarded for having z-scores below -5 standard deviations.

Table 11: Nutrition variables and definitions

Variable	Definition
WHZ	Weight-for-height z-score
Wasting	Weight-for-height z-score <−2
Severe wasting	Weight-for-height z-score <−3
MUAC	Mid-upper arm circumference
HAZ	Height-for-age z-score
Stunting	Height-for-age z-score <−2
WAZ	Weight-for-age z-score
Underweight	Weight-for-age z-score <−2

Wasting, severe wasting, WHZ, and MUAC

In this section, we explore the seasonality of child nutritional status—with a focus on wasting—by analyzing the prevalence of wasting, severe wasting, as well as WHZ and MUAC. Since wasting is our primary outcome indicator, we go one step further and disaggregate the data by sex, age, and village.

Seasonality of wasting and severe wasting

The regression analysis (Table 24 in Annex A) of the wasting and severe wasting data over time identifies two peaks: in May and October, with the lowest level of wasting occurring at the end of January. The first peak in May corresponds to the end of the dry season and start of the rains (*rushash*), while the second peak corresponds to the end of the rains and prior to the start of the main harvest (*darat*). The January nadir or trough occurs during the cool dry season (*shita*).

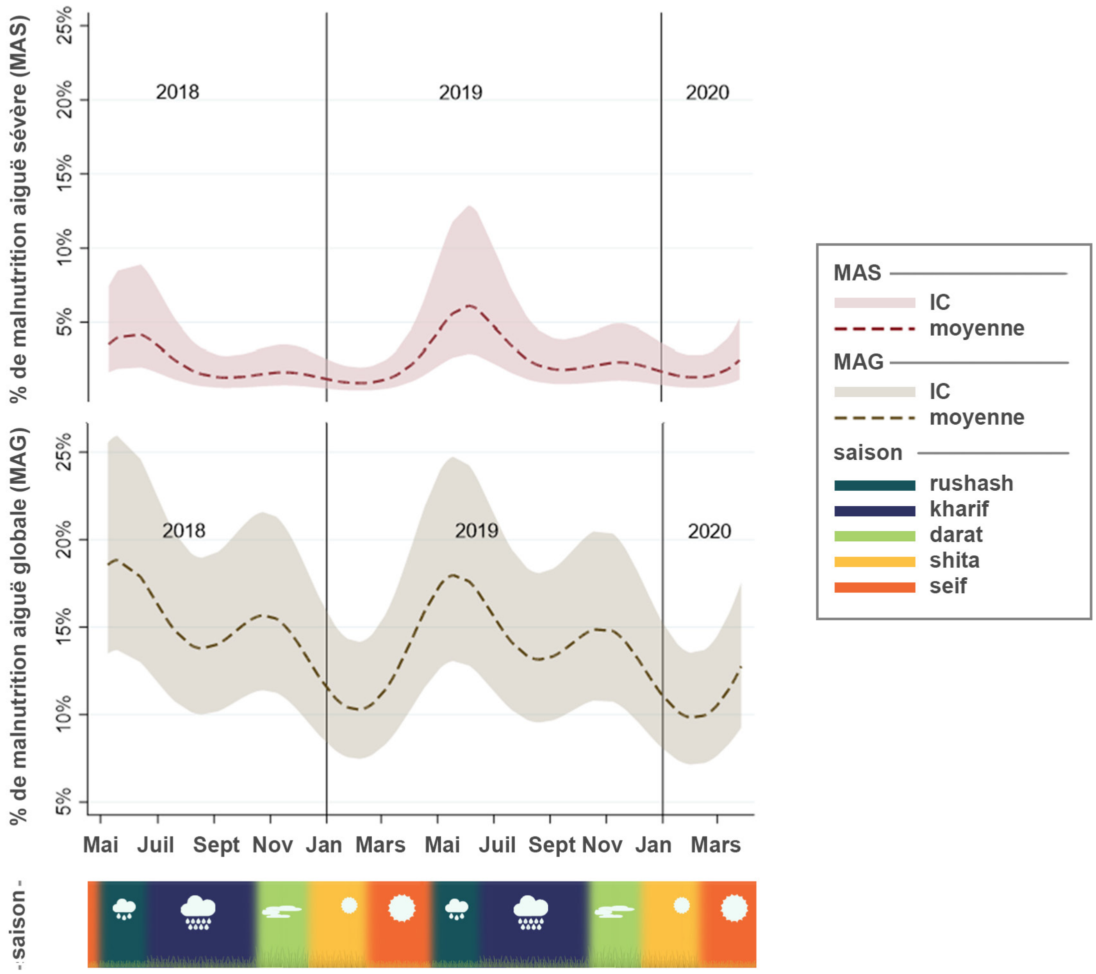
This trend is clearly visible in Figure 19, using the predicted values from the model (for the raw data see Figure 32 in Annex A). It is particularly important to point out the improvement in child nutritional status that occurs between the two peaks for both wasting and severe wasting; this indicates the likely role of different drivers at different of times (May vs October), and the likely absence or mediation of those drivers in January. It is also reassuring to see that the identified "twin peaks" trend corresponds with what is observed in the national trends of the SMART data for Chad (Figure 2 in the Introduction).

Having almost two years of data allows us to also say something about the variability in seasonality across years. To do so, we reran the same models but separately for the first 12 months (May 2018 to April 2019) and the last 11 months (May 2019 to March 2020) (Table 25 in Annex A). For the former, the reduction in wasting over time was so strong that we had to remove the time trend in order to truly observe seasonality. Both years show extremely similar (and significant) seasonal trends. The two peaks in the first year are identified as occurring on May 31 and October 21, with the lowest level of wasting on February 6. During the second year, the two peaks occurred on May 29 and October 9, with the lowest level of wasting on January 31. While we saw a significant reduction in wasting across the two years (a significant and negative time trend in the two-year model), wasting again increased in 2020, with possibly comparable levels to what we observed in 2018 (Figure 20). We also observed a distinction between the two years in the magnitude of the peaks and in the difference in magnitude between May and October. The larger peak was in May 2018, when the wasting prevalence was 21 percent (CI: 14–29 percent); in October 2018 the peak was smaller at 17 percent (CI: 10–24 percent). In 2019, on the other hand, May prevalence was 12 percent (CI: 5–18 percent) and October prevalence is 15 percent (CI: 8–21 percent). Thus, the size and primacy of the two peaks vary by year. It should be recalled that according to the IPC, there was no distinction in food insecurity in Sila Province between the two years, which points to the role of other drivers in the difference between the two years of data collection.

Wasting by sex

A review of wasting by sex reveals different seasonal patterns for boys and girls (see Figure 21 for predicted trends and Figure 33 in Annex A for the raw trends). Wasting has far greater seasonal oscillation for boys and tends to be (relatively) more consistent across the year for girls. The variation in seasonality by sex is even more apparent when separate regression models are run for boys and girls (Table 26 in Annex A). While seasonality is observed across both sexes, for girls, only one peak is significant (a July peak and a January nadir), while boys have two significant peaks in wasting: May 18 and October 26, with the lowest wasting on February 2.

Figure 19: Predicted severe wasting (top) and wasting (below) over time (May 2018-March 2020)



Besides seasonality, we also observed other important differences between the two sexes. When we compared wasting prevalence for the children available for measurement in our sample, there was no significant difference between girls and boys. However, we observed huge differences in the availability of boys and girls in our sample to start with. Across all age groups, girls make up a larger proportion of the total sample (Table 12). We collected information on whether a child was available for anthropometry, and if not, whether this was because the child was absent or sick. It turned out that boys were not more likely to be absent or sick, thus the sex distribution in our data seems to indicate that some boys were omitted from listed household occupants. One possible explanation for this omission is suggested by the qualitative finding that boys are more likely than girls to be watched by a caregiver other than the mother (such as an older brother, grandparent, etc.) and were therefore not always identified as part of the original household roster. As the enumerators followed mothers to the field in order to conduct the interview and measure the children that were with her, it is possible that our sample was thus inadvertently biased away from boys.

Figure 20: Predicted wasting by year: May 2018 to April 2019 (left) and May 2019 to March 2020 (right)

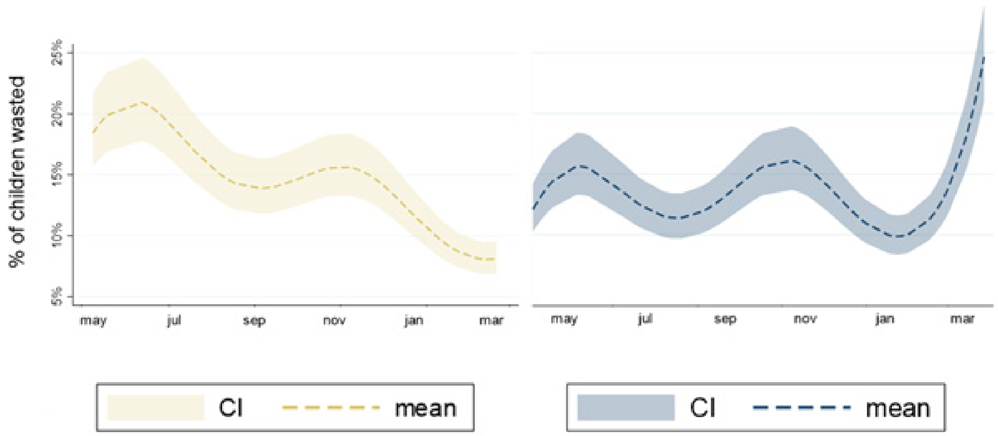


Figure 21: Predicted wasting prevalence by sex and season

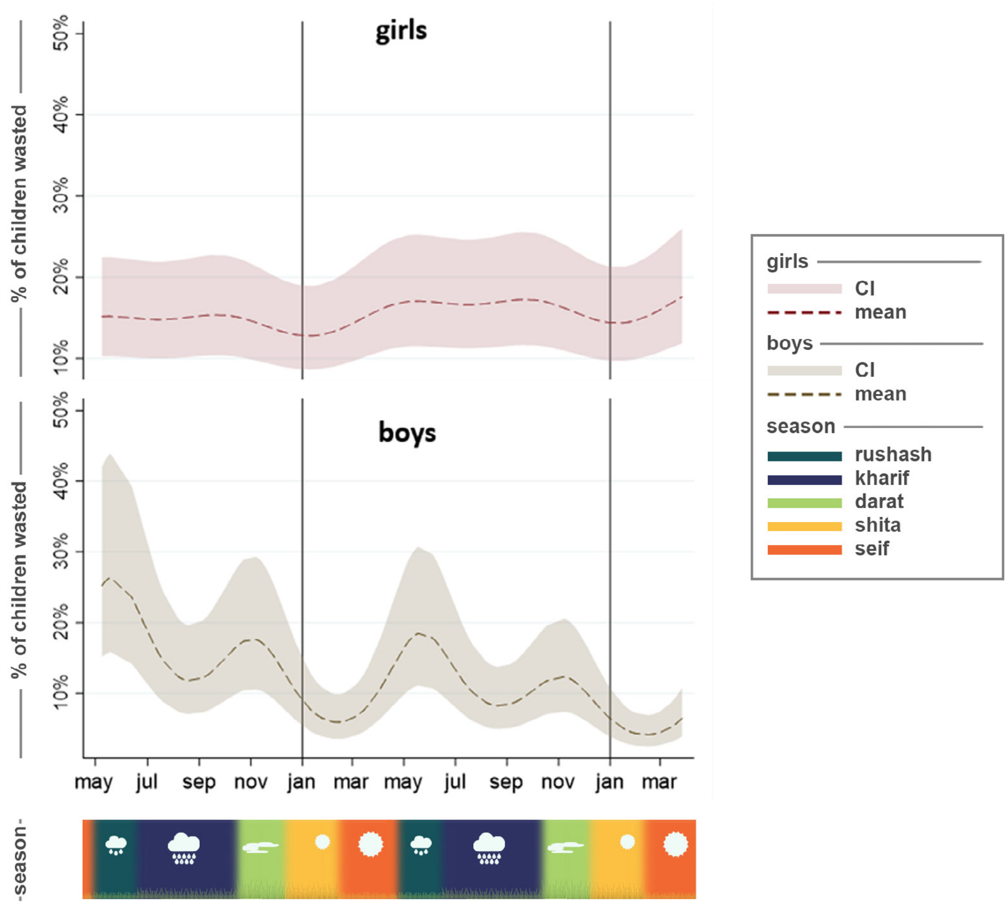


Table 12: Sex distribution of total sample by age group

	Boys (%)	Girls (%)
6-11 months	42.29	57.71
12-23 months	45.42	54.58
24-35 months	46.23	53.77
36-47 months	40.96	59.04
48-59 months	36.64	63.36
6-59 months	**41.89**	**58.11**

Table 13: Prevalence of wasting by age group

Age group	Mean	95% CI
6-11 months	15%	10-19%
12-23 months	16%	13-20%
24-35 months	10%	8-13%
36-47 months	12%	9-14%
48-59 months	11%	8-13%

Wasting by age group
Age (in months) is strongly associated with the probability that a child is wasted, with younger children significantly more likely to be wasted (the same is true for MUAC and WHZ: younger children score significantly lower). On average, each additional month of age reduces the probability that a child is wasted by 2.5 percent. The distinction is particularly apparent for children under the age of two years (Table 13). Children aged between 24 and 59 months have a 70 percent less chance of being wasted compared to younger children.

Children under the age of twenty-four months tend be significantly more likely to be wasted (Alderman and Headey 2018). WHZ tends to decline from birth and reach its lowest point at around 12 months and slowly increase thereafter; this is consistent with an improved immune system among older children that diminishes the impact of infection on the child's weight (Victora, de Onis et al. 2010; Richard, Black et al. 2012). However, in severe food insecurity or famine conditions, the proportional increase in wasting and mortality tends to be greater among older children. This might be because older children no longer have the added protection of breastfeeding or are not supported in the same way with supplementary feeding during relief programs (Young and Jaspers 1995).

We also observed a difference in the magnitude of the seasonal patterns between infants aged 6-23 months and children over the age of two years. (It should be noted, however, that the sample size difference—664 observations of children aged 6-23 months versus 1,910 for children aged 24-59 months—makes a direct comparison difficult). A seasonal pattern with two *different* sized peaks is clear (Figure 22 and Table 27 in Annex A) for children aged 24-59 months, while the peaks for children 6-23 months are equal in size. Another distinction between the two age groups regarding seasonality is the timing of the peaks. For children aged 6-23 months, both peaks occur about a month later (June 6 and November 16) than those for children 24 months or older (May 7 and October 4).

Based on the predicted values, we hypothesize that for infants drivers in both July and November have an equal impact on the probability of being wasted, while for older children the pre-rainy season peak (May 7) is greater than the pre-harvest peak (October 4). In addition, improvement over time (in terms of the magnitude of the peaks) is observed for children under 24 months, while seasonality across years seems to be consistent for children over 23 months. This could help us further identify the drivers of acute wasting for children under 24 months as it would have to be a driver that changed drastically between 2018 and 2019.

Wasting by village
Finally, we present child wasting data by community, looking at the overall average for the year and specifically in May and October, the two main peaks of wasting identified in the regression analysis (Table 14). Maramara consistently had the lowest prevalence of child wasting, while Taiba Badria had one of the highest levels of child wasting. We discussed in the section on water contamination some of the possible reasons why Maramara might have some of the lowest contamination in our

Figure 22: Predicted wasting over time by age group: 6–23 months (left) and 24–59 months (right)

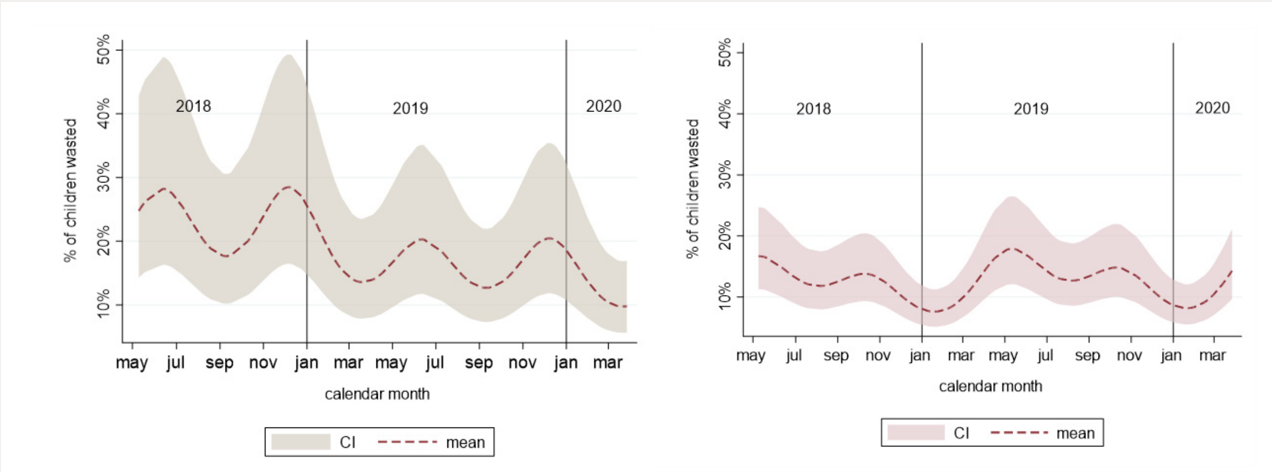


Photo 15: Water trough in Maramara (left) and in Taiba (right) in May 2019

sampled communities; this is most likely due to its distance from a seasonal river and hence its limited number of large ruminants. Taiba Badria, on the other hand, was perceived as one of the wealthiest communities with houses constructed out of brick with metal roofs, women wearing lots of jewelry, and households reporting multiple sources of income, including trade of gasoline and oil from Sudan, as well as trade between different marketplaces. An important aspect of Taiba's wealth captured in the qualitative data was the presence of large ruminants. Of all eight communities, Taiba has the largest herd of camel and one of the largest herds of cattle (Table 5). Compared to Maramara (Photo 15), the presence of large livestock was heavily felt during the May 2019 research. It is therefore important to look beyond wealth when assessing malnutrition risk in this region.

Given the small sample size (an average of 15 children observed per community, and just a maximum of four children in Al Kherim), we do not have enough data to say anything definitively on seasonal patterns in wasting on the village level in Al Kherim (Figure 23). However, what we do see is that the stability of malnutrition outcomes (as captured by the "variance" column in Table 14) is strongly related to the malnutrition outcome itself. Communities such as Maramara not only have some of the lowest levels of wasting, but they were also the most stable across the months of data collection (from 0–12 percent wasting in Maramara across the 23 months), unlike Taiba which has the highest variance with wasting prevalence oscillating from 16–44 percent over the duration of the study period. The variability in nutrition outcomes could be related to the variability in the presence of livestock. There is no seasonal livestock mobility in Maramara, but there is very considerable seasonal livestock mobility in Taiba.

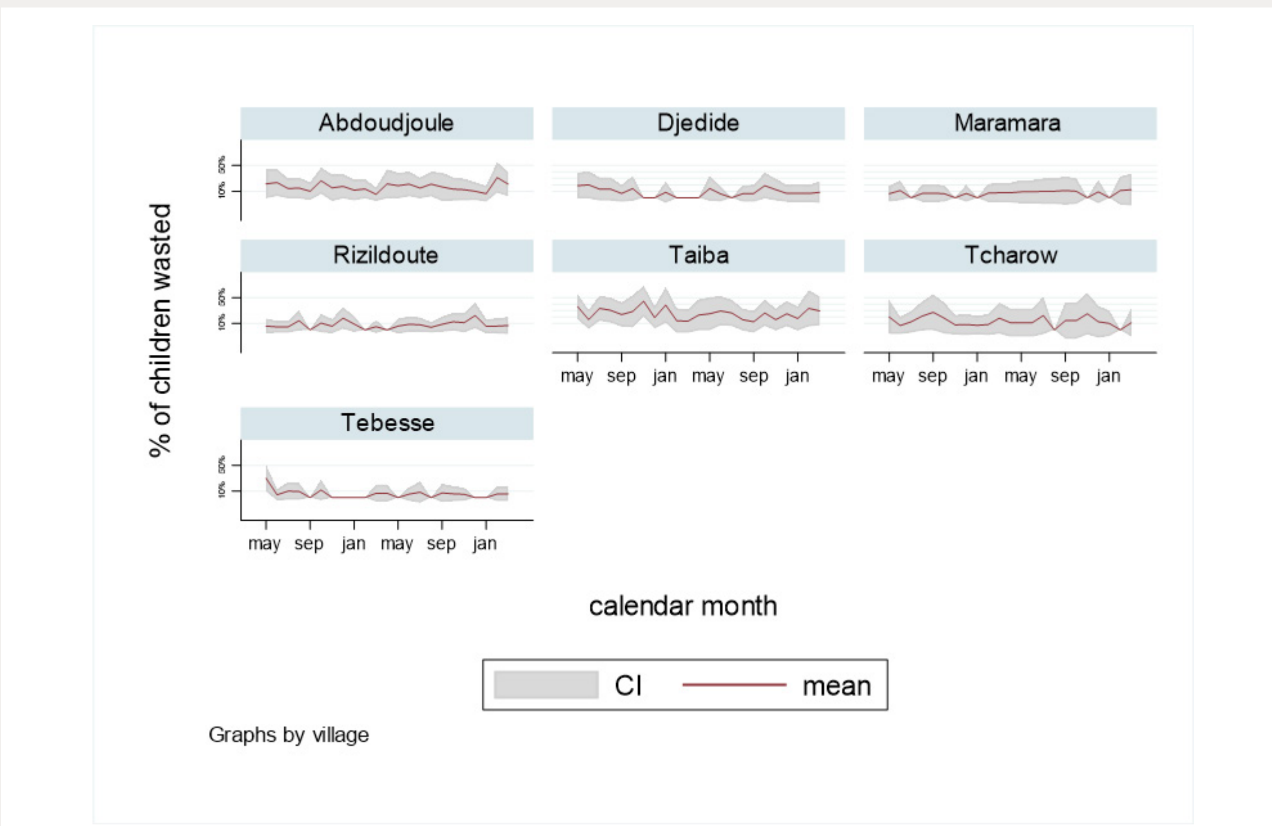
Weight-for-height z-scores

Before describing trends in WHZ, we will first briefly discuss the difference between the implications of mean WHZ, wasting (WHZ<-2), and severe wasting (WHZ<-3). The continuous z-score mean (WHZ) describes the nutritional status of an entire population, while the binary form (wasting or severe wasting) only tells you something about the very

Table 14: Child wasting by village, (whole year, May, and October)

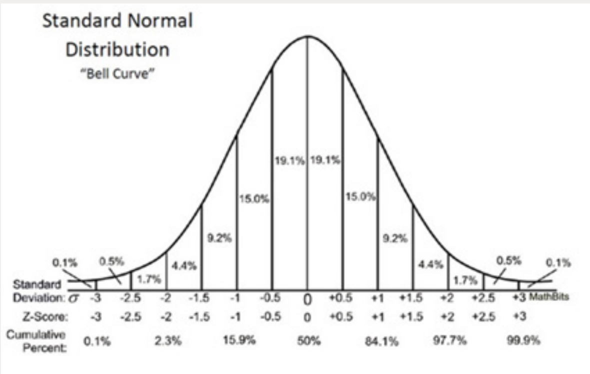
	Whole year (n=2,558observations)			May (n=213 observations)			October (n=224 observations)	
	Mean	Variance	95% CI	Mean	95% CI		mean	95% CI
Abdoudjoul	17%	14%	13-20	20%	5%	35%	21%	7-34
Al Kherim	22%	18%	10-34	20%	0%	59%	20%	0-59
Djedide	8%	*8%*	5-11	*17%*	*3%*	*30%*	*17%*	*3-30*
Maramara	7%	6%	4-10	7%	0%	18%	8%	0-19
Rizildout	8%	*7%*	5-10	*6%*	*0%*	*14%*	*12%*	*2-21*
Taiba	25%	*18%*	21-29	*33%*	*17%*	*49%*	*28%*	*12-44*
Tcharo	12%	*11%*	8-17	*16%*	*0%*	*33%*	*17%*	*0-35*
Tebesse	5%	*5%*	3-8	*15%*	*3%*	*28%*	*6%*	*0-14*

Figure 23: Raw wasting by village and time



* Al Kherim was excluded from the graph because on average only four enrolled children were present; some months only one was present.

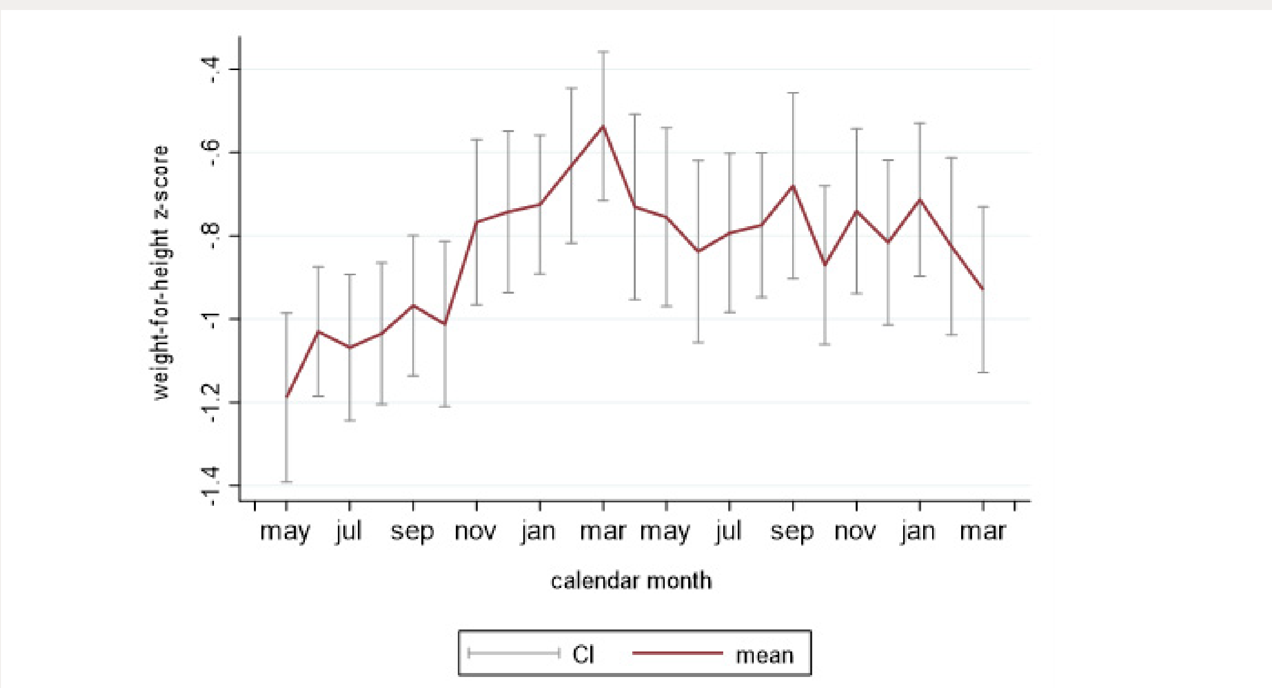
Figure 24: Standard bell curve for a normal distribution



left-hand part of the distribution based on a set cut-off (Figure 24). Thus, changes in the mean z-score imply that the entire distribution has shifted and suggests that most, if not all, individuals have been affected. The binary form of the variable, on the other hand, is more useful in assessing the severity of a situation by providing information only on the left-hand tail, or the most severe cases.

WHZ in our area of study shows a strong seasonal pattern, but unlike wasting, there is only one significant nadir (Table 28 in Annex A) on May 7 (corresponding to the first peak in wasting) and a peak (highest and hence best WHZ) on January 20. However, this nadir is likely being driven by the pattern in WHZ observed in the first year of data collection. A closer look at the WHZ data across the two years (Figure 25), shows an important distinction which mirrors what we observed with wasting. In Year 1, the May nadir is much lower than the October nadir. However, in Year 2, they are equally low, with a bit of oscillation in between. Importantly, while there is a significant difference in WHZ between May of 2018 and May of 2019 (p-value=0.005), there is no significant difference in WHZ between October of 2018 and October of 2019 (p-value=0.313), further indicating that the variability in nutrition outcomes between the two years is caused by the variability of the driver of the May peak, not the driver of the October peak. Again, it should be recalled that the IPC reported no distinction in food security in Sila between the two years either, corresponding to the theory that the

Figure 25: WHZ over time



October peak is related to food intake, while the May peak is not.

As with wasting, there is no significant difference in the WHZ between girls and boys, and children under the age of 24 months have a significantly lower WHZ.

MUAC

MUAC exhibits significant seasonality with two nadirs (Table 29 in Annex A) on June 22 and November 21, with the highest peak on March 10 (Figure 26). The time periods identified as the worst and best for MUAC correspond most closely to the patterns of wasting for children 6–24 months.

Underweight and WAZ

Seasonal trends in underweight and WAZ are partially apparent, but they not as large as those we found with wasting and WHZ (Table 30 in Annex A). "Underweight" is defined as having a weight-for-age z-score (WAZ) below -2 standard deviations and can be due to either wasting or stunting, or both, and thus is interpreted as a composite indicator. Thus, a portion of the seasonality captured in WAZ and underweight is likely to be a reflection of the seasonality in WHZ and wasting respectively. According to the regression output, unlike wasting, there is only one peak in both underweight and WAZ. The proportion of children underweight peaks on July 7 and reaches its lowest point on February 19. WAZ follows almost the exact same pattern: at its worst on July 15 and at its best on February 2.

The regression results also indicate a significant increase in the proportion of children underweight. A review of the raw underweight prevalence by month indicates a troubling trend (Figure 27): while we see an improvement in underweight between July 2018 and February 2019, that improvement is not observed over the same time period in 2019/2020. Instead, the prevalence of underweight reaches its peak in July 2019, improves slightly in August 2019, and then stays at that level through March 2020 with only a small dip in January. While not displayed here, WAZ behaves exactly the same as underweight prevalence. Thus, the recovery that we would expect to see associated with the normal 2019 harvest is not apparent in the underweight data.

Figure 26: Raw MUAC data by month: mean and confidence intervals

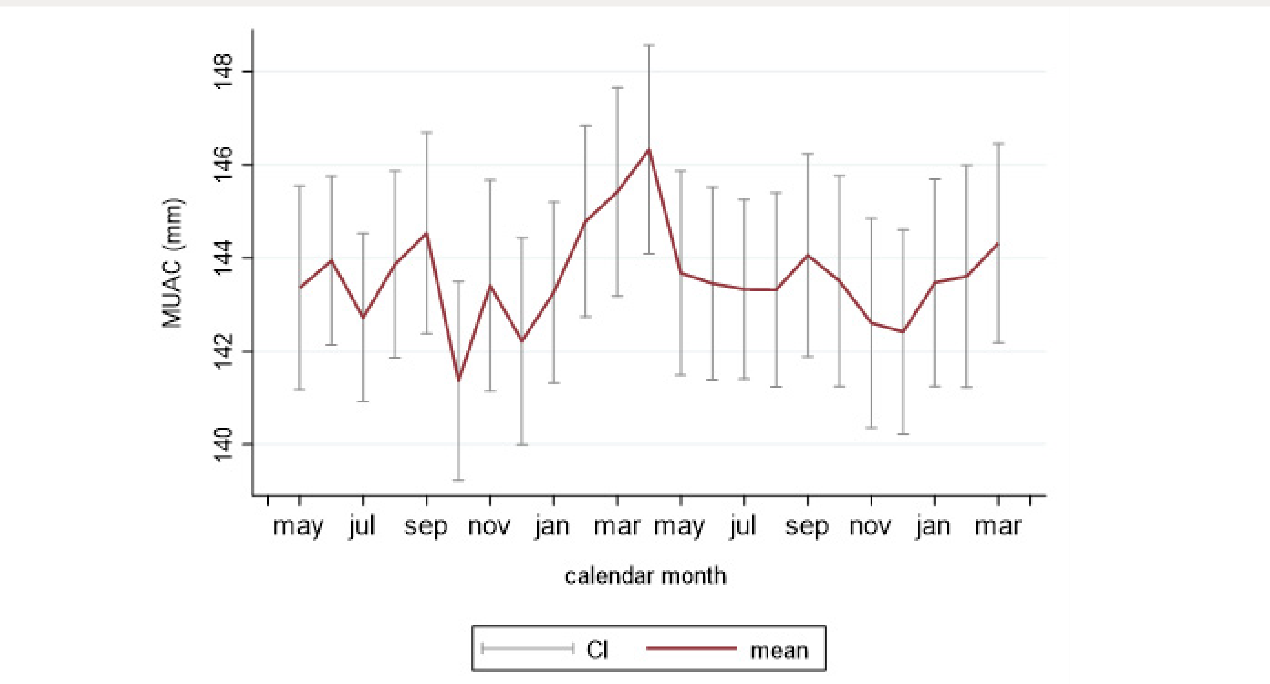
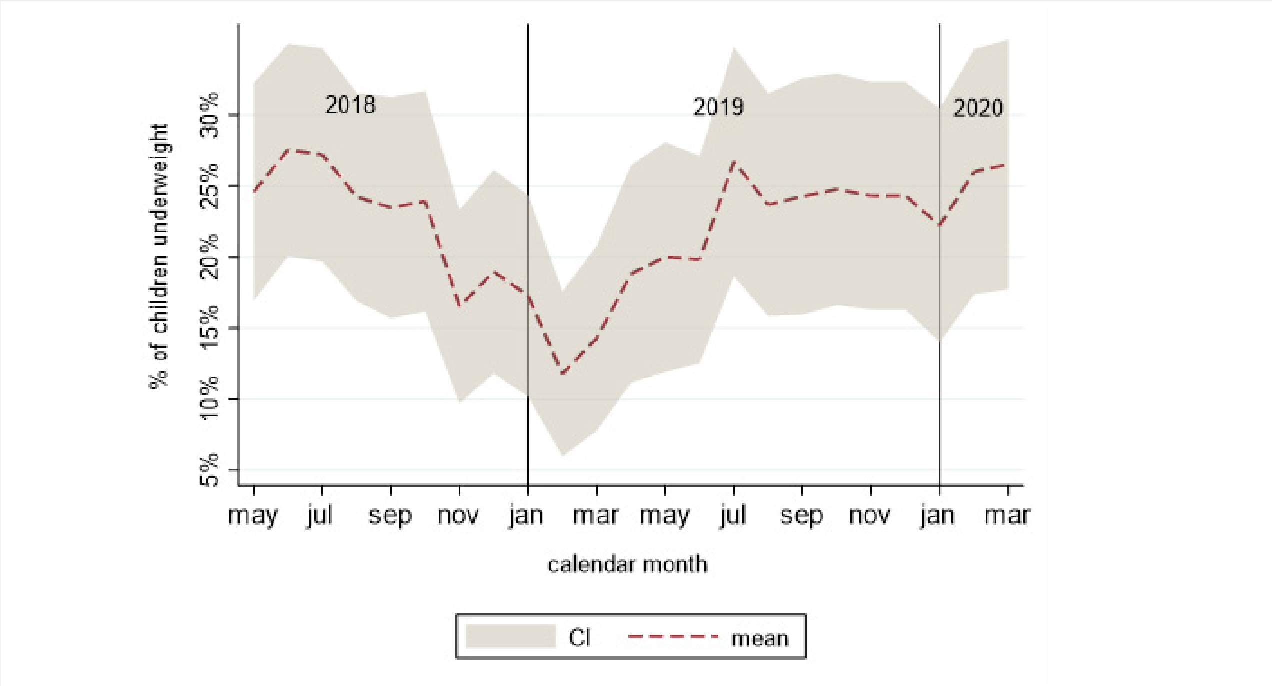


Figure 27: Raw underweight prevalence by time



Stunting and HAZ

We see some evidence of seasonality in HAZ and stunting (Table 31 in Annex A and Figure 28). What is particularly critical is the significant increase in stunting and significant decrease in HAZ in the data across the two years. Thus, it seems that something in the second half of 2019 is impacting both height and weight gain.

HAZ is at its highest on October 20 and April 11, and lowest on July 20 and December 30. In some ways, HAZ and WAZ both indicate that height and weight attainment during the normal harvest of 2019 did not match height and weight attainment in 2018. One possible explanation is the fact that our sample did significantly (p-value<0.001) age over time from an average age of 33 months in May of 2018 to an average of 36 months in 2019, and older children tend to have a higher likelihood of being stunted (Victora, de Onis et al. 2010). However, it is unlikely that the slight (albeit significant) increase in the average age of our sample would explain *all* the apparent increase in stunting over time.

Child morbidity

We also explored whether a child had been sick in the two weeks before our data collection, and if so, what the child was sick with. Morbidity is expected to be highly seasonal, with some (but not all) research indicating that malaria and diarrhea peak during the rainy season and that respiratory illness peaks during the dry season (Tomkins 1993). Our data correlates with the literature and results from the 2019 SMART survey data for Sila (27 percent diarrhea, 42 percent fever, 29 percent respiratory illness) and allows us to look at the peaks of individual illnesses with greater detail and nuance than what a binary rainy/dry season perspective would elicit.

We started by looking at the seasonality of illness more generally in response to the question "has your child been ill in the past 2 weeks?" On average, in any given month half of the children (51 percent, with a minimum of 40 percent and a maximum of 60 percent) were reported as having been ill. Despite the small range, seasonality is very evident in the pattern of illness (Figure 29 and Table 32 in Annex

Figure 28: Raw HAZ over time

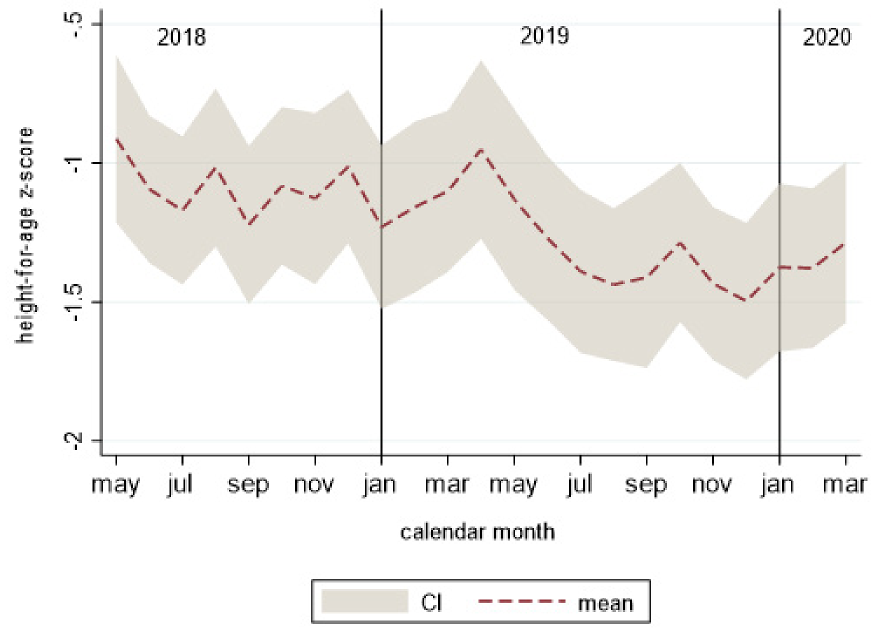


Figure 29: Child ill over past two weeks by month (raw data)

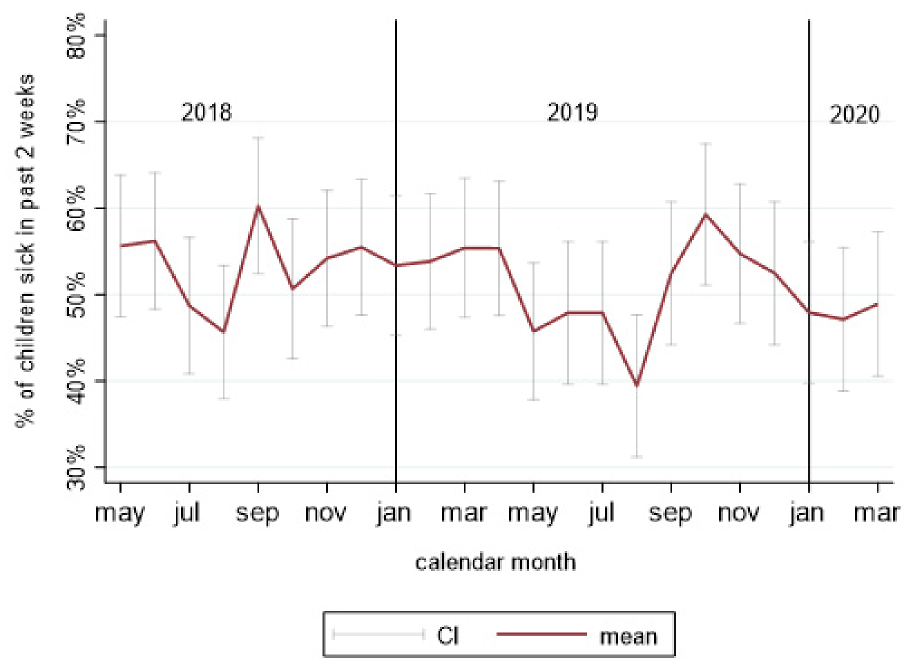
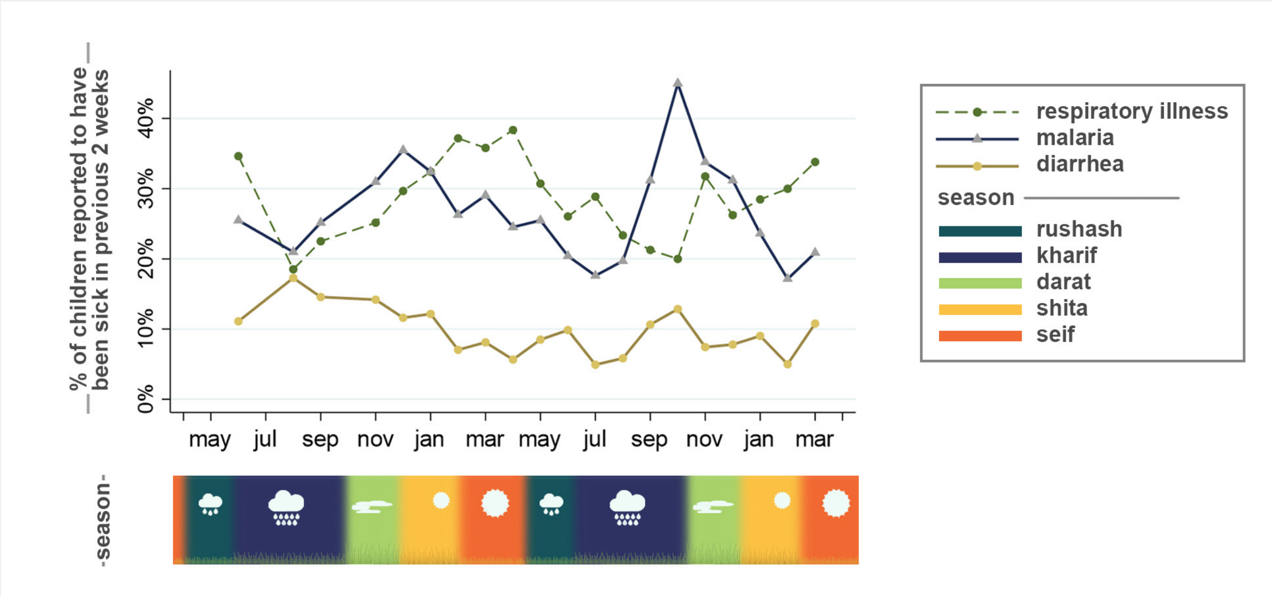


Figure 30: Raw morbidity data over time



A) with two even sized peaks in early November (3) and late March (28), and the periods of lowest illness being mid-July (13) and end of January (29) (Figure 26).

Next, we broke down the data on illness by three specific morbidities: respiratory illness, malaria,[142] and diarrhea.[143] The most commonly reported morbidity was respiratory illness, reported in about 25 percent of all children across the two years, followed by malaria (23 percent), and diarrhea, either wet or bloody (8.5 percent). Each of the morbidities exhibit a seasonal (Figure 30), but very different, pattern (Table 33 in Annex A). Respiratory illness displays only one peak at the end of *seif* (beginning of April) and is at its lowest at the end of *kharif* (mid-September). Malaria has one peak at the beginning of *darat* (November).

Finally, we look the seasonality of diarrhea. Prevalence of diarrhea exhibits two peaks, with the main peak at the end of *kharif*/beginning of *darat* (October) and a smaller peak in *seif* (March). However, unlike respiratory illness, malaria, and fever, the pattern for diarrhea does not look consistent across the two years. So we ran a separate analysis on diarrhea for the first versus the second year of data collection, with the understanding that key months (May, July, and October) are missing from the Year 1 data. In the first year, the peak occurs in August (on the 10th) and the lowest prevalence in March (31st). In the second year, the peak occurs in October (13th) and the lowest prevalence in July (13th). The regression analysis indicates that diarrhea and respiratory illness are the morbidities most consistently correlated (albeit in different directions) with wasting even when controlling for other morbidities and the observed seasonality (Table 34 in Annex A).[144] A child with diarrhea is twice as likely to be wasted as a child without diarrhea, while a child with respiratory illness is a third less likely to be wasted than a child without respiratory illness. The latter finding is a bit difficult to interpret. Surprisingly, we did not find a relationship between diarrhea prevalence and coliform contamination at water sources or in water transport and storage containers.

142 Caveat: in the qualitative data, malaria was described by some households as "fever during rainy season", so we combined fever and malaria into one variable in the quantitative analysis as malaria.
143 Data on specific morbidities is missing for May, July, and October 2018. Data at this point in time was collected using paper surveys and unfortunately the information on specific morbidities was absent during this month and could not be recovered.
144 We also checked for the inclusion of lag terms in this regression and did not find any significance.

What is associated with child malnutrition?

In this section, we bring the data together to try to understand what is associated with acute child malnutrition. Specifically, to test hypothesized associations around water contamination from livestock as a driver of child nutritional status we focused on: coliform contamination across the water chain; sharing water resources with animals; livestock ownership (from the CRAM/BRACED endline); food insecurity (from the CRAM/BRACED endline); and morbidity.

First, as an additional review on seasonality we looked at the relationship between our monthly nutrition outcome indicators and three climatic variables: rainfall, temperature, and vegetation cover (expressed as normalized difference vegetation index, or NDVI) (Table 35 in Annex A). Overall, we found a significant relationship between wasting, severe wasting, WHZ, and WAZ in relation to the climatic variables. There was no relationship with other nutrition outcomes (underweight, HAZ, and stunting), a finding that corresponds to the lower level of seasonality observed in those variables in our above analysis.[145] Temperature is consistently associated with more wasting and severe wasting and with lower WHZ and WAZ. Rainfall has no relationship with wasting, severe wasting, WHZ, or WAZ. NDVI is a bit inconsistent, with greater vegetation associated with both a worse WAZ score but a lower probability of a child being severely wasted. This finding does not imply a direct causal pathway—but rather confirms that children are more vulnerable to wasting in the hot dry season—and is potentially related to the pathway for increased contamination as temperature increases and water quantity decreases.

Second, we looked at the relationship between our nutrition outcome indicators and coliform contamination (Table 36 in Annex A). Of all the nutrition outcomes, only wasting was correlated with coliform contamination at the water source and there was no relationship with coliform contamination in the transport or storage containers. The lack of a relationship with contamination at the transport and storage container means there is no difference in nutrition outcomes between children in households with cleaner storage or transport containers and those with dirtier containers. By the time we progress along the water chain to the storage and transport containers, most households are already using contaminated water, and hence the distinction is not apparent. In addition, we did see a distinction in the relationship with coliform contamination in households that reported using the same type of water source for both animal and human consumption: in these households the relationship between wasting and coliform contamination is stronger (lower p-value and higher coefficient): each additional coliform colony is associated with a four percent increase in the odds of a child being wasted. Conversely, there is no relationship between water contamination at the source and wasting in households that did not report using the same water source for humans and animals. For households who use the same water source for animal and human consumption, each additional coliform colony is associated with a four percent increase in the odds of a child being wasted.

Third, we combined the above analysis with additional variables (from CRAM/BRACED 2017) that might help elucidate the potential drivers of child malnutrition in the Goz Beida region of Chad: food security from BRACED 2017 (MAHFP broken up to create a monthly binary variable: food secure vs food insecure); livestock wealth from BRACED 2017 (measured using TLU/capita); whether the child had diarrhea; and community-level cattle ownership (from BRACED 2017). In this analysis, we unfortunately had to switch to looking at WHZ as opposed to wasting because of the complexity of a mixed effects logit model with harmonic terms on binary outcomes versus continuous outcomes. Our statistical software simply could not compute it. When running our complex mixed effects model controlling for individual child trajectories and village clustering, we only saw significant relationships of WHZ with coliform contamination when limiting

145 We were unable to run this regression on underweight, so cannot speak to its significance.

our sample to boys and specifically looking at WHZ (Table 15): greater contamination is associated with lower WHZ. We hypothesize that this is related to different weaning practices for boys and girls (as discussed above) and hence boys might have more opportunities to consume contaminated water, and that, by extension, contaminated water is more closely related to their nutrition outcomes. All other key variables, except livestock wealth (TLU/capita) are significant across the complete sample and the only-boys sub-sample. In the complete sample, having diarrhea is correlated with 0.13 lower WHZ, each additional cow in the community is correlated to 0.005 lower WHZ), and being food insecure that month is associated with 0.15 lower WHZ. For the only-boys subsample, diarrhea is associated with 0.20 lower WHZ, each additional coliform colony is associated with 0.01 lower WHZ, each additional cow is associated with 0.01 lower WHZ, and being food insecure is almost irrelevant for the subsample, associated with 0.001 lower WHZ.

Fourth, for the rest of this section, we relaxed our conditions for identifying significant relationships with our key nutrition outcomes by simplifying our models to OLS and logit regressions, thus allowing us to look at relationships with wasting as well. The difference between our mixed effects models (used throughout the report above) and OLS or logit model (used below) is that the former allowed us to look at these relationships for our individual child trajectories, while the OLS model looks at overall averages. When we ran our mixed effects model we included the equivalent of a variable for each child (about 160 extra variables) and a variable for each village (another 8 variables), which is what allows us to talk about the relationship of the individual trajectories of each child, and controlling for village clustering. Thus, the OLS and logit outputs hint at the relationships that might exist with a larger sample size, but these relationships are not as robust as our findings above on overall seasonality, or specifically for boys, or households reporting the same type of water source for animal and human consumption.

If we run a simple OLS or logit regression, the relationship between coliform (at the source) and wasting extends to severe wasting, WHZ, and WAZ (Table 16) with greater contamination correlated to worse nutrition outcomes. As with the analysis on wasting above, for all three variables, limiting the sample to households who reported using the same type of water source for animal and human water consumption only strengthens the relationship despite the fall in sample size.

Next, we then reran the simple model on the complete list of possible drivers (available in our dataset) (Table 17). When it comes to wasting, having diarrhea is associated with twice the risk of being wasted; each additional coliform colony

Table 15: Full mixed effects regression on WHZ

	Full sample			Boys sub-sample		
	coef.	p-value	95% CI	coef.	p-value	95% CI
Age (months)	0.006	0.003	0.002-0.011	0.009	0.009	0.002-0.015
Girl	-0.051	0.673	-0.286-0.184			
Diarrhea	-0.130	*0.018*	-0.237--0.022	*-0.204*	*0.010*	*-0.360--0.049*
Coliform (source)	-0.003	0.377	-0.010-0.004	-0.011	0.044	-0.021-0.000
Village cattle proxy	-0.005	*0.057*	-0.009-0.000	*-0.008*	*0.040*	*-0.015-0.000*
TLU/capital	-0.065	*0.677*	-0.369-0.240	*0.307*	*0.319*	*-0.297-0.911*
Food insecure	-0.158	*0.000*	-0.221--0.095	*-0.194*	*0.000*	*-0.287--0.101*
Constant	-0.844	*0.000*	-1.114--0.574	*-0.923*	*0.000*	*-1.266--0.580*

is associated with a three percent rise in the odds of a child being wasted; and each additional cow is associated with a one percent increase in the odds of a child being wasted. With regard to WHZ, girls' scores are lower by 0.08 standard deviations compared to boys; the scores of children with diarrhea are 0.39 standard deviations lower than those without diarrhea; each additional coliform colony and each additional cow is correlated with scores 0.01 standard deviations lower; each unit of TLU/capital is associated with a score 0.15 standard deviations lower, and coming from a food insecure household is associated with a score lower by 0.12 standard deviations.

The relationship between coliform contamination and water source means that the inclusion of both variables reduces the observed seasonality of one or the other (issue of multicollinearity). Thus, we ran the same regression, but replaced the contamination variable with the water source in order to be able to comment on both relationships (Table 18). We observed the same relationships that we saw in the above regression and gained more insight into the relationship between wasting and WHZ with water sources. For both wasting and WHZ, getting water from a *machiche*, *hit*, or open source (wadi/pond/stream) is associated with a 40, 50, and 100 percent higher probability that a child will be wasted, respectively. In relation to WHZ, getting water from a *machiche*, *hit*, or open source was associated with WHZ being lower by 0.14, 0.31, and 1.43 standard deviations respectively. It is worth noting that a garden well—a water source specifically and consistently associated with protection against livestock—is not significantly worse than a borehole, with respect to nutrition outcomes.

Finally, the role of food insecurity is especially fascinating (see Figure 31 for seasonal patterns in food insecurity matched on the households from the BRACED 2017 data). We found that food insecurity matters for WHZ, but not for wasting. This likely indicates that food insecurity shifts the whole population distribution, with children, on average, having a lower WHZ score when food insecurity is high, but when it comes to what tips children, particularly boys, over the edge to being malnourished it is the role of water contamination, likely by cattle, and particularly when specific water

Table 16: OLS and logit regression on nutrition outcomes

		Full sample				If same type of water source used for animal consumption			
		coef.	p-value	95% CI		coef.	p-value	95% CI	
Severe wasting (Logit)	*Coliform at source*	0.04	0.0	-0.01	0.09	0.06	0.02	0.01	0.12
	Girls	0.19	0.52	-0.40	0.78	0.27	0.48	-0.48	1.02
	Age (months)	-0.04	*0.00*	-0.06	*-0.02*	*-0.03*	*0.01*	*-0.06*	*-0.01*
	Constant	-2.87	0.00	-3.58	-2.15	-3.13	0.00	-4.06	-2.21
WHZ (OLS)	*Coliform at source*	-0.02	*0.00*	-0.03	*-0.01*	*-0.03*	*0.00*	*-0.04*	*-0.02*
	Girls	-0.10	*0.02*	-0.19	*-0.01*	*-0.08*	*0.19*	*-0.19*	*0.04*
	Age (months)	0.00	*0.42*	0.00	*0.00*	*0.00*	*0.97*	*0.00*	*0.00*
	Constant	-0.77	*0.00*	-0.89	*-0.65*	*-0.69*	*0.00*	*-0.85*	*-0.53*
WAZ (OLS)	*Coliform at source*	-0.01	*0.09*	-0.02	*0.00*	*-0.01*	*0.02*	*-0.02*	*0.00*
	Girls	-0.04	*0.35*	-0.14	*0.05*	*-0.05*	*0.43*	*-0.16*	*0.07*
	Age (months)	0.00	*0.11*	0.00	*0.01*	*0.00*	*0.02*	*0.00*	*0.01*
	Constant	-1.30	*0.00*	-1.43	*-1.18*	*-1.34*	*0.00*	*-1.50*	*-1.18*

Table 17: Logit regression on wasting and OLS regression on WHZ

	Wasting (logit)				WHZ (OLS)			
	coef.	p-value	95% CI		coef.	p-value	95% CI	
Age (months)	-0.010	0.024	-0.019	-0.001	0.000	0.792	-0.003	0.003
Girl	0.227	0.102	-0.045	0.498	-0.083	0.058	-0.170	0.003
Diarrhea	0.769	*0.000*	0.379	*1.159*	*-0.392*	*0.000*	*-0.545*	*-0.238*
Coliform at source	0.030	0.018	0.005	0.055	-0.013	0.006	-0.023	-0.004
Village cattle proxy	0.009	*0.000*	0.004	*0.014*	*-0.006*	*0.000*	*-0.008*	*-0.004*
TLU/capital	-0.325	*0.198*	-0.819	*0.169*	*-0.169*	*0.017*	*-0.308*	*-0.031*
Food insecure	0.057	*0.684*	-0.216	*0.329*	*-0.120*	*0.008*	*-0.210*	*-0.031*
Constant	-2.097	*0.000*	-2.502	*-1.692*	*-0.526*	*0.000*	*-0.658*	*-0.394*

Table 18: Logit regression on wasting and OLS on WHZ (n=2553)

	Wasting				WHZ			
	coef.	p-value	95% CI		coef.	p-value	95% CI	
Age (months)	-0.01	0.17	-0.01	0.00	0.00	0.55	0.00	0.00
Girl	0.23	0.08	-0.02	0.48	-0.09	0.02	-0.17	-0.01
Diarrhea	0.67	*0.00*	0.30	*1.04*	*-0.38*	*0.00*	*-0.52*	*-0.24*
Water source (reference = borehole)								
Machiche	0.33	*0.06*	-0.01	*0.68*	*-0.14*	*0.02*	*-0.25*	*-0.03*
Man-made reservoir	-0.36	*0.23*	-0.94	*0.23*	*0.13*	*0.09*	*-0.02*	*0.28*
Open well	2.19	*0.12*	-0.59	*4.98*	*-1.43*	*0.05*	*-2.82*	*-0.03*
Open source	0.75	*0.00*	0.33	*1.17*	*-0.31*	*0.00*	*-0.47*	*-0.15*
Saraf	0.00				-0.34	0.64	-1.73	1.06
Garden well	-0.71	0.34	-2.15	0.73	-0.06	0.69	-0.37	0.24
Hit	0.40	*0.02*	0.06	*0.73*	*-0.15*	*0.01*	*-0.26*	*-0.04*
Village cattle proxy	0.01	0.03	0.00	0.01	-0.00	0.00	-0.01	0.00
TLU/capital	-0.29	*0.20*	-0.74	*0.16*	*-0.18*	*0.01*	*-0.32*	*-0.05*
Food insecure	0.04	*0.77*	-0.22	*0.30*	*-0.12*	*0.01*	*-0.20*	*-0.03*
Constant	-2.28	*0.00*	-2.67	*-1.88*	*-0.46*	*0.00*	*-0.59*	*-0.33*

sources are being used for both animal and human water consumption.

Bringing it all together

Given that for a large portion of our potential drivers of wasting we did not have quantitative data, in this section we summarize seasonal trends across a host of qualitative and quantitative variables in this study (Table 19). The *rushash* peak of wasting corresponds to the time of year when water access is the most limited; cadavers and fecal matter are washed in with the first rains; animals and humans are more likely to share the same source of water; and, the presence of large ruminants begins to increase, putting added pressure on water sources. This season is also identified as the one when animals are most likely to be sick. These challenges result in increased animal-related water contamination, particularly from cattle possibly introducing *Cryptosporidium parvum* into water sources, a pathogen which is linked with environmental enteropathy in children (Rogawski and Guerrant 2017). In addition, *rushash* is also associated with an increased workload for women in preparing the land and hence reduced time for child care and breastfeeding. Moreover, a lack of access to land near the communities leads many women to move to temporary settlements during *rushash* and *kharif*, leaving their children in the care of grandparents or older siblings and thereby more likely to consume water rather than breastmilk at exactly the time when the water source could be most contaminated by animals.

On the other hand, the wasting peak immediately prior to *darat* corresponds to the period of highest food insecurity and a greater burden of malaria and diarrhea. The second, smaller peak in *darat* amongst children in Goz Beida likely reflects the more traditional thinking of food intake and morbidity as the main drivers of child wasting.

Figure 31: Percentage of households that are food insecure by month (BRACED, 2017)

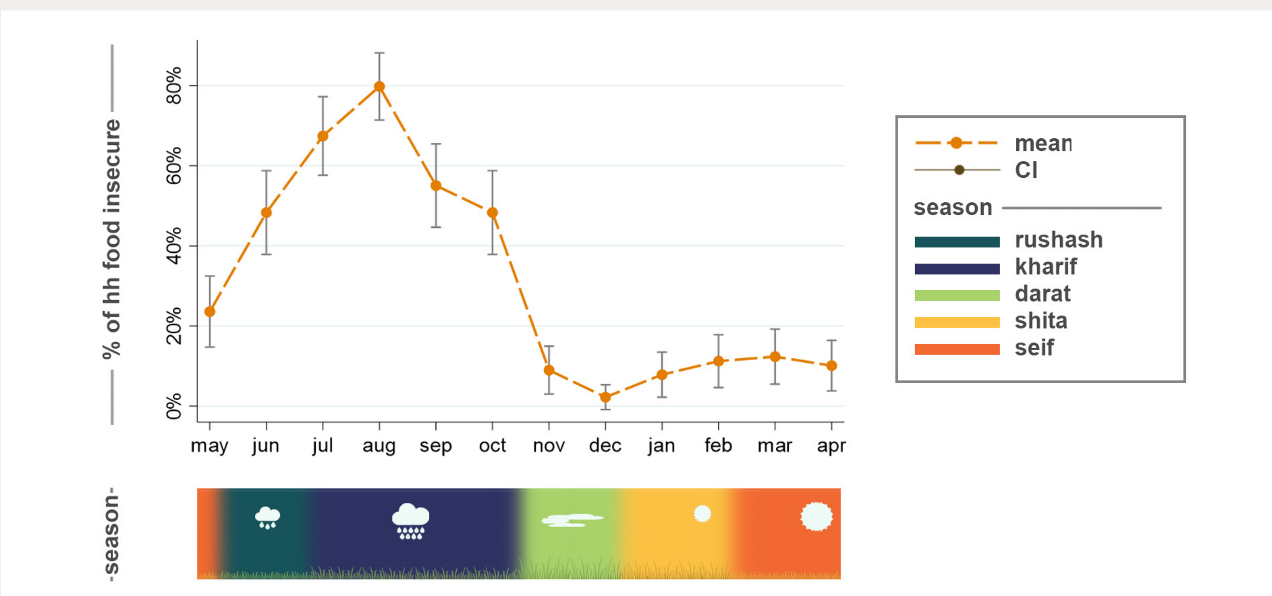


Table 19: Basic, immediate, and underlying drivers of wasting by season

			rushash	*kharif*	*darat*	*shita*	*seif*
Basic Drivers	Environment	Rainfall					
		Temperature					
		Vegetation					
	Livelihoods	Livestock close to communities					
		Farmer-herder conflict					
		Women's workload					
		Women in *damkoutch* or *diyar*					
Underlying drivers	Food insecurity	Food insecurity					
	Inadequate social and care environment	Less time with children					
		Poor hygiene behaviors					
	Insufficient health services and unhealth environment	Poor health seeking behavior					
		Poor water access					
		Sharing water with animals					
		Animal disease					
Immediate Drivers	Food intake	Poor milk access					
		Reduced breastfeeding					
	Morbidity	Malaria					
		Respiratory illness					
		Diarrhea					
Acute Malnutrition							

Note: darker colors indicate a driver is a greater problem during the season, compared to lighter colors. Blank cells indicate the driver was not identified by either qualitative or quantitative data.

Discussion, implications for programming, and future research

In this section we review the overall findings from the 23 months of data collection (May 2018 through March 2020) for the Malnutrition and Coliform Seasonality Study in eight communities in the Goz Beida area of the Sila Region of Chad. We then discuss how these findings might be applied to improve Concern Worldwide's programming on water contamination and child malnutrition.

Discussion

Seasonality

Variability of rainfall and temperature in Sila and across the Sahel drives the availability of natural resources such as water and pasture, which in turn drives households' livelihood strategies and decisions. Consequently, variability affects almost everything related to livelihoods: when households carry out rain-fed agriculture, when they grow cash crops, when they work on market gardens, when and where they migrate with their animals, what animals they own, access to water sources, the types of water sources available, proximity to water sources, and when men migrate for other livelihood opportunities.

The seasonality of livestock mobility and community livelihoods specializations partly drive when and where contact occurs between humans and animals (particularly at water sources). For example, while the number of cattle reported by Tebesse is one of the largest among our primarily pastoralist communities, we did not observe a single cow near the village in May 2019. This is most likely because the water and grazing resources close to the village are insufficient to support larger pastoralist herds at this time of year and so livestock are taken to areas with permanent water sources and sufficient dry pasture or fodder. On the other hand, Djedide, a predominately farming community that owns the fewest cows, the presence of cattle is far more apparent: during the dry *seif* season cattle generally remain near the village because it is located near the wadi with multiple *hits*. Testimonies from FGDs corroborate that certain communities have more contact with cattle than others, and that this varies according to their livelihood specializations and their access to water. Our research suggests that most contact with cattle takes place at the end of *seif* and in *rushash*—the start of the rainy season and after harvesting, when cows come near the villages before leaving for a *makhalaf* or for more long-distance migration—but this varies by village and livelihood specialization.

The quantitative data confirmed the seasonal patterns of sharing water sources between animals and humans. The type of water source used is directly related to the availability of water in the wadis and riverbeds and hence varies monthly. Unsurprisingly, the same seasonal variability is observed with households that reported getting water for their livestock. Thus, a clear seasonal pattern is observed when it comes to sharing water sources between humans and animals. Shared use of water sources is most apparent during *seif* when households use *hits* to collect water for both animals and humans. Water sources are least likely to be used for both animal and human consumption during the rainy season, when animals primarily get their water from wadis and ponds and households get water from shallow *machiches*.

Livelihood specialization, the seasonality of livelihoods, and water access also affect household hygiene and care practices. When access to water is reduced (such as during *seif*) bathing and household cleaning is reduced. Furthermore, when women are in a *damkoutch*, they only have access to wadi and *machiche* water for cleaning and personal hygiene. Care practices are also affected by the seasonality of women's workloads. During the rainy *kharif* season, women are fully occupied carrying out critical livelihood activities and providing food for the family and thus have the least amount of time to care for their children.

The interpretation of the coliform data is a bit more difficult because it does not allow a distinction to be drawn between human and animal related contamination, nor what pathogens are present in the water. We do see a significant relationship between mean village level coliform contamination on the one hand and type of water source, presence of cattle, and whether humans share water sources with animals on the other hand. However, these are just associations. We could be missing information on behaviors that are associated with both coliform contamination and greater water-source sharing, with perhaps some communities more likely to openly defecate.

Morbidity data also indicates a clear seasonal pattern corresponding to the literature: malaria and diarrhea peak at the end of the rainy season, while respiratory illness has a very visible peak during the dry season. Of all the morbidities, diarrhea was consistently associated with a significantly higher risk of wasting, again corresponding to the literature (Brown 2003).

We see a clear seasonal pattern in our quantitative data on child nutritional status. We see the highest prevalence of wasting, severe wasting, and WHZ at the end of *seif* and into *rushash*. We observed a clear improvement in June when heavy rains are established and wasting drops. Then wasting steadily rises to a secondary smaller peak in October. The lowest prevalence in wasting was in February followed by a gradual increase until the May peak.

However, the difference in scale between the May and October peaks is not consistent across the two years of data collection. While the same months are identified as associated with the worst levels of wasting, in the first year of data collection (May 2018 to April 2019), the May peak was significantly higher than the October peak. In the second year of data collection (May 2019 to March 2020), the May peak fell fairly dramatically and was equivalent in magnitude to the October peak. Importantly, the distinction between the two years in terms of child wasting is primarily observed in terms of the difference between May 2018 and May 2019. However, given the observed trend in wasting in January–March 2020, it appears as if the 2020 May peak might be again comparable to May 2018.

Another important distinction in relation to the seasonality of wasting is the difference between boys and girls and between age groups. When it comes to seasonal patterns, the high level of inter-year variability appears to be primarily (though not solely) driven by the significant changes over time in wasting for boys, with girls' wasting prevalence remaining much more stable across the two years (though not lower on average). We also see that the difference in seasonal patterns between the two years of data collection is primarily due to a reduction in the May 2019 peak for children under the age of 24 months, while wasting seasonality for children aged 24 months and older stays relatively consistent across the two years.

The seasonality of livelihoods and livelihood specialization also affects food security. Access to food increases following the harvest, while access to animal milk is highest during the rainy season. Some households are further able to supplement their diet with produce from market gardens, mainly done at the beginning of *shita*.

The pronounced seasonality of household livelihoods filters down and affects the seasonality of water contamination and both animal and human health. Key informants consistently reported that cattle are more vulnerable to disease at the beginning of the rainy season. Consequently, taking in all these seasonal patterns together we can say that the end of *seif* is when animals and humans are the most likely to share limited and diminishing water sources and when women have the least access to water for hygiene practices. As the rains start, contamination is washed into the water sources and *hits* are destroyed, forcing households to rely on *machiches* and wadis. Simultaneously, in some villages, more animals begin to migrate into the area increasing contact between animals and humans. Women's workloads increase, thus reducing their ability to take care of children, and they also migrate to areas where water sources are limited to wadis and *machiches*. The demographic most affected by the events occurring around the beginning of the rains appears to be boys under the age of 24 months. As we discuss below, this could be due to both biological differences and differences in breastfeeding practices that make boys more likely to consume water than breast milk during this particularly vulnerable period of growth.

Putting it all together - what is associated with child malnutrition?

In this section, we review our findings to identify the drivers of child malnutrition in the Goz Beida area using the 23 months of longitudinal quantitative data and our qualitative inquiry. We present the possible drivers in order of importance, as identified by the quantitative component of the study (the qualitative data corroborates this ranking, but on its own is insufficient to establish a hierarchy of influence.)

Gender

Gender affects the seasonal pattern of wasting. Boys experience far greater seasonality than girls and in the sex-disaggregated analysis only boys showed a significant relationship between coliform contamination at the water source and the probability of being wasted. Interestingly, the CRAM/BRACED program had the greatest impact on preventing wasting in boys who had been born during the program's duration (Marshak et al. 2020). Furthermore, when reviewing the sustainability of this program two years after the cessation of programming (2015–2017), we found that it had no impact for boys who were born after the program ended (6–23 months in 2017). Moreover, we noted a significant increase in wasting prevalence for these boys (Marshak et al. accepted). Thus, while the program did have an impact, that impact was not transferred to young boys who were born after the cessation of CRAM/BRACED.

However, even though seasonality is far more pronounced among boys than girls, we did not observe a significant difference in overall WHZ or wasting across sex. Furthermore, when controlling for possible drivers of WHZ, we found that girls do have a significantly lower WHZ score. It is important to note that the study sample sizes are fairly small, and so perhaps more consistent significant difference exists, but it is not sufficiently large to be picked up in this research. The difference in seasonality might partly explain why boys across numerous studies in the Sahel show higher levels than girls of poor nutritional outcomes, particularly when it comes to stunting (Svedberg 1990; Wamani, Astrom et al. 2007). Multiple studies carried out in the Sahel show that boys have higher prevalence of wasting compared to girls (WaST 2017). The latest SMART data from Chad (August 2019) further shows the difference in wasting prevalence with 14.8% (CI: 13.7 to 15.9%) of boys wasted compared to 10.9% (CI: 9.9 to 11.9%) of girls wasted. The difference in wasting might be related to the timing of the surveys: if nutrition surveys are carried out during the periods of greater seasonal variability between boys and girls (such as May and September/October, especially in 2018) then boys might appear more nutritionally vulnerable, despite the fact that as a yearly average, there is little distinction by sex. Understanding the difference in drivers by sex is critical to making sure that (a hypothetical) program benefits both boys and girls.

Research from Mali using longitudinal data collection finds the same distinction that we did in eastern Chad: greater seasonal variability amongst boys as compared to girls (Adams 1994). Possible explanations range from favoritism towards girls (Cronk 1989) to more biological reasons that leave younger boys more vulnerable to mortality and morbidity (Elsmen, Hansen-Pupp et al. 2004). Our study provides slightly more insight around why boys might exhibit greater seasonality and a more robust relationship between wasting and water contamination. Boys, due to cultural perceptions of masculinity, were reported to be weaned much earlier than girls. Women reported that it was not good for boys to spend too much time with their mother and that the family and child will be stigmatized if they do. As a result, boys might consume more water as a replacement for breastmilk; experience lower frequency of breastfeeding and feeding; benefit from less supervision by and interactions with caregivers; have a lower focus on hygiene practice; and have more direct access to contamination.

Water: sources, contamination, sharing with animals, and livestock mobility

Child malnutrition, specifically wasting, and to a degree WHZ, underweight, and WAZ are significantly associated with coliform contamination at the water source, but not with contamination in transport or storage containers. As other contaminants are introduced into water along the water chain, we no longer see a distinction in child wasting related to contamination, probably because the load of contamination is high across the majority of households and captures all origins of contamination, not just zoonotic. If our hypothesis that *Cryptosporidium parvum* is the main driver of child wasting is correct, it is likely that *C. parvum* is primarily introduced at the water source—where the greatest concentration of cattle would be present—as opposed to in the village. Furthermore, contamination at the source was more strongly correlated with poor nutrition outcomes in households reporting to use the same type of water source for both animals and humans. Water is most likely to be contaminated at the end of *seif* (due to the scarcity of water and therefore increased sharing with animals) and during *rushash* (due to fecal matter being washed into the water sources by the first rains). Another factor in some villages is the increased presence of livestock at this time of year, which is linked to the return or transit of some herds during their seasonal migration. However, as noted earlier, we do not have data on open defecation, which might also be seasonal and thus cannot confidently rule out the role of contamination from human fecal matter in child wasting.

Certain types of water source were more strongly correlated with both contamination and poor nutrition outcomes. Higher wasting prevalence and lower WHZ were both correlated with getting water from a *machiche*, open source (wadi/pond/stream) or *hit*, as compared to a borehole. These three sources also had the highest relative level of coliform contamination. However, it is important to note that it might be less about the water source type per se, than the presence of contaminants. For example, traditional garden wells are associated with very low levels of contamination and with similar levels of nutrition outcomes as boreholes. This could mean that traditional water sources might not contribute to poor nutritional status if communities adopted practices that reduce the presence of animals at these sources. However, once again, we cannot exclude the role of open defecation, which might also be correlated to the different types of sources.

The hypothesis relating to the role of shared water sources and animal-related contamination as a possible driver of wasting is further supported by the consistent significance of community-level cattle ownership with regard to worse nutritional outcomes, as initially identified in the CRAM/BRACED study (Marshak, Young et al. 2016). Furthermore, contamination from cattle is probably a more important driver of nutritional status than contamination from other livestock. Cattle are much more likely to be present at the water source, a presence that was correlated with child nutrition. Fecal matter from small ruminants (goats and sheep) and poultry, on the other hand, is more consistently found in the direct environment of the compound and likely impacts contamination in water transport and storage containers (goats are kept very close to the storage container in the compound), and the presence of these animals near the compound was *not* correlated with nutrition status. Cattle are a source of the pathogen *Cryptosporidium parvum*, which has also been linked to environmental enteropathy (Rogawski and Guerrant 2017), and particularly with high pathogen loads right at the start of the rains (Molbak, Hojlyng et al. 1990; Perch, Sodemann et al. 2001)

Food security

The quantitative data confirms that food security is extremely important for child nutritional status. However, food security appears to be primarily correlated to moving the whole distribution of WHZ, rather than driving the most severe outcomes, such as wasting. It is important to remember, though, that while we have food security data for households we studied, it dates from 2017. In both years of data collection, according to FEWSNET, Sila was at IPC Phase 1, meaning minimal to no food insecurity. But despite the low level of region-wide food insecurity, levels of wasting continued to surpass emergency thresholds during the research period. In addition, we saw a large disparity in levels of wasting between the first and second year of data collection. And, while we unfortunately cannot directly compare household levels of food insecurity between the two years, there were no such observed differences at the regional level, which suggests that other key drivers have a role in the differences in wasting prevalence over time. This means that while food security programs are important for the entire population prior to the harvest period, to effectively address wasting during the pre-rainy seasonal peak, programs would do well to focus on water access and shared use of water by animals and humans.

Hygiene and care practices

A greater workload for women during the planting and harvest seasons leaves them with less time to dedicate to caring for their children. Lower access to water during *seif* means women are not able to wash their dishes, clothing, and children as frequently as they would want. Direct contamination from fecal matter in the soil where children crawl due to the proximity of sedentary animals can further affect hygiene (although this study did not collect this information quantitatively to be able to look at associations with nutritional outcomes).

Wealth

The relationship between wealth and child malnutrition does not appear to be clear-cut in this study. In the CRAM/BRACED 2012–2017 analysis, wealth—using the Morris Score Index (Morris, Carletto et al. 2000)—was positively associated with higher WHZ (Marshak, Young et al. 2017). However, that was not found to be the case in our eight communities. Taiba Badria, identified as an extremely wealthy community in terms of both assets and livestock (relative to some of our other villages) also had one of the highest levels of child wasting and the lowest proportion of clean water sources (51 percent of sources had no coliform in Taiba compared to 87 percent in Maramara). It is possible that it is this wealth—or factors associated with it, such as ownership of large ruminants—that makes a large contribution to the communities' poor child nutrition outcomes.

Borehole use and sustainability

As expected, we found that among the various types of water sources boreholes have one of the lowest levels of coliform contamination and are associated with better nutritional status (in comparison to wadis, *machiche*, and *hits*) when a water source is shared with animals. However, it is worth noting that garden wells, which are just deep traditional wells dug in private areas away from animals, also showed low levels of contamination, but unfortunately were associated with increased levels of conflict (see section on conflict below). An unexpected finding was that despite the association with better nutritional status and respondents' knowledge about the better quality of borehole water, borehole use was still minimal and inconsistent across villages and time. According to the qualitative study—which revealed that even though the boreholes in Al Kherim, Tebesse, and Tcharo still worked, they were underutilized—aversion to borehole use is related to preferences, maintenance and cost of maintenance, and household mobility. We will now explore these three factors in turn.

Households reported that they do not like the taste of borehole water. They prefer water from *hits* and *machiches* even though they know it is more likely to be contaminated. Households generally reported prioritizing taste over risk of contamination; however other reasons (which we discuss below) are likely equally important.

Another issue, though probably linked with preference, is borehole maintenance and functionality. In the eight sampled communities, only two boreholes were found to be functional, public, and utilized in May 2019: one in Maramara and another in Rizildout. Most of the other boreholes had broken down. In some interviews, households reported that there is little incentive to fix the borehole during times of year when water from natural sources is plentiful. There were also instances were boreholes constructed by NGOs have been privatized (as in Tcharo). The borehole in Taiba further contributed to conflict, as neighboring communities would use it without paying fees, and therefore the community decided it was not worth continuing to repair it. The only community (in the first year of data collection) where we found that a borehole was both being maintained and consistently used was in Maramara, where households had no other options. In the second year of data collection, borehole use in Maramara significantly dropped, with households reporting both that the borehole broke down and that money from the water committees was being taken by the marabout and chief. It would require future research to more fully investigate the economic disincentives and influences of borehole use and maintenance.

Household mobility during the planting and harvest periods contributes to the limited use of boreholes during these seasons. Women perform most of the agricultural work and sometimes have to migrate to distant fields for long periods of time, taking their young children with them. When in their fields, they can only get water from the *machiches* and wadis, both sources that were associated with high contamination and child malnutrition in our regression analysis.

While boreholes stand out as one of the best sources of non-contaminated water, they are not the only such source. The traditional garden well was the one other source that was consistently comparable to a borehole in terms of water quality (across all our regression analysis models). We want to be cautious when drawing conclusions about this source, considering it was used by less than 2 percent of households and usually only wealthier households have a market garden well. However, it is still worth exploring why they might have so little contamination. The market garden well was specifically described as being fenced in to make sure animals are not able to access it. While we are careful not to suggest that NGOs should emphasize market garden construction as they are possibly associated with increased conflict between communities (see section below), the fact that they are less associated with contamination or poor nutritional status could provide lessons for how to protect other traditional sources from contamination.

Conflict over access to water and other natural resources

Respondents frequently mentioned conflict between communities during this study. Access to water sources for different communities and households with different livelihood specializations was cited as the greatest source of conflict along with crop residues. One such conflict occurred during our May 2019 data collection near Rizildout over crop residues between pastoralists migrating with their herds and a primarily agricultural community, resulting in numerous deaths.

Market gardens were noted as particularly contributing to conflict because they are usually cultivated on some of the most fertile land and near the wadi. As this practice, carried out by primarily farming communities that tend to come from the predominant ethnic group in the region, increases, water points for migrating herds are reduced, leading to conflict. There was also an instance of a borehole causing conflict between two primarily pastoral communities (Taiba and its neighbor), as one community would not pay the fees. Consequently, as NGOs increase access to important natural resources—especially water—they in turn could be exacerbating conflict, limiting access to other users of wadi resources, and potentially favoring one group at the expense of another.

Program implications

In this section, we discuss possible program implications coming out of the findings. However, we hope that community-level dissemination and feedback, as well as the research-to-programming workshop with Tufts and key Concern program staff from Goz Beida, Ndjamena, Dublin, and across other Concern country-programs, will lead to a much more tangible and realistic list of interventions and community programs.

Timing of programming activities

Programming around farming, including things such as climate-smart agricultural practices, is extremely seasonal. Both messaging and in some cases provision of inputs, such as seeds and tools, must correspond to the agricultural calendar to be effective. While adapting programs to seasonal practices is customary for the food security sectors and interventions, it is far less common for other sectors, such as WASH, gender, and health and nutrition.[146] Yet, as this study illustrates, seasonality

146 A rare example in the field of nutrition is Concern's community-based management of acute malnutrition (CMAM) surge approach, which is strongly related to seasonal patterns in morbidity and nutrition.

is critical across all aspects of household livelihoods, resource access, behaviors, and child-level outcomes and so it needs to be equally reflected in program timing across all sectors.

Programming and messaging around nutrition needs to be done year-round, but the focus of the messaging must adapt to seasonal drivers. For example, during *seif*, programs should focus on shared use of water sources by both animals and humans, particularly around *hits*, *machiches*, and wadis. Messaging at *rushash* needs to further emphasize the dangers posed by these water sources during the first weeks of rain, not just for human consumption but also for daily children's play. While households were able to identify that this time water is at a particular risk of contamination and children are more likely to be sick, the perception was that existing strategies (such as time of day and how long they should wait at the source) limit contamination.

Given that borehole maintenance is unlikely to occur year-round, support to communities who have boreholes is most critical in preparation for *seif*, when other sources dwindle and both households and animals almost exclusively rely on *hits*. At a minimum this support should include monitoring the quality of the water in the boreholes.

A second period of concern relating to child nutrition is the end of the rainy season. Programming needs to continue to focus on household and child food security during this time. It is possible that the lack of a large peak of wasting at the end of the rainy season is due to the efficacy of current programming around food security, and the focus on food security as a driver of wasting.

Certain communities are more vulnerable at different times of year and seasonal programming prioritization needs to reflect this. For example, households with large herds, but limited cash crops or market gardens, experience a period of hardship during *seif* but get income from animal products during *rushash* and *kharif*, when animals return from the south and calves are born, increasing milk production and access to meat. Households who rely mostly on rain-fed cultivation have a period of hardship in *kharif*, before the harvest. Households who have market gardens benefit from income in *shita* and *seif*.

Finally, a woman's workload determines not only childcare practices and hygiene, but also her availability and ability to attend meetings or internalize messaging. Women are particularly busy at the time of year when water access diminishes and contamination increases (*rushash*) and throughout *kharif*, likely exacerbating the impact on child nutrition. Children are usually cared for by older siblings while the mother is in the field. Program designers need to think critically about how to message at this time of year without monopolizing the women's time, making sure suggested practices do not add to their already heavy workload, further reducing time with the children. Similarly, *kharif*, especially during a good production year, brings about a greater presence of men and ensuing marital conflict over finances. While programs around gender are critical in this context, it is important that they do not exacerbate existing divisions during this already tense period. Program design should take a participatory approach in exploring with women what would help lessen their workload at this critical time.

Targeting of programming activities

Sex differences have come out as critical in this study, with boys showing the greatest seasonal variability, but also improvement over time (similar to the CRAM/BRACED impact). The goal of our sex-disaggregated observations and analysis is not to identify one group as more vulnerable than the other, but rather to show that depending on the sex of the child, different programs and messaging might be required. When it comes to our hypothesis around the role played by water contamination from animals in poor nutrition outcomes, it appears that this it is far more relevant for boys than for girls. This possibly explains why CRAM/BRACED, with its strong emphasis on WASH and borehole construction, was so impactful for boys, but also saw the greatest increase in wasting prevalence amongst boys born after the cessation of the intervention.

It is important for NGOs to know their communities well, in terms of their history and livelihood specialization, as well as their access to and management of resources and wider economic opportunities. For example, approaches around targeting related to wealth risk missing the most vulnerable children and communities. A better understanding of livestock mobility timing and patterns could also identify communities with the greatest need for messaging around sharing water sources at key time points. Communities with a history of livestock ownership have greater levels of child malnutrition compared to primarily farming families, but with a high degree of variability depending on geography and animal migration. However, we found that some farming communities—those where animals remain near the village or are near wadis that attract migrating animals—have comparable levels of malnutrition to communities with a history of livestock ownership. Organizations need to think more deeply about how certain household and community characteristics—such as access to natural resources, historical knowledge and skills, social networks and support, family structure, gender, age and intergenerational dynamics—as well as existing NGO and government policies, might affect their programming in terms of the type of support and when it is needed.

For programs with the goal of prevention (rather than treatment) of child malnutrition, it will be important that targeting and messaging is done at the community level, including with more temporary groups (groups migrating through the area with their animals) and other caregivers (grandparents), as everyone's behavior can contribute to child-level outcomes, even households who do not have children under the age of five. We found that community-level (water source, livestock mobility, village cattle ownership, access to natural resources) rather than household-level characteristics are key in driving nutrition outcomes. This finding further highlights the need for greater community participation and involvement in programming. What the community does around the water source affects everyone in that community and thus needs community-level understanding and adaption of key practices to reduce contamination. Finally, changes in food security correlate with population shifts in nutrition, which means that programming to improve food security also needs to be targeted at whole communities.

Overall, given the heterogeneities between and within communities, government and NGOs, both international and national, need to apply a participatory approach with the communities, with a strong emphasis on community-led initiatives and a prioritization of local knowledge. This will be integral to developing a more holistic, tailor-made, and community-accepted approach to programming. While more time- and resource-intensive, such an approach is likely to be both more effective and sustainable compared to a one-size-fits-all approach.

Adaptation of programming activities

One of the key interventions explored in this study is the construction of boreholes. Unfortunately, the qualitative research showed that boreholes in most communities were no longer functional or not utilized. While messaging around the use of boreholes could be improved, it is unlikely that this would have a huge impact on utilization considering that barriers around taste preferences, privatization, and household mobility would inevitably remain. Most households in the qualitative data appeared to be clear that boreholes are likely to be less contaminated than other more traditional sources, but they did not change their practices to correspond to this knowledge. What seems to be required, therefore, are innovative campaigns for raising the perception of risk associated with drinking water from unsafe water points to increase community value for the borehole.

While households are aware that some sources are more contaminated than others, perhaps demonstrations and self-assessment around the degree of contamination could prove useful. The use of hydrogen sulfide (H2S) detection kits for household water self-assessment has been shown to be easy and effective in increasing household-level treatment by 24 percent in a study in Tanzania (Matwewe, Hyland et al. 2018). The test requires households to dissolve the H2S powder in 20–100 milliliters of water (depending on the test), shake gently, leave at room temperature for 24–48 hours. Identifying contamination is extremely simple as the mixture turns dark black if the water is contaminated.

The decision to dig a borehole for a community, given the required long-term investment in upkeep, perhaps needs to be made based on the availability of other water sources. If other water sources are inconvenient, there might be more personal and community-level incentives to use and support the borehole. However, if that is not the case, perhaps a better investment for an NGO would be around improving community-level understanding and practices to reduce contamination of more traditional sources. Our research did not identify boreholes as the only option for clean water, and given their lack of sustainability in communities with other options, more traditional clean sources therefore need to be further explored and supported with the community. NGOs and government could consider a perspective based on strengthening systems, one that takes a holistic view of water resources, their seasonal availability, quality, and access.

Gender norms should be considered for behavior change activities on gender, infant and young child feeding (IYCF), and health seeking. IYCF programming should emphasize the need for more equal practices for children across genders. However, given how ingrained these social norms are, it might be helpful to avoid describing these practices in terms of gender "equality" and instead show how certain behavior changes could enhance the qualities that are so valued in each sex (honor of men, what it means to be a good woman, etc.). For example, messaging could aim to make having a healthy child an indicator of social status, something that households, and most importantly males, would want to invest in. Such messaging might focus on how spending more time with their mother makes boys stronger rather than weaker.

To improve the uptake of messaging, NGOs could also use a positive deviance approach, or point to urban wealthy households as an example for other members in the community. In the qualitative research, households spoke highly of the way things are done in Goz Beida. The social networks with better-off and educated people from Goz Beida in the community in Tebesse, for example, were described as an important enabling factor for behavior change. Perhaps increasing contact or exchanges with PD households—as opposed to NGO staff—within and across communities could help in disseminating messaging around hygiene behavior change. Relying on local individuals to help with sensitization could further increase uptake as many NGO staff, unfortunately, are expatriates or primarily from the south of Chad, where practices, religion, and culture are different from what we find in Sila.

One of the most problematic programs or practices identified in this study is the construction of market gardens. The predominance of one livelihood and ethnic group in the use of market gardens, and the negative externalities of this approach on migrating herds and households with livestock cannot be understated. And it is not just market gardens: other activities that inhibit access to natural resources for some groups in general can induce conflict, as is evidenced by the conflict caused by several communities sharing the same borehole but not necessarily paying fees. That is not to say these programs, including those involving market gardens, do not also have positive impacts, but it is important that any future programming related to natural resource access includes negotiation between all affected parties and local and traditional governance structures.

In a similar vein, NGOs need to work with and support local governance structures and traditional institutions. Traditional practices such as *talaaga*, shared herd management (where households with fewer animals send their livestock with other migrating herds in exchange for milk and newborn animals), and exchange of livestock products for farming products, can go a long way in increasing the resilience of the entire region of Sila and promoting the peaceful co-management of natural resources for the benefit of all. For example, better relationships between communities that have different livelihood specializations could allow households with only a few cows to have their animals migrate as part of a larger herd, thus limiting exposure to contaminants. As identified earlier, child malnutrition is as much a community-level as a household-level problem, and so greater collaboration and exchange across these communities could improve overall nutrition in Sila.[147]

While Concern is already at the forefront of multi-sectoral programming to combat child malnutrition (such as with its CRAM/BRACED work), our research underscores the imperative not only to consider all different sectors, but also to integrate the concept of seasonality: addressing the appropriate driver at the right time. Throughout our research, we found inherent links between livestock, water, nutrition, livelihoods, and the wider social structure. A season-blind, purely sectoral approach to programming risks minimizing any positive impact and could even result in negative externalities. A recent paper urges the nutrition community, particularly in area of persistent global acute malnutrition (GAM), to address malnutrition within its wider social, political, and economic context (Jaspers 2019). We recommend that Concern continue to strive to integrate these program sectors further, for example by including communities in decisions made about programming (since communities certainly do not think in terms of program sectors). However, it is equally important to also consider the wider social environment, with a particular focus on existing governance structures and relationships between communities and livelihood groups. NGOs working in this context need to better anticipate the risks and benefits for communities and monitor unexpected effects of laws as well as development activities.

147 One indicator of the status of the relationship between communities might be the number of inter-community marriages. In the qualitative research, households emphasized that marriage is used as an economic, political, and livelihood strategy between communities and can foster improved relationships. A review of the incidence of inter-marriage between communities could therefore give organizations a snapshot to gauge their connectivity and mutual trust.

Annex A: Additional tables and figures

Table 20: Mixed effects logit regression on cleaning storage container

	coefficient	p-value	95% CI	
Time	-0.001	0.005	-0.002	0.000
sin2pie	0.508	0.000	0.273	0.743
cos2pie	0.224	0.072	-0.020	0.468
sin4pie	0.024	0.825	-0.192	0.241
cos4pie	-0.026	0.832	-0.262	0.211
constant	2.858	0.000	2.361	3.356

Table 21: Negative binomial mixed effects regression on storage coliform

	coefficient	p-value	95% CI	
Time	-0.003	0.000	-0.004	-0.003
sin2pie	0.079	0.233	-0.051	0.208
cos2pie	0.039	0.559	-0.093	0.171
sin4pie	0.155	0.012	0.034	0.276
cos4pie	0.246	0.001	0.107	0.385
constant	2.822	0.000	2.546	3.099

Table 22: mixed negative binomial regression on source, transport, and storage coliform

	Source				**Transport**				**storage**			
	Coef.	*p-value*	*95% CI*		*Coef.*	*p-value*	*95% CI*		*Coef.*	*p-value*	*95% CI*	
Time	-0.00	0.00	-0.00	-0.00	-0.00	0.00	-0.00	-0.00	-0.00	0.00	-0.00	-0.00
sin2pie	-0.06	0.56	-0.26	0.14	0.01	0.89	-0.17	0.19	0.09	0.25	-0.06	0.25
cos2pie	0.40	0.00	0.23	0.57	0.02	0.72	-0.13	0.19	-0.01	0.84	-0.16	0.13
sin4pie	0.29	0.00	0.14	0.45	0.30	0.00	0.15	0.44	0.21	0.00	0.08	0.33
cos4pie	0.38	0.00	0.23	0.54	0.34	0.00	0.18	0.49	0.18	0.01	0.04	0.31
source (reference=borehole)												
machiche	1.71	0.00	1.40	2.02	1.04	0.00	0.76	1.33	0.76	0.00	0.49	1.02
man-made reservoir	-0.33	0.18	-0.82	0.15	0.30	0.10	-0.05	0.67	0.08	0.63	-0.27	0.44
open well	3.19	0.00	2.32	4.07	1.39	0.00	0.42	2.36	1.14	0.01	0.24	2.04
open source	1.40	0.00	0.92	1.87	0.70	0.00	0.23	1.18	0.52	0.01	0.09	0.95
saraf	3.00	0.00	1.57	4.42	2.81	0.00	1.13	4.49	1.56	0.04	0.04	3.07
garden well	1.36	0.00	0.45	2.26	0.94	0.02	0.11	1.76	0.74	0.05	-0.01	1.50
hit	1.58	0.00	1.23	1.94	0.85	0.00	0.51	1.19	0.47	0.00	0.17	0.77
share w/ animals	0.29	0.03	0.02	0.55	-0.05	0.68	-0.32	0.21	0.04	0.71	-0.19	0.27
village cattle proxy	0.01	0.01	0.00	0.01	0.00	0.25	-0.00	0.00	0.00	0.36	-0.00	0.00
Constant	1.29	0.00	0.78	1.80	2.04	0.00	1.68	2.39	2.38	0.00	2.03	2.72

Table 23: Mixed effects logit model with harmonic terms on 'no coliform found at the source'

No coliform at the source	Coef.	P-value	95% CI	
time	0.006	0.000	0.005	0.007
sin2 pie	0.115	0.402	-0.154	0.385
cos2pie	-0.272	0.017	-0.494	-0.050
sin4pie	-0.474	0.000	-0.671	-0.276
Cos4pie	-0.356	0.001	-0.564	-0.149
source (relative to borehole)				
machiche	-1.922	0.000	-2.329	-1.515
man-made mud reservoir	0.406	0.201	-0.216	1.027
open well	-3.635	0.000	-5.023	-2.247
river/stream/pond	-1.734	0.000	-2.410	-1.058
saraf	-15.944	0.968	-798.978	767.091
traditional garden well	-1.397	0.014	-2.510	-0.285
hit	-1.921	0.000	-2.428	-1.415
same water source for animals and humans	-0.503	0.006	-0.863	-0.142
# of cattle	-0.005	0.288	-0.013	0.004
constant	-0.315	0.272	-0.877	0.247

Table 24: Mixed effects regression on wasting and severe over time: daily and harmonic trend

	wasting				Severe wasting			
	Coefficient	p-value	95% CI		coefficient	p-value	95% CI	
Time	-0.001	0.046	-0.002	0.000	0.000	0.882	-0.002	0.002
sin2pie	-0.038	0.755	-0.275	0.199	0.205	0.387	-0.260	0.671
cos2pie	-0.382	0.004	-0.640	-0.125	-0.775	0.002	-1.265	-0.285
sin4pie	-0.297	0.009	-0.521	-0.074	-0.520	0.019	-0.954	-0.086
cos4pie	-0.182	0.151	-0.432	0.067	0.035	0.882	-0.429	0.499
constant	-3.357	0.000	-4.163	-2.550	-5.595	0.000	-6.842	-4.348

Table 25: Mixed effects regression on wasting on time by year of data collection

	May 2018-April 2019 (n=1420)				May 2019-March 2020 (n=1154)			
	Coefficient	p-value	95% CI		coefficient	p-value	95% CI	
Time					0.009	0.050	0.000	0.017
sin2pie	-0.204	0.224	-0.533	0.125	-0.156	0.495	-0.604	0.292
cos2pie	-0.740	0.000	-1.085	-0.395	-1.073	0.046	-2.126	-0.020
sin4pie	-0.522	0.001	-0.833	-0.211	-0.591	0.038	-1.148	-0.033
cos4pie	-0.067	0.695	-0.404	0.269	-0.163	0.477	-0.613	0.286
constant	-3.970	0.000	-4.883	-3.057	-10.117	0.001	-15.932	-4.303

Figure 32: Raw wasting by month and sex

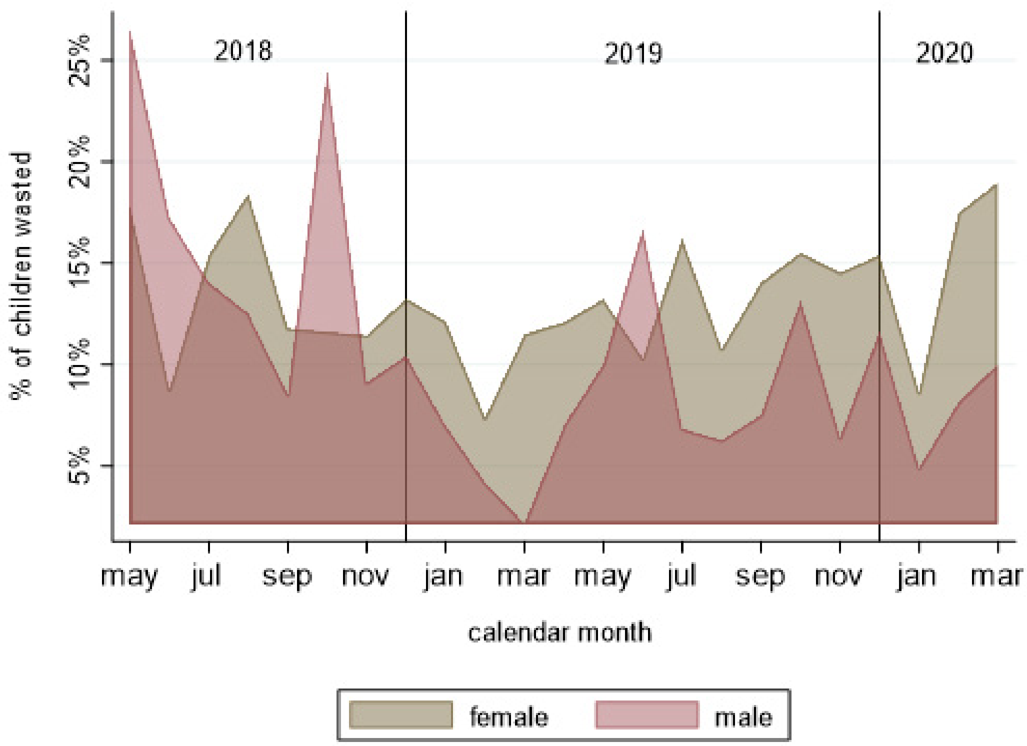


Table 26: Mixed effects regression on wasting by sex

	Girls (n=1523)				Boys (n=1051)		
	coefficient	p-value	95% CI		coefficient	p-value	95% CI
Time	0.000	0.873	-0.001	0.001	-0.003	0.001	-0.005–-0.001
sin2pie	-0.062	0.687	-0.365	0.240	-0.054	0.789	-0.453–0.344
cos2pie	-0.317	0.059	-0.645	0.011	-0.469	0.034	-0.903–-0.034
sin4pie	-0.141	0.342	-0.432	0.150	-0.547	0.003	-0.912–-0.183
cos4pie	-0.176	0.274	-0.491	0.139	-0.184	0.390	-0.605–0.236
constant	-3.641	0.000	-4.731	-2.552	-2.972	0.000	-4.135–-1.808

Table 27: Mixed effects regression on wasting by age group

	6-23 months (n=664)				24-59 months (n=1910)			
	Coefficient	p-value	95% CI		coefficient	p-value	95% CI	
Time	-0.001	0.251	-0.003	0.001	0.000	0.692	-0.001	0.001
sin2pie	-0.164	0.441	-0.580	0.253	0.023	0.877	-0.273	0.320
cos2pie	-0.190	0.369	-0.603	0.224	-0.533	0.002	-0.874	-0.192
sin4pie	-0.340	0.074	-0.712	0.032	-0.292	0.047	-0.581	-0.004
cos4pie	0.119	0.577	-0.299	0.536	-0.344	0.034	-0.661	-0.027
constant	-2.494	0.000	-3.674	-1.314	-4.417	0.000	-5.606	-3.227

Table 28: Mixed effects regression WHZ (n=2574)

	coefficient	p-value	95% CI	
Time	0.000	0.009	0.000	0.000
sin2pie	0.016	0.388	-0.021	0.054
cos2pie	0.112	0.000	0.073	0.151
sin4pie	0.026	0.137	-0.008	0.061
cos4pie	0.019	0.329	-0.019	0.058
constant	-0.944	0.000	-1.127	-0.761

Table 29: Mixed effects regression on MUAC

	coefficient	p-value	95% CI	
Time	0.008	0.000	0.007	0.009
sin2pie	0.640	0.000	0.333	0.946
cos2pie	0.057	0.730	-0.265	0.378
sin4pie	0.471	0.001	0.183	0.759
cos4pie	-0.321	0.047	-0.638	-0.005
constant	139.334	0.000	137.300	141.367

Table 30: underweight and WAZ over time

	Underweight				WAZ			
	coefficient	p-value	95% CI		Coefficient	p-value	95% CI	
Time	0.000	0.070	0.000	0.001	0.000	0.343	0.000	0.000
sin2pie	-0.108	0.121	-0.244	0.029	0.035	0.006	0.010	0.061
cos2pie	-0.210	0.004	-0.352	-0.067	0.069	0.000	0.042	0.095
sin4pie	-0.036	0.582	-0.164	0.092	0.010	0.394	-0.013	0.034
cos4pie	0.042	0.555	-0.099	0.183	-0.001	0.935	-0.027	0.025
constant	-1.481	0.000	-1.736	-1.226	-1.254	0.000	-1.479	-1.029

Table 31: Regression on stunting (logit) and HAZ (mixed effects) on time

	Stunting				HAZ			
	coefficient	p-value	95% CI		Coefficient	p-value	95% CI	
Time	0.001	0.011	0.000	0.001	-0.000	0.001	0.000	0.000
sin2pie	-0.067	0.306	-0.195	0.061	0.034	0.039	0.002	0.067
cos2pie	-0.012	0.858	-0.143	0.119	-0.009	0.591	-0.043	0.025
sin4pie	0.073	0.232	-0.047	0.192	-0.013	0.396	-0.044	0.017
cos4pie	0.111	0.099	-0.021	0.242	-0.051	0.003	-0.084	-0.017
constant	-1.253	0.000	-1.491	-1.014	-1.070	0.000	-1.331	-0.808

Table 32: Mixed effects logit regression on whether a child is ill

	coefficient	p-value	95% CI	
Time	-0.001	0.000	-0.001	-0.001
sin2pie	-0.018	0.739	-0.124	0.088
cos2pie	0.163	0.005	0.049	0.276
sin4pie	-0.065	0.202	-0.166	0.035
cos4pie	-0.106	0.062	-0.217	0.006
constant	0.590	0.000	0.300	0.879

Table 33: Mixed effects logit regression on morbidity

		Coefficient	p-value	95% CI	
respiratory illness	Time	0.000	0.122	-0.001	0.000
	sin2pie	0.339	0.000	0.217	0.461
	cos2pie	0.108	0.082	-0.014	0.230
	sin4pie	-0.053	0.353	-0.165	0.059
	cos4pie	0.031	0.639	-0.097	0.159
	Constant	-0.779	0.000	-1.044	-0.513
Malaria	Time	0.000	0.718	-0.000	0.001
	sin2pie	-0.19	0.002	-0.309	-0.071
	cos2pie	0.323	0.000	0.195	0.450
	sin4pie	-0.059	0.307	-0.172	0.054
	cos4pie	-0.033	0.601	-0.156	0.090
	Constant	-1.631	0.000	-1.8935	-1.369
Diarrhea	Time	-0.002	0.000	-0.003	-0.001
	sin2pie	-0.275	0.005	-0.468	-0.083
	cos2pie	0.102	0.317	-0.097	0.301
	sin4pie	0.004	0.964	-0.174	0.182
	cos4pie	-0.139	0.191	-0.347	0.069
	Constant	-1.782	0.000	-2.302	-1.262

Table 34: Mixed logit regression of wasting on morbidity

wasting	Coef.	P>z	95% CI
time	-0.001	0.102	-0.002
sin2pie	0.043	0.689	-0.166
cos2pie	-0.264	0.021	-0.488
sin4pie	-0.235	0.018	-0.431
cos4pie	-0.121	0.276	-0.340
respiratory illness	-0.377	0.040	-0.737
malaria	0.172	0.350	-0.189
diarrhea	0.776	0.001	0.331
constant	-2.668	0.000	-3.272

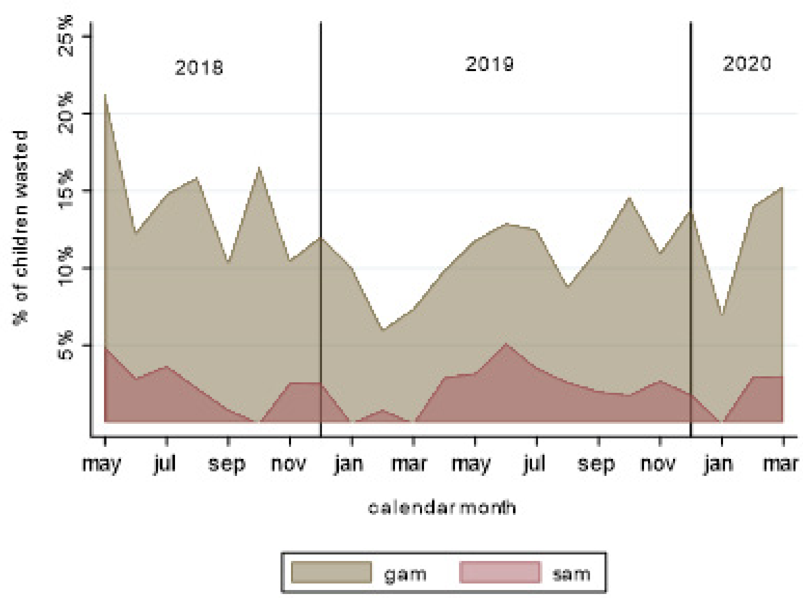
Table 35: Mixed effects regression on nutrition outcomes

		coefficient	*p-value*	*95% CI*	
wasting (n=2558)	NDVI	0.605	0.810	-4.337	5.546
	rainfall	-0.013	0.314	-0.039	0.013
	temperature	0.063	0.000	0.029	0.098
	constant	-5.624	0.000	-7.570	-3.678
Severe wasting (n=2558)	NDVI	-8.689	0.064	-17.893	0.515
	rainfall	0.012	0.578	-0.030	0.053
	temperature	0.091	0.006	0.026	0.156
	constant	-5.472	0.002	-8.983	-1.962
WHZ (n=2558)	NDVI	-0.325	0.417	-1.111	0.461
	rainfall	-0.001	0.604	-0.005	0.003
	temperature	-0.016	0.000	-0.021	-0.011
	constant	-0.331	0.044	-0.654	-0.009
WAZ (n=2586)	NDVI	-0.731	0.007	-1.267	-0.195
	rainfall	-0.002	0.253	-0.005	0.001
	temperature	-0.008	0.000	-0.012	-0.004
	constant	-0.833	0.000	-1.115	-0.551

Table 36: Mixed effects regression on wasting

		Coefficient	p-value	95% CI	
all (n=2182)	coliform (source)	0.033	0.071	-0.003	0.070
	Constant	-3.808	0.000	-4.501	-3.114
share source with animals (n=1349)	coliform (source)	0.045	0.027	0.005	0.085
	Constant	-3.855	0.000	-4.669	-3.041
don't share source with animals (n=833)	coliform (source)	-0.014	0.818	-0.129	0.102
	Constant	-3.874	0.000	-4.875	-2.873

Figure 33: wasting and severe wasting over time, raw data



Annex B: Sampling strategy for positive and negative deviant households

Sampling strategy based on coliform contamination

Identify community and household practices associated with lower and higher coliform from source to transport and storage container.

Community hygiene practices:

Using observational and participatory techniques to identify practices at the water source associated with no contamination at the borehole in Abdoudjoul, Rizildout, and Djedide and at the traditional well in Al Kherim and Djedide. Similarly, identify practices associated with greater contamination at the borehole in Taiba Badria and Tcharo and at the traditional well in Taiba Badria. In addition, compare practices at the *machiche* versus traditional well in Al Kherim. For additional exploration on *machiche* practices, compare Tcharo *machiche* versus Abdoudjoul and Al Kherim. In total, this makes six villages to go for data collection.

Village	Source	Coliform level
Abdoudjoul	Borehole	0
Rizildout	Borehole	0
Djedide	Borehole	0
Maramara	Borehole	0.33
Tebesse	Borehole	1.23
Taiba Badria	Borehole	5.3
Tcharo	Borehole	5.5
Al Kherim Al Mourna	Traditional well - deep	1.7
Djedide	Traditional well - deep	3.2
Tcharo	Traditional well - deep	5.3
Abdoudjoule	Traditional well - deep	6.8
Tebesse	Traditional well - deep	9.1
Taiba Badria	Traditional well - deep	19.9
Tcharo	*Machiche*	5
Tebesse	*Machiche*	5.7
Taiba Badria	*Machiche*	14
Abdoudjoule	*Machiche*	18
Al Kherim Al Mourna	*Machiche*	21

Note: No reported borehole use in Al Kherim

Household level hygiene practices along the water chain:

Here we will explore three categories of household all of which are accessing coliform-free water from the borehole: 1) clean transport and storage, 2) contaminated transport, and 3) increasing contamination from transport to storage. For all three we will use observational and participatory methods at the household level to identify household strategies that might be associated with the three categories of contamination along the water chain. In total, this makes three villages out of the above six for household level case-studies related to hygiene practices along the water chain.

			Coliform Level	
Village	Source	HH_ID	Transport	Storage
Abdoudjoul	Borehole	-	0	0
Abdoudjoul	Borehole	-	16	16
Abdoudjoul	Borehole	-	6.5	11.5
Djedide	Borehole	-	0	-
Djedide	Borehole	-	8	8
Djedide	Borehole	-	8	12
Djedide	Borehole	-	7.5	2
Rizildoute	Borehole	-	0	0
Rizildoute	Borehole	-	0	5.5
Rizildoute	Borehole	-	0	0
Rizildoute	Borehole	-	0	0
Rizildoute	Borehole	-	6	8
Rizildoute	Borehole	-	6.5	10
Rizildoute	Borehole	-	20.5	20.5

Annex C: Survey Instrument

Metadata

Z1	Code de la personne interrogée (Identifiant du ménage unique)	☐☐☐☐
Z2	Code de l'enquêteur	☐☐
Z3	Date de l'entrevue (JJ/MM/YY)	☐☐ / ☐☐ / ☐☐
Z4a	Code du village	☐☐
Z5	Heure de début (utiliser l'horloge 24 heures, HH:MM)	☐☐ : ☐☐

Approche de l'habitation

1. *Présentez-vous.*
2. *Demandez à parler à la personne sur votre liste.*
3. *Si elle est disponible, procédez au consentement oral.*
4. *Si elle n'est* ***pas*** *disponible, demandez quand elle est susceptible d'être de retour. Si elle reviendra le même jour ou le lendemain, heure de retour prévue pour le même jour.*
5. *Si vous ne pouvez pas l'interviewer ce jour-là, allez au prochain ménage sur la liste. S'il n'y a plus d'autres menages sur la liste, allez chez le superviseur pour un autre ménage.*

A ***EAU***

Cette section concerne l'ensemble du ménage. Un ménage est un groupe de personnes *qui prennent normalement leurs repas ensemble.*

A7a	D'où provient l'eau que le ménage utilise généralement ? (pour la consommation du ménage)	0 = forage ou puit réhabilité 1 = puits traditionnels 2 = machiche 3 = rivière/cours d'eau/étang 4 = hafir	☐	**Si 1, 2, 3 ou 4 → B22**
A8	Utilisez-vous le même récipient pour la collecte d'eau des wadi/rivière/ marigot/étang/fontaine or puit traditionnel ?	0 = oui 1 = non	☐	
B22	Où cherchez-vous principalement l'eau pour votre bétail maintenant ?	0 = forage ou puit réhabilité 1 = puits traditionnels 2 = machiche 3 = rivière/cours d'eau/étang 4 = hafir 5 = jardin d'eau	☐	
B22b	Avec quel récipient les betails boivent l'eau?	0 = bassin 1 = hote / abreuvoir 2 = directe du riviere	☐	
G5	Combien de fois nettoyez-vous le réservoir de stockage? / Bidons de stockage	0 = une fois par semaine ou plus 1 = une fois toutes les deux semaines 2 = moins d'une fois toutes les 2 semaines 3 = pas régulièrement ou jamais	☐	**Si 3 →G7**

G6	Qu'est-ce que vous utilisez pour laver le réservoir? / Bidons	0 = savon ou cendres 1 = eau de Javel et chlore 2 = sable et de petites pierres 3 = eau seulement	☐	
	Demandez à voir le réservoir/ Bidon			
G7	*Est-ce fermé? / Est-ce qu'il est fermé ?*	0 = oui 1 =non	☐	
G8	*Est-ce propre?/ Est-ce qu'il est propre ?*	0 = oui 1 = non	☐	
G9	Utilisez-vous le même récipient pour le stockage et le transport de l'eau?	0 = oui 1 = non	☐	**Si 0 → K1**
G10	Combien de fois nettoyez-vous votre récipient de transport ?	0 = une fois par semaine ou plus 1 = une fois toutes les deux semaines 2 = moins d'une fois toutes les 2 semaines 3 = pas régulièrement ou jamais	☐	
G11	Qu'utilisez-vous pour nettoyer votre récipient de transport?	0 = savon ou cendres 1 = eau de Javel et chlore 2 = sable et de petites pierres 3 = eau seul	☐	
	Demandez à voir le récipient de transport.			
G12	*Est-ce fermé?/ Est-ce qu'il est fermé ?*	0 = oui 1 =non	☐	
G13	*Est-ce propre ? Est-ce qu'il est propre ?*	0 = oui 1 =non	☐	

K SANTE MATERNELLE

Cette question ne concerne que le répondant SEULEMENT.

K1	Etes-vous enceinte?	0 = oui 1 =non	☐
K2	Allaitez-vous un bébé ?	0 = oui 1 =non	☐
K6a	MUAC / La circonférence du bras	*en millimètres*	☐☐☐
K6b	MUAC / La circonférence du bras	*en millimètres*	☐☐☐
K6c	MUAC / La circonférence du bras	*en millimètres*	☐☐☐

L SANTE INFANTILE

Cette question ne concerne que les enfants moins de 60 mois dans le ménage. S'il y a plus de quatre enfants moins de 60 mois, utilisez un questionnaire supplémentaire pour Santé. Un ménage est un groupe de personnes qui prennent normalement leurs repas ensemble

			Child 1	Child 2	Child 3	Child 4
L1b	Unique Child ID / Indentité unique de l'enfant					
L2	Sexe de l'enfant	0 = féminin 1 = masculine				
L3	Age de l'enfant (en mois)	**Si <6 mois □L11**				
L4	Poids (kg) Si le répondant ne peut pas peser l'enfant parce qu'il est malade = 888.8 S'il n'est pas là (c.-à-d. absent de la maison) = 999.9	*En kilogrammes au gramme le plus proche*	.	.	.	.
L4a	Poids (kg) Si le répondant ne peut pas peser l'enfant parce qu'il est malade = 888.8 S'il n'est pas là (c.-à-d. absent de la maison) = 999.9	*En kilogrammes au gramme le plus proche*	.	.	.	.
L4b	Poids (kg) Si le répondant ne peut pas peser l'enfant parce qu'il est malade = 888.8 S'il n'est pas là (c.-à-d. absent de la maison) = 999.9	*En kilogrammes au gramme le plus proche*	.	.	.	.
L5	Taille Si le répondant ne peut pas mesurer l'enfant parce qu'il est malade = 888.8 S'il n'est pas là (c.-à-d. absent de la maison) = 999.9	*En centimètres*	.	.	.	.
L5a	Taille Si le répondant ne peut pas mesurer l'enfant parce qu'il est malade = 888.8 S'il n'est pas là (c.-à-d. absent de la maison) = 999.9	*En centimètres*	.	.	.	.

L5b	Taille Si le répondant ne peut pas mesurer l'enfant parce qu'il est malade = 888.8 S'il n'est pas là (c.-à-d. absent de la maison) = 999.9	*En centimètres*	☐☐☐ . ☐	☐☐☐ . ☐	☐☐☐ . ☐	☐☐☐ . ☐
L6	MUAC Si le répondant ne peut pas mesurer la circonférence du bras de l'enfant parce qu'il est malade = 888 S'il n'est pas là (c.-à-d. absent de la maison) = 999	*en millimètres*	☐☐☐	☐☐☐	☐☐☐	☐☐☐
L6a	MUAC Si le répondant ne peut pas mesurer la circonférence du bras de l'enfant parce qu'il est malade = 888 S'il n'est pas là (c.-à-d. absent de la maison) = 999	*en millimètres*	☐☐☐	☐☐☐	☐☐☐	☐☐☐
L6b	MUAC Si le répondant ne peut pas mesurer la circonférence du bras de	*en millimètres*	☐☐☐	☐☐☐	☐☐☐	☐☐☐

	l'enfant parce qu'il est malade = 888 S'il n'est pas là (c.-à-d. absent de la maison) = 999					
L7	Presence of bilateral pitting oedema? / Présence d'œdèmes bilatéraux ?	0 = oui 1 = non	☐	☐	☐	☐
L11	Votre enfant a-t-il été malade durant les deux dernières semaines ?	0 = oui 1 = non (**si non□ fin de l'interivew**)	☐	☐	☐	☐
L12	Si oui, de quelle maladie l'enfant a-t-il été atteint? (*cocher toutes les réponses pertinentes)* (Marquez de toutes les réponses appropriées)	0 = maladie respiratoire / difficulté à respirer 1 = malaria / paludisme 2 = fièvre 3 = diarrhée aqueuse 4 = diarrhée sanglante 5 = rougeole 6 = malnutrition 7 = autre	☐☐☐☐☐☐☐☐	☐☐☐☐☐☐☐☐	☐☐☐☐☐☐☐☐	☐☐☐☐☐☐☐☐

L'interview se termine ici. L'enumerateur devrait remplir ce qui suit apres avoir quitte l'habitation

Z FIN DE L'INTERVIEW

Z7 Heure de fin (utiliser l'horloge 24 heures, HH:MM) ☐☐ **:** ☐☐

Z10 Y at-il eu des problèmes lors de l'entretien ? (*écrire dans la case*)

Z11 Autres commentaires? (*écrire dans la case*)

Annex D: Water Testing Procedure

Sample Collection

1. Water samples are collected in sterile polypropylene sample containers with leak proof lids.
2. Sampling procedures

2.1 Storage Temperature and Handling Conditions: Ice or refrigerate water samples at a temperature of 1-4°C during transit to the laboratory. Use insulated containers to assure Proper maintenance of storage temperature. Take care that sample bottles are not totally immersed in water from melted ice during transit or storage.

2.2 Holding Time Limitations: Analyze samples as soon as possible after collection.
Drinking water samples should be analyzed within 30 h of collection.
Do not hold source water samples longer than 6 h between collection and initiation of analyses, and the analyses should be complete within 8 h of sample collection.

Calibration and Standardization

1. Check temperatures in incubators twice daily to ensure operation within stated limits.
2. Check thermometers at least annually against certified thermometer

Quality Control (QC)

1. Pre-test each batch of Agar for performance (i.e., correct enzyme reactions) with known cultures (E. coli, and a non-coliform).
2. Test new lots of membrane filters against an acceptable reference lot

Procedure

1. Prepare Agar
2. Label the bottom of the Agar plates with the sample number/identification and the volume of sample to be analyzed. Label QC plates and the Agar sterility control plate(s).
3. Using flamed forceps, place a membrane filter, grid-side up, on the porous plate of the filter base. If you have difficulties in removing the separation papers from the filters due to static electricity, place a filter with the paper on top of the funnel base and turn on the vacuum. The separation paper will curl up, allowing easier removal.
4. Attach the funnel to the base of the filter unit, taking care not to damage or dislodge the filter. The membrane filter is now located between the funnel and the base.
5. Put approximately 30 mL of sterile dilution water in the bottom of the funnel.
6. Shake the sample container vigorously 25 times.
7. Measure an appropriate volume (100 mL for drinking water) or dilution of the sample with a sterile pipette or graduated cylinder and pour it into the funnel. Turn on the vacuum and leave it on while rinsing the funnel twice with about 30 mL sterile dilution water.
8. Remove the funnel from the base of the filter unit
9. Holding the membrane filter at its edge with a flamed forceps, gently lift and place the filter gridside up on the Agar plate. Slide the filter onto the agar or pad, using a rolling action to avoid trapping air bubbles between the membrane filter and the underlying agar or absorbent pad. Run the tip of the forceps around the outside edge of the filter to be sure the filter makes contact with the agar or pad. Reseat the membrane if non-wetted areas occur due to air bubbles.
10. Invert the agar petri dish and incubate the plate at 35°C for 24 hours. Pad plates used with MI broth should be incubated grid-side up at 35°C for 24 hours. If loose-lidded plates are used for Agar, the plates should be placed in a humid chamber.

11. Count all blue colonies on each plate under normal/ambient light and record the results. This is the E. coli count. Positive results that occur in less than 24 hours are valid, but the results cannot be recorded as negative until the 24-hour incubation period is complete.
12. Expose each plate to longwave ultraviolet light (366 nm) and count all fluorescent colonies [blue/green fluorescent E. coli.

Data Analysis and Calculations

Use the following general rules to calculate the E. coli 100 mL of sample:
1. Select and count filters with # 200 total colonies per plate.
2. Select and count filter with # 100 target colonies.
3. Calculate the final values using the formula: E. coli/100 mL x 100ml

Annex E: Qualitative survey guide

Water source contamination

- Why such a low contamination in Maramara compare to Abdoudjoul? (comparing PD vs ND communities)
- Preferences and differences across sources for rainy days. Does rainfall (the day off) affect water collection. Does rainfall (the day off) affect taste and preferences of water collection?
- For the specific water sources that have been tested for coliforms by Concern; how are they managed locally and by whom? Are there specific rules or regulations related to livestock?

Water access and management

- What are the current main types of water sources for human and livestock by species? May water use vs June?
- Governance for each water source by users? Is there a payment structure?
- Water sources preferences: taste preference of water and what influence preferences?
- What are the constraints to changing those preferences? Score seasonally on a Likert scale e.g. score water quality by water source by season, asking participants to create a huge seasonal diagram on the ground (figure with seasonal changes in score over time.)
- Boreholes use: Review functionality of borehole in our 8 villages (analysis shows borehole use has steadily gone down) Payment structure? Maintenance?
- Water sources management: How the water sources are protected from contamination?
- Description of *rushash*: When did the rains start? How does this transition affect water use and quality?
- Use of hit, machiche and wadi (conduct interviews at the water sources) in May vs June. How are people using them? Time of day? Relation to rainfall? Where are the livestock? What type of livestock?
- Identify, compare, and contrast water management and utilization practices in the Goz Beida area associated with different levels of contamination and different water sources by season.

Using the coliform data collected as part of the quantitative data collection on 8 villages we will identify and compare community and household practices across low and high levels of contamination at each point along the water chain. Specific issues to explore include:

- Who (livestock species/ people) uses these water sources, by season?
- How do conditions in the vicinity of the water point change seasonally?
- Who collects the water for home use (by gender /age) and what water hygiene practices do they use along the water chain?

Livestock management

- What are the seasonal livestock mobility patterns by species in the study communities and how does this influence their use and access to water resources?
- What are the seasonal types of mobilities?
- How does access to water differ?
- How does the environment where children are playing differ?
- What are the gender roles and responsibilities for managing livestock herds by season?
- Species using water sources – approximate numbers per day during different seasons
- Max capacity, when does the well run dry or become so contaminated it can no longer be used?
- How about on market day, where animals here for market are drinking water?

- Where are the livestock brought in during *rushash* getting their water? What time of day do they get water? How frequently do the livestock get water? Who gets the water? Does this change from May to June? Is there a payment structure (By different species of animals)?
- What institutional arrangements are made between different communities for sharing natural resources in May and June?
- Density of cattle in each community: Asks chief or Key informant a Numeric of the cattle for each village and season (put a number by village by season by species)
- Where (distance) are the animal (by species, by livelihoods specialization) located at this season (beginning of rain), are they coming closer at night?
- Animal sick near the house: what sick animals are kept closer to the home. (by species? By disease?) Livestock disease – how does it compare to last year
- what are the Community level institutions for livestock care?
- Institution for livestock mobility: The ministry of pastoral activities and chief of tribes demarcate *Murhal* (transhumant corridors)? chief of canton to release the animals? What is the local vocabulary? Explore how Ministry of Pastoral activities (is that its correct name, presumably Goz Beida level ?) and chief of tribes working together – this mixing of the modern formal institution and the older more traditional institution, has been shown to be super important in relation to positive institutional change and potentially as an entry point for agencies to support this.
- Livestock management: Pasture for livestock? What are the gendered roles and responsibilities in relation to livestock in May and June? Who supervises what livestock, when (by season), and why? Where are those livestock at nighttime by species by livelihoods specializations (inside the house, inside the compound, near the home, in a kraal, etc.) and why? -Have they been able to expand their herd in the past five years
- What traditional or modern regulations or rules of use (institutions) are there that influence livestock mobility and their access to water resources? (e.g. livestock mobility -local rules about grazing of crop residues, or rules that restrict access to particular pastures at certain times of the year, or water committees, and or rules that restrict or limit livestock access to certain water sources)
- Identify the structures and institutions governing water and livestock management practices in the Goz Beida Area.
- Herders: Are these proficient herders or those recognized locally as being particularly good at what they do?- suggests that owners are not herder and vice versa. Unclear if the herder is a hired herder or family member of the owner.
- Access and utilization of milk (cow, goat, sheep, camel) Payment? When animals give birth, better access to milk? (by species and livelihood specialization)
- Explore contamination thought milk? seasonal patterns of access to milk and how that differs by livelihood specialization
- Season where most of contact with cattle takes place?

Livelihood specialization and mobility

- Seasonal mobilities: *damkoutch*, *marchech* and *makhalaf* (May vs June OR End of dry season vs *rushash* vs *seif*) When this year did people start going to move seasonally? (by livelihood specialization) Who goes to the *damkoutch*? (father, mothers, children?), specifics HH (most vulnerable? Large Households? new arrivals?) Where is the *damkoutch*? (How far?) Time spent in the *damkoutch*? Daily routine in the *damkoutch*?
- Where does the mother and child get water while at the *damkoutch*? Are animals present?
- What livestock are present while they are the *damkoutch* and why? Own livestock and other household's or communities' livestock ? Where do the livestock get water at the *damkoutch*?
- What containers do they use? How does the environment in the *damkoutch* compare to the village? How often do they come back at the village while camping in the *damkoutch*? (For market, meeting, health, Water, festivities, death...) Access and utilization of milk (cow, goat, camel)

- Reason for sedentarization: maybe two different livelihood trajectories – the former could be either pastoralists who dropout or sedentarize and then don't have access to land, or poor farmers; the second case of camel herders is an example of restrictions on camel mobility associated with conflict. Maybe these are quite different reasons for close proximity of people and livestock.
- Explore vulnerability profiles to shocks and coping strategies according to livelihood groups and seasonality: vulnerability profiles to shocks (animal and crops or diseases, conflicts, floods, other, climate hazard) would differ as they rely on different type of sources of incomes at different time of the year, so they won't use to the same coping strategies. How variables as gender, age, marital status, economical wealth and genealogy will affect the social status and thus, the access to certain livelihoods and thus, the use of natural resources?
- Try to determine where ethical groups/ tribes of eight villages are located in the agropastoral spectrum

Childcare and feeding practices

- Observe some **food hygiene practices**
- **Child feeding practices** (e.g. are hands cleaned before feeding children)?
- How care practices would also vary according to livelihood specializations at this time of the year?
- **Care practices and interactions** between main caregiver (mothers) and their young children. Especially: places were children are staying while their mother is fetching water, preparing the land, looking for woods and cooking, and possible risks of contamination. (direct or via water or food/milk)
- **Contamination risks:** Observation of children in contact with the child/ feces by age/ gender and livelihood specialization by season/ by animal species (*chaile*, chicken, baby animal, goat, cattle, donkey.). Where do they play, what are they putting in their mouths (e.g. are they ingesting soil, feces)? Are they interacting with animals – and which animals? Recreational activities (of children < 5)
- What are the **community's perceptions of drivers of child undernutrition in the beginning of rainy season** (by livelihood specialization, age and sex of children)
- **Possible explanations for May peak**? It seems to be more prominent in community with pastoral history: Acute Malnutrition starts to increase again around March, April, possibly peaks in May, and then shows a small improvement in June. What drives the disintegration in March/April? What drives the small improvement from May to June?
- **Chronic wasting** (same kids wasted month to month): Use positive and ND (differences with non-chronically wasted kids) Case study to look at Health seeking behavior constraints, Care practices, feeding practices?
- **Vulnerabilities according to sex and age of children**: What could be the distinction between boys and girls (boys show much greater seasonality; Children 6-23 months are almost twice as likely to be acutely malnourished as children 24-59 months)? Any distinction in childcare practices by gender, by age for children under 5? What about in regard to breastfeeding practices, feeding practices? Health seeking behavior?

Annex F: Qualitative data collection approaches

Key informant interviews

Key informant interviews are in-depth interviews with people who know what is going on in a community. These community experts, with their knowledge and understanding, provided insight on the following subjects: history of the community, livelihoods and livelihood spectrum, access to and governance of natural resources, seasonal mobility, animal ownership, subgroups (ethnic, livelihoods, or vulnerable groups), water sources and institutions involved in water management, animal care practices, land access and management, arrangements and conflicts with other communities, gender norms, health practices and behavior, and child care practices.

Observations

The study team used structured observations to provide rich, contextual information on behaviors; daily routines; participant interactions with their environment, objects around them, and other individuals; and on the community environment generally. Observations highlighted bias or information hidden by interview or focus groups participants. The study team specifically observed the following: management and use of and behavior around water sources; behavior during water transportation; water management behavior in households, potential sources of contamination along the water chain; proximity of animals and animal feces to water sources and in homes; hygiene practices in households (in village or encampments) including, availability of a handwashing station, presence of soap, overall cleanliness of children and clothes, care practices of children under five (place where they are staying when their mother/caregiver is working, children under the watch of other children); and food and body hygiene.

Storytelling for discussions around livestock

Storytelling involves participants discussing "typical" stories from their communities during focus groups. The study team invented fictional characters, presented a "typical situation" (conflict between spouses, seasonal mobility of an owner of large cattle, etc.), and asked participants to discuss the characters' behavior. This helped initiate discussions on sensitive subjects, such as animal ownership, animal mobility, and/or spousal relationship and the decision-making power among women.

Scoring risks game around water management and hygiene practices

This tool involved participants identifying contamination risks along the water chain. They were asked to rate risks according to its importance (high, medium, low, no risk). Using the scoring risk game helped explore participants' knowledge and attitudes about levels of risk related to their current behavior. Risk game was particularly useful to assess perceptions about hygiene practices and/or behavior change levers and barriers.

Daily activities chart

This method was used as part of in-depth interviews or focus groups discussion. Respondents (mothers of children under five) were asked what they did yesterday from the moment they got up in the morning. They explained their daily routine right through to when they went to bed at night. For each activity, we asked where their children were and who took care of them. This method was useful to understand women's workload and explore their physical proximity and surveillance of children. In addition, this help to identify children's playground area during the day.

Seasonal calendars

Seasonal calendars are useful to identify how patterns/behaviors change seasonally and to explore determinants of change. The study team explored seasonal variations for the following topics: water source access and utilization, hygiene practices, sources of food and incomes, mobility of humans and animals, women's workload, men's workload, child care practices, animal management practices, arrangements and conflicts with other communities, women's decision-making power, child feeding practices, and child health status.

Gender box

This tool required participants to place "typical" women/girls and men/boys in "gender boxes" and identifying the roles, qualities and behaviors expected of them. Participants then explored what happens if a woman/girl or man/boy does not do what is expected of him/her. During this exercise, the study team asked the participants to find four objects: one each to represent a woman, a man, a girl, and a boy. The participants were then asked to mention all qualities, roles, and behaviors expected of each while pointing the object. Then, participants were asked about behaviors not aligned with societal expectations for each of them. Gender boxes were particularly useful in exploring issues related to gender vulnerability and differences in feeding and care practices for boys and girls in a non-threatening way.

Mapping

The respondents, together with the study team, sketched a map of natural resources (water sources for human and livestock, grazing zones, cultivated areas, seasonal movement routes for livelihood purpose, transhumant corridors, etc.). Respondents were asked to illustrate locations on the map, but also to provide underlying reasons for movements and resource use. Respondents spontaneously started to draw map in the sand to illustrate some points. This method was particularly useful to identify distance to water points and grazing area, but also identify those are shared between different communities.

Likert scale

The Likert scale tool was used to gauge attitudes, values, and opinions of communities about: taste preferences for water sources by season and by time of day, and water quality by source and by season. The respondents (men and women separately) were asked to pile beans in proportion to their relative preference or perception of quality for each water source (e.g. one bean for the least preferred to five beans for most preferred). The study team then counted the number of beans placed on the symbol for each water source. This technique allowed the study team to see nuanced variations in preferences and opinions about water.

In depth household case studies of positive and negatives deviant households

We used the semi-structured individual interview and observation approach, to allow the participant to speak without interrupting and to follow up on statements that seemed ambiguous or unclear. Negative and positive case studies were used as comparative method of data analysis used to establish points of comparison and identify potential risk factors and protective factors. PD and ND approach were used to compare variations in children nutritional status, variations in water sources coliforms contaminations, and variations in water contamination during transport and storage. This approach also helped to have a good understanding of community perceptions of underlying factors linked with water contamination and child undernutrition.

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